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# IIM-ATM 2024 & NMA

78th Annual Technical Meeting of IIM

International Symposium on Transformational Technologies in Materials & Manufacturing

20-22 November 2024 at GKVK, Bengaluru

# BOOK OF ABSTRACTS

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## POSTERS

# POSTER ABSTRACTS

# Development of graphene carbon-fiber epoxy composites

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## Abstract

Carbon-fiber composites are extremely useful in light-weight applications requiring high strength and toughness. Graphene addition, through processes like spray-coating and electrodeposition, while making the composite has been shown to enhance the strength, wear resistance, water resistance as well as fatigue life. Flexural strength as well as interlaminar shear strength can be extended only in certain special conditions by the addition of graphene and the limitations and advantages of adding graphene will be discussed in this presentation.

**Key words**:polymer, composite, graphene, strength, voids

# Optimization of Sodium Titanate Coatings on Titanium for Improved Scratch Resistance and Apatite Formation

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## Abstract

Titanium alloys are considered prime candidates for biomedical implants owing to their favorable strength-to-weight ratio, reduced stiffness, excellent biocompatibility, and corrosion resistance. Nonetheless, the inherently bioinert titanium dioxide layer formed on titanium surfaces impedes hydroxyapatite (HA) formation, leading to suboptimal osseointegration and potential long-term implant failure. Consequently, surface modification of titanium has emerged as a critical strategy to enhance long-term implant stability. This study developed a facile chemical approach to impart bioactivity to commercially available pure titanium and its alloy, Ti-6Al-4V. Substrates were immersed in a 5M NaOH aqueous solution followed by heat treatment at 600°C, forming a thin sodium titanate layer. The surface morphology, phase composition, microstructure, and elemental bonding states of the modified surfaces were characterized using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS), respectively. Heat treatment parameters were optimized to achieve superior scratch resistance and apatite-forming ability of the sodium titanate layer.

**Key word**: bioactivity, sodium titanate, alkali and heat-treated titanium, apatite layer

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# Effect of aging temperature on the mechanical properties, corrosion, and wear properties of nickel rich NiTi shape memory alloy for the biomedical application.

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## Abstract

NiTi shape memory alloys (SMAs) have been widely applied in biomedical fields due to their excellent shape memory effect, super-elasticity, and biocompatibility. In this study the effect of thermal ageing of NiTi-based shape memory alloy (SMA) focusing on the precipitate formation and its impact on the microstructure, transformation temperature, hardness, elastic modulus, corrosion and wear properties is evaluated. The as received NiTi which was solutionized for 2 hours at 950ºC followed by water quenching to homogenize the sample. The ageing treatment was conducted in a vacuum furnace at a temperature range of 350ºC to 650ºC for 5 hours. The effects on the microstructure and phase evolution were analyzed using X-Ray Diffraction (XRD), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy with energy dispersive spectroscopy (SEM-EDS). Subsequently, the mechanical properties were evaluated through Vickers hardness, instrumented micro indentation and reciprocating tribometer in Simulated Body Fluid (SBF). Along with these tests potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) was conducted on the aged samples in SBF for evaluation of corrosion properties. Thus, the preliminary study shows influence of the ageing process on austenitic and martensitic transformation temperatures, primarily attributed to the formation of mainly Ni4Ti3 precipitate. These lenticular-shaped precipitate changes the Ni composition of the matrix which in turn impacts the transformation temperatures, Vickers hardness, elastic modulus, and corrosion properties. With increase in aging temperature, the size of the precipitates increases, leading to an initial increase in hardness up to 450ºC, after which hardness decreases indicating change in coherency of precipitates within matrix. The same trend is seen in corrosion rate as well which initially increases and then decreases. The wear rate, wear volume and coefficient of friction is also affected by ageing process. These results indicate that the properties of shape memory alloy are influenced by the ageing conditions and will provide a better approach to optimize aging parameters to manufacture NiTi SMA with a better combination of microstructure, phase stability, and mechanical properties to be utilized in biomedical field.

Keywords: NiTi shape memory alloy; thermal ageing; microindentation; potentiodynamic polarization, EIS

# In-depth Mechanism of Corrosion and Mechanical behavior of Ni-rich NiTi Alloys through Optimized Heat Treatment and Phase Transformation

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## Abstract

NiTi based SMAs are widely employed in biomedical applications owing to their distinct properties such as shape memory effect (SME) and pseudoelastic effect (PE), resulting to extraordinary shape recoverability along with high corrosion resistance and biocompatibility. The present study investigates the in-depth mechanism of corrosion and mechanical behavior of a Ni-rich NiTi alloy (50.80 at% Ni) under different heat treatment conditions. The as- received alloy is initially solution treated at 850 °C for 2 h and subsequently aged at either (i) 350 °C for 2 h, named as HT_1 or (ii) 550 °C/ for 2 h, named as HT_2. Primarily equiaxed grains of size of ~ 35±4 3.7 µm are noted to form in both the aged alloy specimens. TEM analysis confirms the presence of the B2 phase, R-phase, and Ni-rich (Ni4Ti3) precipitates in them. However, the volume fraction of these phases and size of precipitates are different in the aged alloys. The microstructural modification through thermal treatment is noted to influence the corresponding corrosion and mechanical properties of the NiTi alloys. HT_2 alloy is effective to alter the microstructure and hence corrosion behavior of NiTi alloy in physiological solution like Hank's solution at 37 °C taking into consideration of its biomedical application. After 30 days of long-term immersion, HT_2 alloy develops another Ca-P layer along with a uniform TiO2 oxide layer, which is beneficial for the cell growth during immersion period. In contrast, HT_1 alloy forms a thin and inhomogeneous oxide layer, leading to pitting corrosion after long term immersion. Additionally, the estimated critical transformation stress (538 MPa) for stress induced martensite transformation is higher for HT_2 alloy as compared to that of HT_1 alloy (460 MPa) which is beneficial for manufacturing of bio-medical devices in austenitic stage. Further, the localized strain field distribution over the gauge length during tensile tests is assessed through digital image correlation study. Both HT_1 and HT_2 alloy specimens show occurrence of the Lüders band-type patterns during tensile deformation. Further investigation identifies the different stages of Lüders band generation and propagation and also, calculates the corresponding local strain rates. Interestingly, these local strain rates within the Lüders band are higher than the global strain rate observed during testing, providing light on the underlying mechanism of this phenomenon. Overall, the optimized thermal treatment of HT_2 alloy results in different phase fraction of primary and secondary phases, along with Ni4Ti3 precipitates, providing insight into the enhancement of corrosion resistance and mechanical properties in Ni-rich NiTi alloys.

**Key words**: SMA, Ni-rich precipitates, corrosion resistance, Lüders band formation

# Synthesis, Characterization and Prospective Applications of 2D-MoS2 Hybrid in Gas Sensing.

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**Abstract**

2D materials have potential applications as a gas sensor. Due to their inherent layered structure, ultrathin two-dimensional nanosheet architectures, transition-metal dichalcogenides (TMDs), have recently piqued the curiosity across the scientific community. Due to its intriguing electrical, chemical, mechanical, and optical characteristics, graphene-like MoS2 is very promising for the development of gas sensors. Here, we have synthesized MoS2 and its hybrid with Carbon Nanotube (CNT), Xenes and ZnO using liquid phase exfoliation and then characterized them using X-Ray diffraction (XRD), Raman Spectroscopy and Scanning Electron microscopy (SEM). We have fabricated thin film of these hybrid materials over insulation displacement termination (IDT) connector via drop caste method. These thin films generally have high surface energy. This property favours the selective adsorption of various harmful gases bases on their hybrid chemical structure. Gas sensing machine was employed to test these hybrid materials for their selectivity and sensitivity of gases using the four-probe setup. In the experiment, we concluded that the hybrid materials demonstrated high gas selectivity and sensitivity.

We have designed a device based on the aforementioned hybrids for detecting hazardous gases like NO2, NH3, etc. This gas sensing device safeguard the environment, reduce harmful gas leaking in residential as well as industrial areas thereby hindering their consumption and improving overall wellbeing of the people.

These hybrid materials have promising potential for practical applications in gas sensing in future. Our study offers a promising prospect for efficiently detecting, monitoring such hazardous gases, which can have positive impact on environmental remediation.

**Keywords**: 2D materials, Nanomaterials, Gas Sensing, Semiconductor,

# Assessment of thermal and emission energy behaviour of metallic-ion substituted hydroxyapatite for biomedical applications

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## Abstract

Among all the engineering materials such as metals, polymers and ceramics, it is found that ceramics are widely gaining importance for biomedical applications. In case of ceramics, mainly calcium phosphate-based ceramic i.e. Hydroxyapatite Ca10(PO4)6(OH)2 is widely used in biomedical field. This is due to its properties such as excellent biocompatibility, biodegradability. HA finds various applications such as joint replacements, bone grafts, and orthopedic applications. But still HA has some shortcomings such as excessive brittleness, inferior osteogenic capacity, poor antibacterial properties. In the recent past, researchers made their efforts to overcome the aforementioned limitations by preparing composites, altering the structure, changing the chemical composition of HA and by substitution of metallic ions. Among all methods available, substitution of metallic ions obtained favorable results for various biomedical applications. Henceforth, in the current study, HA has been substituted with four metallic elements i.e. Fe2+, Mg2+, Co2+, Ag+, to enhance its properties. The synthesis of both pure and substituted HA has been processed with microwave synthesis technique. Furthermore, various tests like XRD, DSC, Raman and Photoluminescence were done for both pure and substituted HA samples. The XRD patterns exhibit purity of HA and confirm the substitution of metallic ions by significant change in crystallinity and crystallite size of HA. The enhanced emission energy of HA after substitution of ions at mainly 1.5% concentration shows out to be a potential candidate for biomedical applications. Although to validate the ongoing hypothesis about substitution of metal ions, further in-vitro and in-vivo studies yet to be performed in future.

**Keywords** : Hydroxyapatite, XRD, DSC, Raman, Photoluminescence

# Strontium Titanate modified Magnesium alloy for Temporary Implant applications

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## Abstract

Disasters, aging population and accidents increase the current demand for orthopedic implants. Magnesium alloy is a potential biomedical implant because of its good mechanical properties and biocompatibility [1]. However, as the fulfillment of Mg based implants in physiological environment depends on the interaction at tissue-implant interface, surface modification appears to be a suitable solution to control the rapid degradation rate [2].

The present investigation aimed at the development of strontium titanate (STO) coating on AZ31 Magnesium alloy by electrophoretic deposition to improve the bioactivity and degradation resistance. The formation of STO coating was confirmed by morphological studies viz., X-ray Diffraction and Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy studies. The SEM micrographs of the as formed coating gave evidence of the uniform deposition of strontium titanate on magnesium surface. The adhesion strength of the developed coating was determined using pull Off adhesion test and the coating detachment pressure value was found to be 358 psi. Bio mineralization studies of the developed coating was carried out by immersing the specimens in simulated body fluid for a period of 7 days and the results evidenced the apatite forming ability of the coated sample. The corrosion behaviour of bare and the STO coated samples were examined by means of potentiodynamic polarization and electrochemical impedance spectroscopy analysis. The decrease in corrosion current (Icorr) value (1.12 x 10-5 A/cm2) observed for coated samples was attributed to the formation of protective strontium titanate layer on the magnesium surface. Having evaluated the corrosion protection using EIS studies, it was found that the deposition of strontium titanate significantly improved the degradation resistance of bare magnesium substrate. The obtained results indicates that the developed strontium titanate coated magnesium alloy appears to have potential in biodegradable implant applications.

Key words: magnesium alloys, strontium titanate, surface modification, degradation resistance, Biomineralization

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# Effect of Iron Content on Microstructure, Mechanical Properties, and Creep Behaviour of TiB Whisker-Reinforced Titanium Matrix Composites

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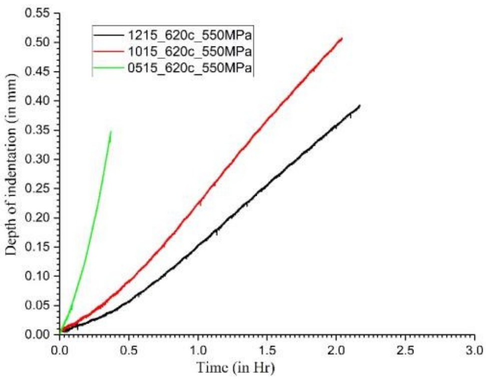
## Abstract

This investigation examines the influence of iron content (0-15 wt.%) on the microstructural, mechanical, and creep characteristics of titanium matrix composites (TMCs) reinforced with TiB whiskers. The TMCs were fabricated via vacuum arc melting. X-ray diffraction and microstructural analysis revealed distinct phase evolution with increasing iron content: a single α phase for 0% Fe, a dual-phase α+β microstructure for 5% Fe, and a single β phase for 10- 15% Fe, all incorporating TiB whiskers. Hardness measurements exhibited minimal variation (450-550 HV10) across all composites. Instrumental indentation testing (IIT) correlated the composite modulus (E-IT and E*) to phase composition and microstructure. The matrix and bulk composite hardness (H-IT) peaked at 5% Fe due to the α+β lamellar structure. The η-IT values indicated predominantly ductile behavior in the synthesized composites. Notably, the creep rate increased with rising iron content despite iron's known high diffusivity in titanium. These findings elucidate the complex interplay between iron content, microstructure, whisker morphology, and mechanical properties in TiB-reinforced TMCs, providing a foundation for designing advanced composites tailored for demanding applications.



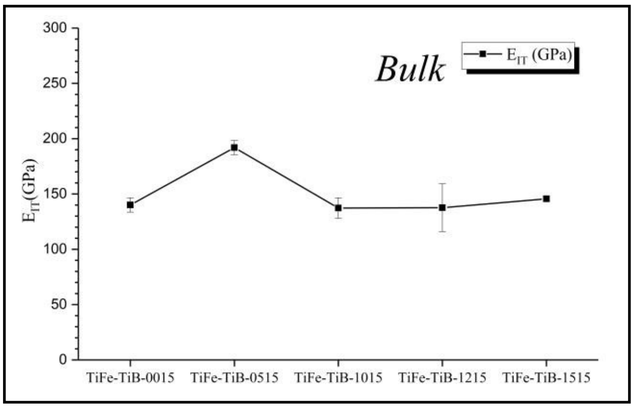




Fig. 1 Variation of elastic modulus (E-IT) with composition.

Fig. 2 Creep behavior of TMCs with composition at 620ºC and 550 MPa constant load

**Key words** : Fe based β-Ti-TiB Composite, Titanium Matrix composites (TMCs), Instrumental indentation testing (IIT), Impression Creep Test.

# Synthesis and Machine Learning-based Hardness Prediction in Ti Alloys intended for Biomedical Applications

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## Abstract

Titanium alloy displays outstanding performance and a wide range of applications in aerospace, automotive, marine, military, sports, and biomedical industry. In the design of biomedical materials like bone implants, mechanical incompatibility integrity is considered as one of the important parameters for successful application. Traditional material design approaches require intense calculations and experimental procedures. Recently, it is found that the data-driven model results offer novel approach to expedite the materials design method. Many researchers have contributes in expanding the experimental dataset in titanium-based alloys. These studies can be effectively enhanced using machine-learning models. Incorporating advanced techniques such as deep learning and neural networks will enable the analysis of more complex relationships and patterns within the microstructural data. This approach will facilitate the development of predictive models to tailor alloy design, by optimizing the mechanical properties for specific applications. The exploration of novel alloying elements and their synergistic effects on titanium alloys will also be a key area of investigation, aiming to achieve superior performance characteristics for advanced engineering applications. In this work, commercially used pure Titanium (CP- Ti) and Ti-alloys (Ti-6Al-4V, and Ti-15Mo alloys) were synthesized to investigate the influence of microstructural evolution on mechanical (hardness) and corrosion behavior. Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) techniques were employed to understand the microstructures and phase formation. The average hardness values of the samples were estimated by Vickers hardness test. The anti-corrosion behavior of the samples was studied through potentiodynamic scanning and electrochemical impedance spectroscopy (EIS). Besides, data-driven machine learning methods were proposed to predict the effect of constituent alloying elements (Al, V, Mo, etc.) and applied load on the hardness value. Three ML algorithms, namely eXtreme gradient boosting (XGBoost), artificial neural networks (ANN) and random forest (RF), were used in this study.

Keyword: Ti Alloys, Characterization, ML models, Bio medical applications, Deep learning.

# Evaluation of Mechanical and Electrochemical Properties of Laser Surface Melted Ti6Al4V in Simulated Body Fluid Medium

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## Abstract

Ti6Al4V is the most widely used titanium alloy in implant fabrication among the various available titanium alloys. Clinical research has demonstrated the biosafety of titanium and its alloys for a considerable amount of time. However, in recent times there has been an increased number of reported cases where implant failure was caused by allergic responses and persistent implant inflammation by the in vivo deterioration of titanium-based implants. Poor tribological behavior, such as low strain hardening, low shear resistance to plastic deformation, and the formation of a loose metal oxide layer, restricts the continued use of titanium implants. The naturally formed passive layer on the surface of titanium alloys is very thin; its thickness is as small as a few nanometers after 30 days of exposure to a simulated body fluid. This biologically active apatite layer, which resembles human bone in structure, is necessary for the integration of the implant with the bone. Therefore, it is advantageous to opt for surface modification techniques that can simultaneously improve the corrosion resistance and biocompatibility of titanium-based implants in the human body. One such promising technique is the laser surface treatment of titanium alloys to enhance corrosion, wear as well as osseointegration and bioactivity of the bone-implant interface of Ti-based implants.

The aim of this work is to evaluate the influence of Laser surface melting (LSM) on the corrosion and tribo-corrosion behavior as well as the bioactivity of Ti6Al4V alloy in a simulated body fluid medium (SBF) for assessing its use for biomedical implants. Laser surface melting was carried out on Ti6Al4V substrate by melting within a narrow range of optimum process parameters for the formation of a surface with improved wear, corrosion and tribo-corrosion resistance. The effect of applied power and shrouding gas on the microstructure, phase, surface hardness, wear, corrosion, and tribo-corrosion resistance (against ZrO2 in SBF) is established. LSM under argon atmosphere led to the formation of a composite structure consisting of acicular α' martensite and α. LSM under nitrogen atmosphere led to the formation of titanium nitride (TiN and Ti2N) dispersed in α matrix. There is an increase in surface microhardness (1.5-5 times) both under argon and nitrogen atmosphere when compared to untreated Ti6Al4V. There is also a significant improvement in wear, corrosion, and tribo-corrosion resistance properties in SBF post-laser processing compared to untreated Ti6Al4V. Bioactivity in terms of calcium phosphate deposition followed by dipping in SBF was found to increase with time due to LSM, though nitriding offered marginally higher bioactivity than only melting

Keywords: laser surface melting, Ti6Al4V, tribo-corrosion, bioactivity, simulated body fluid

# Investigating the role of Sn addition on the mechanical and biocorrosion behavior of novel Mg-Zn-Si alloy

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## Abstract

Over the years, Titanium, Cobalt and Stainless Steel based alloys are used to manufacture permanent biomedical implants. These implants are non-biodegradable which necessitates a second surgery after healing of the fracture. Recently, magnesium (Mg) and its alloys have gained interest for biomedical applications, such as stents, screws, etc. Due to their low weight, high strength-to-weight ratio, good biocompatibility and biodegradability in body fluids, Mg based alloys have become a potential candidate for these applications. These alloys have close resemblance with human bone in terms of density and modulus of elasticity. Earlier research has demonstrated that combining Mg with zinc (Zn), silicon (Si), and Tin (Sn) results in better biocompatibility and biodegradability. Sn is a crucial alloying component, but its impact on the microstructure and mechanical/functional properties of Mg-Zn-Si alloy has not been largely explored.

The current study establishes the relationship between processing, structure and properties of Mg-Zn-Si-xSn alloys (x=0, 1, 2, 3, and 4 wt.%). The microstructural characterization of pressure die casts was carried out using SEM coupled with EDS, XRD and EBSD. The type, distribution and volume fraction of second phases present in the as cast alloy were identified using both scanning electron microscopy (2D) and X-ray tomography (3D). Subsequently, mechanical properties were evaluated using Vickers hardness (HV) and bulk compression testing. Further, these alloys were hot rolled up to 30% at 300°C and subsequent microstructural characterization was performed. Additionally, the corrosion behavior of these alloys has been studied. The corrosion behavior of these alloys was evaluated using potentio-dynamic polarization test, hydrogen evolution test and weight loss measurement in HBSS (Hanks Balance Salt Solution). Post corrosion analysis was carried out using Raman spectroscopy, X- ray photoelectron Spectroscopy and SEM. It has been observed that variations in Sn content have a considerable impact on mechanical and biocorrosion properties.

Keywords: Magnesium alloy, XRT, Biodegradability, Corrosion

# Enhanced Water Purification Using Magnetic Ni@C Nano adsorbents for Methyl Orange

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## Abstract

In this study, Ni@C nanoparticles were Synthesized, which was subsequently used as an adsorbent for removing methyl orange (MO) from an aqueous solution. The sol-gel process was applied to prepare the particles at 500, 600 and 700 ℃ temperature in an N2 atmosphere and these were named as N5, N6 and N7 respectively. The phase, shape, and size of the nanoparticles were ascertained using the transmission electron microscope (TEM) and the X-ray diffraction pattern. Both the Raman spectra and the TEM micrograph supported the existence of a carbon covering over Ni with a size range of 43 to 94 nm. For the N7 sample, the Ni@C nanocomposite's maximum specific magnetization among the three was 55.78 emu/g. Using the BET method, specific surface areas of 2.29×105, 3.66×105, and 5.48×105 cm2/g were noted for N5, N6, and N7, corresponding to average pore sizes of 49.30, 37.25, and 35.27 nm. Rapid MO adsorption from aqueous solutions at varying concentrations was demonstrated by the magnetically separated Ni@C nanoparticles. After five cycles, the N7 adsorbent still had an adsorption capacity of 81%, which was the better MO adsorption capacity (~32 mg.g-1). Adsorption isotherm and kinetics analysis gave critical inputs toward the possible adsorption mechanism.

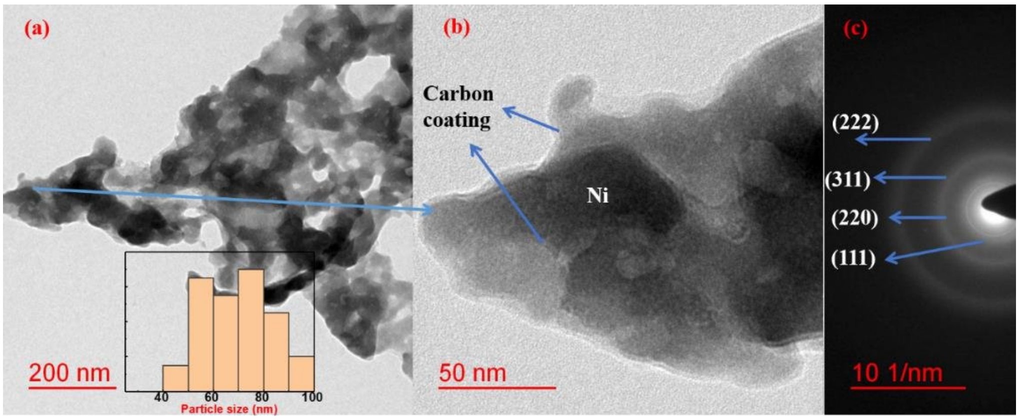


Figure: TEM analysis for N7: (a) microstructure and its inset shows size distribution, (b) microstructure at higher magnification showing C phase and (c) SAED pattern.

**Keywords:** Magnetic nanoparticles; Ni@C; Adsorbent; Pollutant removal.

# Functionally graded aluminium MMCs reinforced with CNT, Y2O3 & SiC

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**Abstract**

In this study, we employed powder metallurgy techniques to fabricate a light-weight, high-strength hybrid reinforced aluminum metal matrix composite (MMC). The investigation focused on the influence of carbon nanotubes (CNT), yttrium oxide (Y2O3), and silicon carbide (SiC) reinforcements on various aspects including structure, morphology, phase composition, thermal stability, and mechanical properties of the composite.

Continuous variation of CNT and Y2O3 (0-2.5 wt%) were done simultaneously to prepare a graded structure upon consolidation. Characterization of the composites was conducted using X-ray diffraction (XRD), scanning electron microscopy (SEM-EDS), indentation techniques and dynamic mechanical analyser (DMA). We found that milling the materials for 20 h resulted in the uniform distribution of reinforcements within the aluminum matrix. Subsequent cryomilling with a B.P.R of 100:1 further reduced agglomeration and cleaved the nanotubes[1], thereby minimizing entanglements.

XRD analysis revealed the formation of feasible reaction products during the processing steps. Mechanical characterizations show gradual increase in strength. Scratch test along all layers shows decrement in the penetration depth and their continuity along interfaces supports the intactness of consolidated layers. Thermal analysis through DTA and DMA indicates stability of powder and the consolidated sample at higher temperatures with 50% reduced coefficient of thermal expansion (12-15 x10-6/K) as compared to pure Al samples.

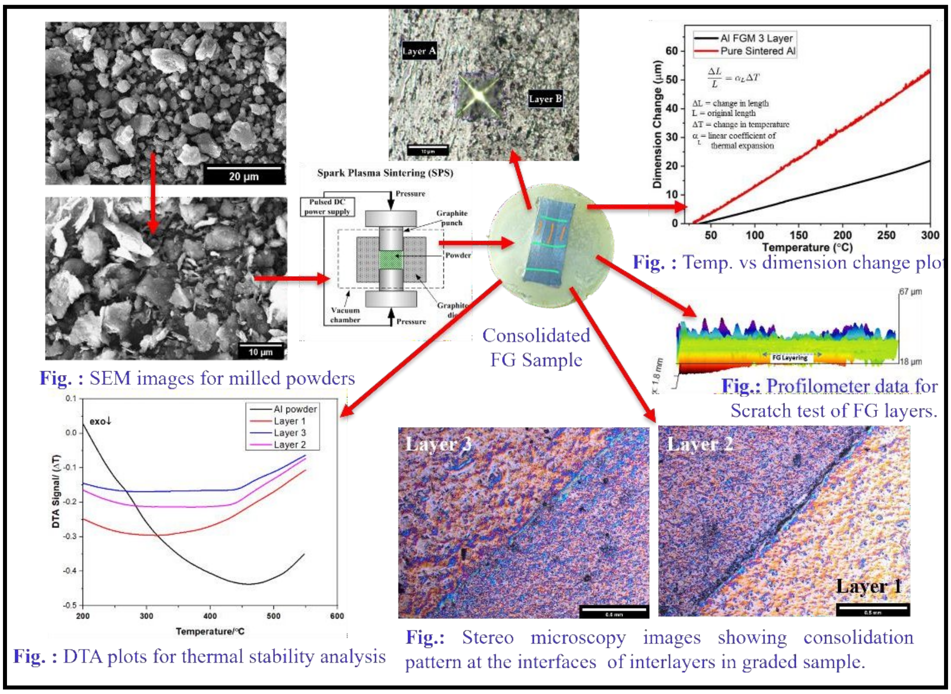


Fig. : SEM images for milled powders

Fig. : Temp. vs dimension change plot

Fig.: Profilometer data for Scratch test of FG layers.

Fig. : DTA plots for thermal stability analysis

Fig.: Stereo microscopy images showing consolidation pattern at the interfaces of interlayers in graded sample.

**Keywords**: Mechanical Milling, Functionally graded materials, Mechano-thermal processing, Powder Metallurgy, Nano Composites, CNT.

**Reference:**[1] Gupta, R., Shadangi, Y., Chattopadhyay, K., Kumar Chaubey, A., & Krishna Mukhopadhyay, N. “Advance processing of cluster-free CNT reinforced 6082 Al matrix nanocomposites: influence of mechanical milling and cryomilling”, Advances in Materials and Processing Technologies, (2024),1–19.

# Investigation of Magnetocaloric Effect in Mn-Ni-Si based Heusler Alloys for Magnetic Refrigeration Applications

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## Abstract

Magnetocaloric alloys exhibit a magnetocaloric effect (MCE) i.e the material undergoes heating and cooling when an external magnetic field is applied or removed, respectively. Traditional magnetocaloric materials, such as those based on La, Gd, and Eu, exhibit significant MCE but are expensive and may pose risks to human health. Consequently, research has now shifted towards more economically feasible and readily available materials, including Heusler and high entropy alloys.

MnNiSi-based alloys have notable advantages: (i). Large Magnetocaloric effect, (ii). Effective Refrigeration Capacity, (iii). Tunable transition temperature, (iv). Non-toxic and cost effective. Earlier, MnNiSi-based alloys included Ge as a raw material for synthesis, but now we have a Ge-free variant. These new Ge-free alloys are more cost effective while maintaining properties comparable to alloys containing Ge.

The study examines the impact of Fe addition on MnNiSi-based Heusler alloys, particularly their magnetocaloric properties and their implications for magnetic refrigeration applications. MnNiSi based Heusler alloys, Mn1-xNi1-xFe2xSi (x=0.33,0.35,0.37,0.39) were prepared using vacuum arc melting. The synthesized samples were characterized using Scanning Electron Microscopy (SEM), the crystal structure was determined through X-ray Diffraction (XRD) and Rietveld refinement, thermal properties were analyzed using Differential Scanning Calorimetry (DSC) and the magnetic properties were measured using the Magnetic Property Measurement System (MPMS). Preliminary studies suggest that MnNiSi- based alloys with Fe addition exhibit promising magnetocaloric effects. This work will specifically explore how iron addition influences these properties, expecting Fe to enhance the MCE and make these alloys more suitable for magnetic refrigeration applications. This research advances the creation of magnetocaloric materials that are both cost-effective and environmentally sustainable. By leveraging the abundant elements in MnNiSi-based Heusler alloys, this study aims to advance the field of magnetic refrigeration, offering potential alternatives to traditional refrigerants and contributing to sustainable cooling technologies.

Keywords: Magnetocaloric alloys, Magnetocaloric effect, Heusler alloys, MnNiSi based alloys, Magnetic Refrigeration.

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# Influence of tool rotational speed on microstructure, mechanical and degradation behavior of friction stir processed (FSP) Zn-based biodegradable alloys

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## Abstract

The problem with permanent or non-biodegradable alloys as implant materials is that additional surgery is required for the implant removal. With biodegradable alloys, implant- related complications and secondary surgery can be avoided altogether. Magnesium (Mg), Zinc (Zn), and Iron (Fe) are the three major metallic materials that comprise the biodegradable alloys domain. Due to suitable degradation rates (unlike Mg and Fe), good biocompatibility, and antibacterial properties, Zn-based alloys are investigated for degradable implant applications. The problem with pure Zn is its poor mechanical properties, which is addressed by alloying and secondary deformation techniques. In the present study, Zn-xMn alloys (where x = 0, 0.4, 0.8, 1.2, and 1.6 wt%) were cast and further processed using friction stir processing (FSP) at tool rotational speeds of 560, 710, and 900 rpm. The as-cast pure Zn exhibited a coarse microstructure. With the addition of Mn, grain refinement occurred, and secondary phase particles (MnZn13) formed due to the limited solubility of Mn in Zn. FSP led to further microstructural refinement, fragmenting and dispersing the secondary phase particles throughout the matrix. The addition of Mn significantly enhanced the mechanical properties of Zn; for example, the ultimate tensile strength (UTS) of as-cast Zn increased by 278% in the Zn-0.8Mn alloy. While FSP had little effect on the strength of pure Zn, it greatly improved the strength of the Zn-Mn alloys. Notably, the Zn-1.2Mn alloy exhibited a 388% increase in UTS, along with 50% ductility. The impact of alloying and FSP on the microstructure will be correlated with the mechanical properties and biodegradability of the Zn-Mn alloys.

Keywords: Zn-Mn alloys, Biodegradable alloys, Friction stir processing, Grain refinement, Biomedical implants.

# Surface Characterization of Plasma Nitrided Porous Titanium for Biomedical application

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## Abstract

The widespread utilization of titanium and its alloys in various industries can be attributed to their remarkable properties. These include a lightweight nature, exceptional strength-to-weight ratio, and high resistance to corrosion. However, the findings of the foundations in surface modification for the appropriate assessment of surface layers still remain very challenging [1]. In this present study, the TiN alloyed layer was successfully formed on a porous titanium (varying porosity range 30-40% and sintering temperature of 1100-12000C) surface by plasma using nitrogen as a shrouding environment. Plasma Nitriding has been carried out using a DC magnetron sputtering system (with a voltage of 0.50 kV and 3-6 Amp current, N2 gas pressure of 5*10-2 bar) with an applied varying temperature(400-5000C) and varying duration(30,60 and 120 minutes). Followed by Plasma nitriding, a detailed characterization of the nitride zone has been undertaken in terms of area fraction of porosities, microstructure, phase and residual stress, microhardness and nano-hardness and compared with as-received microstructure. A significant improvement in average microhardness (400-800 VHN) is noticed following sputter deposition compared to that of as-received porous Titanium (210-280 VHN). Scanning electron microscopy and X-ray diffraction were carried out to investigate the phases developed in the nitrided zone. It was found that the wear resistance improved considerably after the nitriding process.

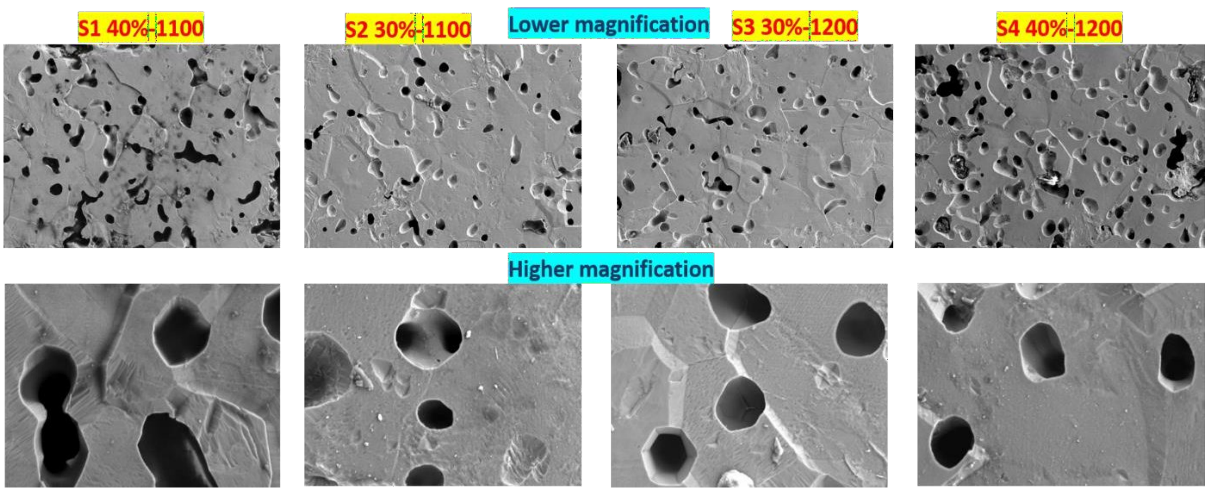


Figure 1. Scanning electron micrograph of the top surface of as received porous Titanium in different process parameters.

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# In-situ micro-arc oxidation coating with corrosion resistance and controlled drug delivery on biomedical magnesium alloy for future implants

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## Abstract

Biomedical implants significantly improve patient's quality of life by supporting or replacing non-functional parts of the human body. These must be biocompatible, requiring not to elicit adverse inflammatory reactions within the human body. Conventional metals and alloys such as stainless steel, titanium and cobalt-chromium provide good mechanical strength but release toxic degradation products into the surrounding tissues. Moreover, they have higher Young's modulus than the human bone, causing stress shielding. It results in weaker bones at the implanted location and requires a second surgery to remove the implant. Also, microbial adherence becomes evident within hours of implantation, resulting in severe inflammatory reactions. It results in poor osteo-integration, leading to rejection. The above complications imply a need for biocompatibility, biodegradability and drug delivery while developing future implants. Magnesium alloys are the materials of choice to meet the above requirements. Despite being a promising material, it remains rapidly corroded by hydrogen evolution while providing mechanical support until the osteointegration and healing process. Yet, this can be overcome by surface modification techniques. In recent years, the micro-arc oxidation (MAO) technique has been adapted to develop a porous adherent oxide layer on the surface of the substrate. These micropores are later sealed to result in a corrosion-resistant surface layer. On the other hand, such morphology can be exploited for drug encapsulation. Hence, we aim to develop a controlled-release antimicrobial composite coating on magnesium alloy with enhanced corrosion resistance in this investigation.

This research aims to develop an in-situ MAO coating of antimicrobial drug-loaded metal-organic framework. The developed MAO composite coating is characterised by techniques such as Field emission scanning electron microscopy (FE-SEM) built-in with energy dispersive spectroscopy (EDS) for the surface morphology and chemical composition. Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) confirm the structural components. Thermogravimetric analysis (TGA) and BET N2 adsorption and desorption methods are done to confirm the thermal stability and drug encapsulation. Electrochemical impedance spectroscopy (EIS) and potentiodynamic polarisation (PDP) are performed for the corrosion studies. The drug release studies use UV-visible spectroscopy at neutral and acidic conditions relating to the microbial infection. Finally, the cytocompatibility and antimicrobial performance are confirmed by in-vitro cell culture studies. The results indicate that the developed MAO antimicrobial composite coating has enhanced corrosion resistance and controlled drug delivery for future implants.

Keywords: Magnesium alloy, MAO, controlled release, corrosion.

# Design, processing, and characterization of Ti -Zr rich refectory complex concentrated alloys aimed for orthopaedical and dental application.

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## Abstract

In the dynamic field of biomedicine, Titanium (Ti) and its alloys have evolved through three generations to improve their suitability for biomedical applications. In first-generation pure Ti, they lacked sufficient strength, making them unsuitable for load-bearing implants. Second- generation Ti-Al-V alloys offered improved strength but had a high Young's modulus, resulting in stress-shielding effects in the bone and harming the human body due to the presence of V and Al. The third-generation of Ti alloys with, such as Ti-Mo-Zr-Sn alloy and Ti-Nb-Ta-Zr alloy, characterized by a body-centered cubic (BCC) structure, achieved a Young's modulus closer to that of bone, enhancing their compatibility. However, these alloys still lacked adequate yield strength. The scientific community has proposed exploring a new alloy design concept to address these issues, specifically the complex concentrated alloys (CCAs) approach with a vast compositional space. In this study, four alloys containing refractory elements such as Ti, Zr, Nb, and Mo, are designed from the compositional space of CCAs and are manufactured using vacuum arc melting, followed by comprehensive structural and microstructural characterization. The subsequent evaluation of mechanical properties aimed to establish a robust correlation between structure and properties. This comprehensive approach enhances the understanding of developed Ti -Zr rich refectory complex concentrated alloys (RCCAs), offering valuable insights for orthopedic and implant applications.

# Structural, Electrical And Thermoelectric Properties Of Co-Evaporated Mg/Bi2Te3 Thin Films Using Thermal Evaporation

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## Abstract

In the field of thermoelectric power generation, there has been a growing interest in flexible and stretchable electronics for energy harvesting. These electronics have various commercial applications, such as powering portable gadgets, smart watches, medical equipment, and sensors. Among the different thermoelectric materials, compounds based on Bi2Te3 are widely regarded as the best at room temperature, with promising applications. The crystal structure of the deposited layer is confirmed using X-ray diffraction technique. Furthermore, the morphology and atomic composition are evaluated using field emission scanning electron microscopy with energy-dispersive X-ray spectroscopy (EDX). The properties of the deposited and annealed thin films are collectively indicated by the material's figure of merit, (ZT) [ZT= (S2σT/k)], where S is the Seebeck coefficient, σ is the electrical resistivity, k is the thermal conductivity, and T is the temperature in Kelvin. For this study, Bi2Te3 thin films were doped with 5wt%, 10wt%, and 20wt% Mg and deposited on glass substrates with thicknesses of 200nm, 800nm, and 1600nm using a thermal evaporation technique at a working pressure of 4.2x10-5 m-bar. The thermoelectric properties of the annealed thin films were then studied at 150°C and 250°C. Results showed that when the annealing temperature increased to 250°C for 60 minutes, the Seebeck coefficient, electrical conductivity, and thermal conductivity of 800nm n-type Bi2Te3-based thin films as-deposited were about −54.96 mV/K, 4.61×105 S/m, and 0.32W/m-K, respectively, leading to enhanced thermoelectric properties and resulting in a high ZT value of 1.32. Finally, the thermoelectric properties of Mg-doped Bi2Te3 and the experimental results will be presented.

**Key words**:Electrical conductivity;Seebeck coefficient;Thermal Conductivity;Thermoelectric-Material.

# Control of local phase-separation patterns in Ag-Cu films through reaction with Si- substrate

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## Abstract

Noble-metal based alloy films exhibiting functional properties are extensively used in fabrication of modern electronic devices and sensors. Producing nanoscale structures via patterning is now routinely used in the manufacture of devices with novel functionalities. Focused ion beam milling (FIB-M) is one of the widely used techniques for nanopatterning of thin films. Here we show that FIB milling can also be exploited to induce a chemical interaction between film and substrate in a localized manner which in turn causes a dramatic shift in local multiphase microstructure. In current study, we deposited Ag-Cu alloy thin films with a thickness of ~40 nm on Si-(100) wafers via magnetron co-sputtering process. The Ag-Cu system is a eutectic between two terminal solid solutions and exhibits optical properties which can be tuned by varying film microstructure. The as-deposited films crystalized into a homogeneous single-phase metastable FCC structure having a grain size of ~10 nm. These films are subsequently annealed in a vacuum furnace to induce phase separation which results in the formation of randomly distributed Ag-rich and Cu-rich domains. Prior to vacuum annealing, an array of submicron sized apertures ($\phi$ 200 nm – 1000 nm) which are deeper than as-deposited film is made on the surface using FIB-milling. These apertures act as an active site that triggers the reaction between Cu-atoms in film and Si substrate atoms resulting in the formation of Cu3Si during annealing. This reaction in turn induces formation of a distinct halo type structure constituted of two zones around the Cu3Si phase. Immediately adjacent to Cu3Si formed in apertures, the first zone within halo is made up of isolated Cu-rich domains dispersed within a continuous Ag-rich matrix. This first zone is enveloped by another annular ring containing domains rich in Ag. We further show that the halo length scale and relative widths of constituent zones can be controlled by varying overall film composition and annealing conditions. In addition to reaction and phase-separation, we also have observed that film de-wetting induced by annealing at higher temperatures and longer times can result in formation of unique microstructural features. Our results demonstrate that in addition to parameters like film composition and thickness, epi-strain, and physical confinement, film-substrate reaction can be used as an additional handle to tune microstructure for obtaining enhanced optical properties.

**Key Words:** Phase separation, thin films, Focused Ion Beam, Electron Microscopy, Characterization

# Significant reduction in the thermal hysteresis of Ni45Ti50Cu5 Melt-spun ribbons with the combined effect of Cu addition and Annealing treatment.

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**Abstract**

NiTi shape memory alloys (SMA) have distinctive characteristics that render them well-suited for a diverse array of electrical actuator and sensor applications. These qualities encompass the shape memory effect and superelasticity. In order to achieve exceptional performance and characteristics, it is necessary to expedite their response time. Examining the phase transformation characteristics of NiTi shape memory alloy (SMA) is essential for that purpose. This research compares the transformation temperatures and thermal hysteresis of Ni50Ti50 SMA with Ni45Ti50Cu5 SMA in the form of ribbons. These ribbons are manufactured using the melt spinning technique at two distinct speeds: 20 and 45 m/s. Subsequently, they undergo annealing at a temperature of 470 °C for durations of 1 hour. By employing analytical techniques including XRD, DSC, SEM, and EDX, it has been determined that all samples demonstrate the presence of Ni4Ti3-Cu precipitates. DSC results indicate that the R20 sample exhibits a single-step transformation, while the R45 sample displays multi-step transformation characteristics. 5 at. % Cu alloy addition, is eliminating multistep phase transformation to some extent in R45 sample. There is a marginal reduction in Ms temperature, and Ht values with Cu alloy addition and annealing treatment in both R20 & R45. This paper provides valuable insights into the influence of Cu addition as well as a suitable annealing treatment on the transformation temperatures of binary NiTi SMAs.

**Key words**: Shape memory Alloy, Melt-spinning, Phase transformation temperatures, Thermal hysteresis, Annealing

# Comprehensive Analysis of Interband Transitions in Defect-Free ZnO Nanoparticlesusing Electron Energy Loss Spectroscopy and DFT

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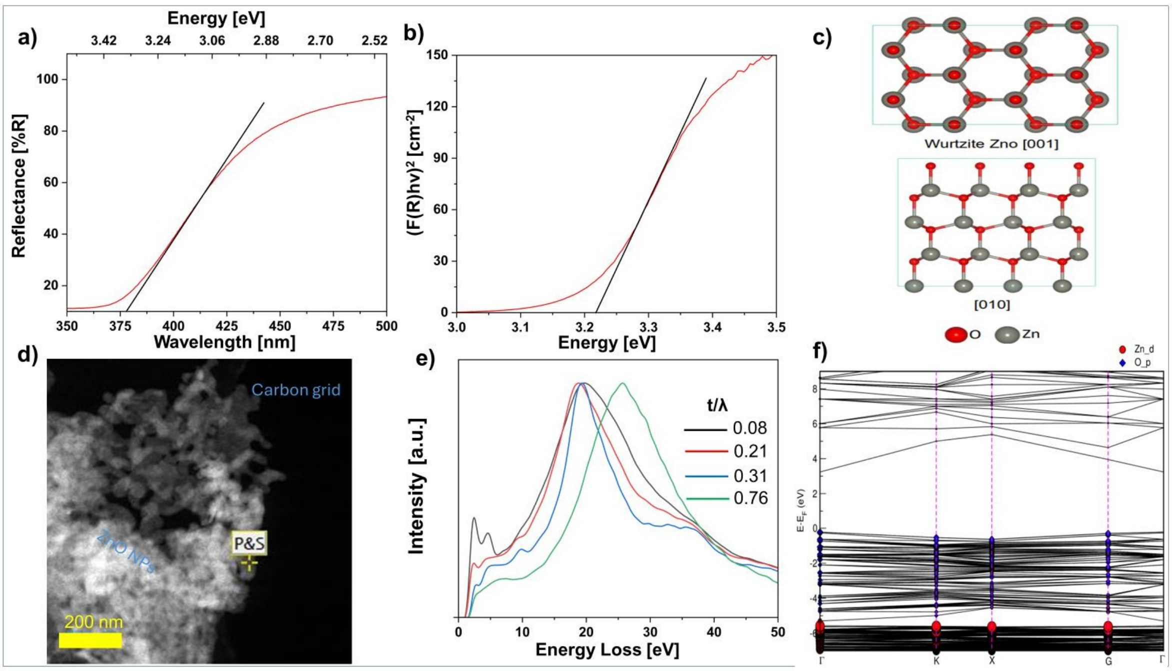
## Abstract

This study investigates the interband transitions in defect-free ZnO (Wurtzite) nanoparticles using a combination of Diffuse Reflectance Spectroscopy, Photoluminescence (PL) spectroscopy, Electron Energy Loss Spectroscopy (EELS), and Density Functional Theory (DFT). Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were employed to determine the nanoparticles' shape, size distribution, and morphology. EELS was utilized to extract band transitions and the dielectric function, corroborated by DFT calculations. PL spectroscopy confirmed the defect-free nature of the nanoparticles, as indicated by the absence of secondary emission bands in the 525-550 nm range. The experimental bandgap was found to be 3.22 eV, aligning with the DFT-computed bandgap of 3.48 eV using the PBE0 functional. The band-decomposed density of states and EELS spectra were compared,




with probable transitions successfully indexed.

Figure:(a) Diffuse Reflectance Spectrum (DRS) of ZnO nanoparticles, indicating a bandgap around 3.2 eV. (b) Tauc plot corresponding to the DRS data, confirming the bandgap of approximately 3.2 eV. (c) Wurtzite unit cell of ZnO. (d) Dark field survey image of the region from which the EELS spectra were obtained. (e) EELS spectra for varying nanoparticle thicknesses, represented by the t/λ ratio, where a higher ratio indicates thicker nanoparticles (λ represents the electron mean free path).(f) DFT-computed band structure of ZnO (Wurtzite) using the PBE0 functional, showing a direct bandgap of approximately 3.48 eV.

**Keywords:** Electron Energy Loss Spectroscopy; Zinc Oxide; DFT; Photoluminescence

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# Development of near superhydrophobic Titanium surface for orthopedic implants application: A study

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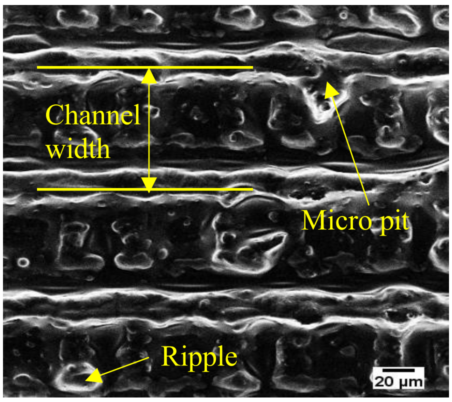
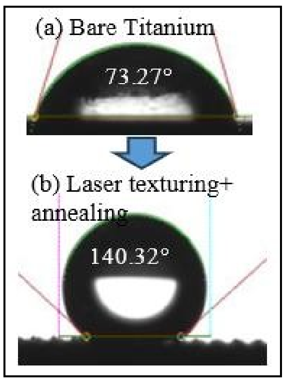
**Abstract**

Titanium has been widely utilized as an implant material in medical applications. However, one of the main causes of implantation failure remains to be inflammation or bacterial infection associated with implants. A superhydrophobic surface with a water contact angle (WCA) of more than 150° has gained importance for its ability to resist bacterial growth due to its self-cleaning characteristics. This study used a fiber laser to fabricate a micro pattern (100 µm channels) over a Titanium surface. The micro pattern surface shows hydrophilic properties right after laser texturing. The mechanism at play is that the ablated materials readily react with oxygen when exposed to the air during the ablation process, producing a thin coating of unstable metal oxide (TiO2). The structured titanium workpiece was annealed at 300°C in a muffle furnace for 3 hours following laser texturing to create a superhydrophobic surface. Micro-nano structures (fig.1) were created owing to the redeposition of ablated material after laser processing. As a result, the textured surface exhibits hydrophobic characteristics. During annealing, titanium reacts with oxygen and transforms into titanium oxide (TiO2) in the rutile phase. Air was entrapped between the rutile TiO2 structure and water, increasing the water contact angle to 140.32° (fig.2). Micro hardness and tribological studies were performed to examine the changes in hardness and wear after laser texturing. Micro hardness was performed with Vicker's micro-hardness tester at a load of 1 kgf for 15 sec. Micro hardness was improved to 360 from 345 after laser texturing and annealing. A pin-on-disc test rig was used to examine the tribological characteristics with a load of 20 N and sliding speed of 200 rpm and sliding duration of 1920 sec. Results indicate that cumulative wear decreased after laser texturing (fig.3).



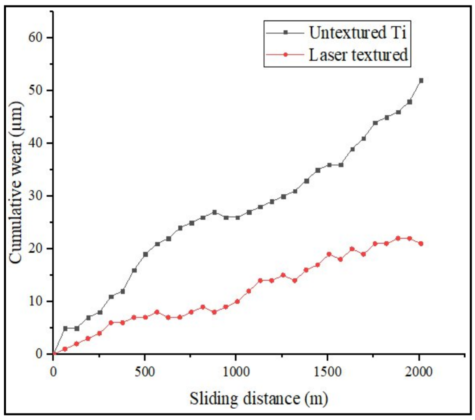




Fig.1 SEM image of textured surface Fig.2 WCA Fig.3 Wear test result

**Key words**: Titanium, Micro texturing, Hydrophobic, Wear, Micro hardness

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# Optimization of 4D Printing Parameters for Shape Memory Polymer Blends: A Comprehensive Characterization Study on TPU/PLA Blend

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**Abstract**

This research delves into the transformative potential of Additive Manufacturing (AM), with a focus on optimizing 4D printing parameters for shape memory polymeric blend composites. Specifically, it examines the mechanical properties of 3D-printed polylactic acid (PLA), thermoplastic polyurethane (TPU) filaments, and extruded PLA\TPU blends with reinforcement of $Fe_2O_3$ magnetic particles, highlighting the significant influence of infill patterns and densities. Findings reveal that PLA achieves the highest tensile strength with a Zig-Zag pattern at 100% infill, while TPU excels in elasticity and self-healing. The study emphasizes the critical role of CAD modeling and slicing in advancing AM technologies. Detailed analyses of the morphological, chemical, and thermal properties of PLA, TPU, and their reinforced blends underscore varying crystallinity levels. Additionally, the research explores how different 3D-printed optimizing parameters impact the stain recovery rate (Rr) and strain fixity rate (Rf) in the shape memory effect (SME) under varying temperature stimuli and response time of PLA/TPU blended $Fe_2O_3$ 3D printed composite. This study underlines AM technology's revolutionary credibility and adaptability in developing advanced polymer- based materials in soft robotics for magnetically actuated applications.

**Keywords:** Additive Manufacturing, 4D printing, PLA/TPU blend $Fe_2O_3$ composite, Shape Memory Effect, Infill Patterns

# Surface hardening of Pure Zn by Ultrasonic Peening for biodegradable implants

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## Abstract

Metallic biomaterials such as stainless steels, titanium alloys and Co-Cr alloys are commonly used for orthopedic implants in the human body due to their structural and electrochemical stability in the human body and excellent biocompatibility. However, the use of such implant materials for short-term clinical applications such as fracture fixation devices require the risk of a secondary surgery to remove the implant. Moreover, the presence of these implants in the human body for prolonged period than necessary can cause other issues like infections, necrosis etc. Therefore, in the past few decades, a lot of attention has been focused on the development of biodegradable implants using new metallic materials. A biodegradable implant material needs to have sufficient mechanical strength, as well as low corrosion resistance and extraordinary biocompatibility so that the implant can degrade within the body by electrochemical reaction within a stipulated time, without causing any severe biological response in the human body.

In this regard, several metallic systems based on Mg, Zn and Fe have been studied for the development of biodegradable alloys. The corrosion resistance of these elements can be given as Fe > Zn .> Mg. Therefore, the use of Zn as an implant material provides the option to for controlled degradation in the human body compared to extremely fast degradation of Mg and Extremely slow degradation of Fe. In spite of the promise shown by Zn as a biodegradable implant, there are issues regarding its performance in terms of surface mechanical, electrochemical and biological response. Therefore, in the present study, an attempt has been made to investigate the mechanical response of Zn by ultrasonic shot peening (USP) which is a shot peening based on severe plastic deformation process. The results show surface hardening by ultrasonic peening process due to grain refinement and microstrain accumulation.

**Key words**: Biomaterials, Implants, Zinc, Biodegradable implants, Ultrasonic Shot peening

# Green Solvent processed Formamidinium based Perovskite for Photovoltaic Application

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## Abstract

The most promising next-generation solar cell technology is organometallic-halide perovskite solar cells (PSCs), which are distinguished by their high power conversion efficiency (PCE) and lower cost.[1,2] Perovskite solar cells based on formamidinium (FA) have achieved a record-high efficiency of up to 25.7%, indicating remarkable potential for industrial commercialization in the future. However, there are still difficulties in utilizing all-green solvent processing to produce high-efficiency FA-based PSCs. Also, it is quite essential to stabilize the black-phase of $FAPbI_3$ perovskite by optimizing the nucleation and growth processes to get uniform crystallization. On the other hand the antisolvent treatment is considered as a most successful technique to deposit uniform and pinhole-free Perovskite. In our work FA-based Perovskite solar cell with uniform crystal growth and 16.08 % efficiency have been fabricated using green solvent (ionic liquid) and without any antisolvent treatment. As a result, we offer a fresh viewpoint on the industrial scale manufacture of PSCs in the future utilizing environmentally safe solvents without compromising with the performance.

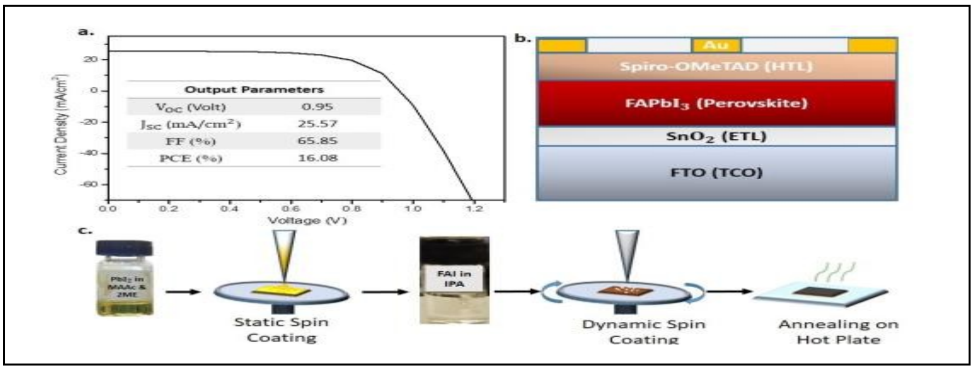


Fig. 1: (a) J-V curve (b) Schematic of device structure & (c) Schematic of Perovskite film deposition without any antisolvent treatment for the PSC device

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**Key words**: Perovskite Solar Cell, $FAPbI_3$, Ionic liquid, Green solvent.

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# Investigating the correlation between porous structure with high temperature thermal insulation performance in silica aerogel made by ambient pressure drying

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## Abstract

Energy is the key element for the growth of various sectors like industries, automobiles, agriculture, construction etc. But at the same time, increase in the energy consumption leads to global warming. So, the energy conservation is a critical global priority. Thermal Insulation plays a key role in this effort by enhancing the energy efficiency of buildings and industrial processes. Efficient thermal insulation minimizes heat transfer, thereby reducing the demand for heating and cooling systems. Conventionally various materials including organic or inorganic fiber battings are being used but with multiple limitations leading to reduce efficiency with time. Hydrophobic silica aerogel based flexible sheets have emerged as efficient thermal insulation barriers. Their superior thermal insulation can be applied in cryogenic systems, high temperature industrial applications and also to defence and aerospace domains. Compared to the conventional materials, aerogels are very light weight and can be used in both ultra hot and subzero conditions with great results. However conventional Supercritical drying (SCD) method of aerogel production make the product expensive and hence restricts its wide use.

The aim of the present study is to produce hydrophobic silica aerogel flexible sheet by cost effective way by avoiding the conventional SCD method and optimize the product compatible for the high temperature applications in the range of 100°C to 600°C for its best thermal insulation performance. Ambient Pressure Drying (APD) was adopted to make hydrophobic silica aerogel flexible sheets by infiltrating aerogel in the glass fiber mats. Such formed sheets with aerogels of various pore size distributions were tested for their thermal insulation performance in the temperature range from 100°C to 600°C. The indigenously built test set-up was used in these studies which complies with ASTM C335. The results are correlated with the morphology and porosity measured using various techniques like, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), BET surface area analysis, thermal analysis etc. The studies reveal that thermal insulation performance can be maximised at certain temperature by tuning pore size distribution, composition and the extent of porosity in the aerogel.

**Keywords**: Energy, Thermal Insulation, Aerogels, Supercritical Drying, Ambient Pressure Drying.

**Unveiling the role of Bi3+ Hetero-valent Doping in MAPbBr3 Perovskite Single Crystals on structural to electrical properties**

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## Abstract

Hetero-valent metal ion doping in lead (Pb) halide perovskites is an effective technique to modulate the ionic and electronic characteristics by inducing dopant charge and tuning the carrier concentration in individual crystals. Bismuth ($Bi^{3+}$) doping in methylammonium lead tri-bromide ($MAPbBr_{3}$) has been documented in the literature thus far to tune the optical characteristics. Nonetheless, a thorough investigation has not yet been conducted into the overall effects of $Bi^{3+}$ doping on the structural and electrical characteristics of $MAPbBr_3$ single crystals. Thus, using both theoretical and experimental methods, we have systematically examined the structural, optical, and electrical properties of pure and doped $MAPbBr_3$ single crystals. The B-site of MAPbBr3 single crystals doped with $Bi^{3+}$ generates lead vacancies (Vpb2-) in close proximity to the electrode contact. Additionally, studies of the doped single-layer electrochemical impedance spectroscopy in relation to bias. Additionally, bias-dependent electrochemical impedance spectroscopy tests on the doped single crystals reveal a high-frequency recombination resistance and a low-frequency semicircle, suggesting that the Bi3+ doping has improved the ion transport characteristics. Ion buildup at the perovskite/electrode interface causes low-frequency negative capacitance, particularly in low-field regimes. Around 0.5 V, a change in capacitance from negative to positive is seen as the voltage rises. These doped single crystals have tuneable ionic and electronic conductivity, making them promising for memristor applications.

**Key words**: Single Crystals, Halide Perovskite, Memristor, Neuromorphic computing

# Surface hardening of Pure Zn by Ultrasonic Peening for biodegradable implants

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## Abstract

Metallic biomaterials such as stainless steels, titanium alloys and Co-Cr alloys are commonly used for orthopedic implants in the human body due to their structural and electrochemical stability in the human body and excellent biocompatibility. However, the use of such implant materials for short-term clinical applications such as fracture fixation devices require the risk of a secondary surgery to remove the implant. Moreover, the presence of these implants in the human body for prolonged period than necessary can cause other issues like infections, necrosis etc. Therefore, in the past few decades, a lot of attention has been focused on the development of biodegradable implants using new metallic materials. A biodegradable implant material needs to have sufficient mechanical strength, as well as low corrosion resistance and extraordinary biocompatibility so that the implant can degrade within the body by electrochemical reaction within a stipulated time, without causing any severe biological response in the human body.

In this regard, several metallic systems based on Mg, Zn and Fe have been studied for the development of biodegradable alloys. The corrosion resistance of these elements can be given as Fe > Zn .> Mg. Therefore, the use of Zn as an implant material provides the option to for controlled degradation in the human body compared to extremely fast degradation of Mg and Extremely slow degradation of Fe. In spite of the promise shown by Zn as a biodegradable implant, there are issues regarding its performance in terms of surface mechanical, electrochemical and biological response. Therefore, in the present study, an attempt has been made to investigate the mechanical response of Zn by ultrasonic shot peening (USP) which is a shot peening based on severe plastic deformation process. The results show surface hardening by ultrasonic peening process due to grain refinement and microstrain accumulation.

**Key words**: Biomaterials, Implants, Zinc, Biodegradable implants, Ultrasonic Shot peening

# Study of microstructure modelling by phase field modelling using CALPHAD

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## Abstract

By understanding and controlling microstructure, we can create advanced materials with specific properties needed for high-performance uses. Spinodal decomposition is one such microstructural phenomenon observed in alloys. It occurs in the phase diagram's unstable region, characterized by an inflection point in the Gibbs free energy curve. This process leads to the formation of two interconnected phases. The Cahn-Hilliard equation, a phase field model, describes the kinetics of spinodal decomposition. This study focuses on the Fe-Cr, Fe-Cu and Al-Cu alloy systems, exploring their spinodal regions to predict microstructural evolution using Thermocalc software based on the CALPHAD technique. The obtained thermodynamic data is further analysed using MATLAB and μ2mech software to understand phase transformations and their impact on material properties.

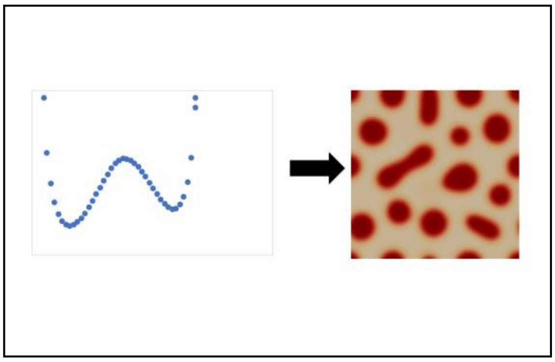

Fig. 1: microstructure evolution using CALPHAD

Key words: CALPHAD, phase field modelling , spinodal decomposition

# Development of Embedded-Atom Method (EAM) Potential for Palladium–Barium Alloy

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## Abstract

An embedded-atom method (EAM) potential for the Pd–Ba alloy system has been developed in order to forward computational research in this alloying system as there is no EAM potential available for this alloy system. The force-matching method has been implemented to develop the EAM potential first, and then, optimisation to converged density-functional theory (DFT) data sets has been done to generate the accurate and reliable potential for the Pd–Ba alloy system. Some physical, elastic and thermal properties of $BaPd_2$ crystal have been calculated through molecular dynamics (MD) simulation using the developed EAM potential and then verified these properties with the help of DFT analysis in order to examine the performance of the potential. Slight deviations in melting points calculation at different compositions of the Pd–Ba alloy system have been observed. Slower kinetics for inter-diffusion through diffusional characteristics study of BaPd2 has been reported using MD simulation with the developed EAM potential.

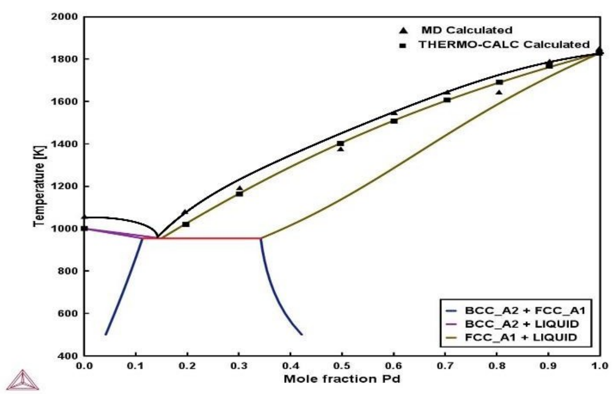


Fig. 1: Phase diagram study of Pd–Ba alloy system using THERMO-CALC and MD simulation

Key words: Embedded-atom method; Pd–Ba alloy; density-functional theory; force-matching method; molecular dynamics

# Material Informatics framework for polycrystalline alloys to develop process-structure- property linkages

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**Abstract**

Material properties often exhibit directional dependence, a phenomenon known as anisotropy, primarily influenced by the crystallographic texture of materials. Crystallographic texture is sometimes overlooked in conventional analyses, despite its importance for accurate alloy design since physics-based models that directly address texture effects are computationally intensive. Thus, simplified reduced-order models capturing the process-structure-property (PSP) linkages—detailing how materials are processed, and how their structure and properties evolve—are essential for effective alloy design. To address this challenge, we present an approach combining reduced order models and machine learning techniques to efficiently capture texture-based PSP linkages.

A fast and efficient quantitative methodology has been developed to capture the process-structure-property linkages within materials by utilising Generalized Spherical Harmonics (GSH) for crystallographic texture representation. The first approach consists of the following main steps: (1) using Generalized Spherical Harmonics (GSH) basis functions to transform orientation data, (2) employing 2-point statistics to analyse spatial correlations between crystallographic orientations, (3) applying Principal Component Analysis (PCA) to reduce data dimensionality while retaining essential features, and (4) using regression-based machine learning models to establish quantitative relationships between processing parameters, structural metrics, and microstructure properties. The 2-point statistics approach captures the spatial distribution and relationships between different crystallographic features, offering a nuanced understanding of how microstructural arrangements influence material behaviour. Additionally, a quantitative measure known as the Texture Index was used to evaluate the intensity of microstructural textures. This technique enables fast and precise calculation of texture indices, which quantitatively measure the overall intensity of the texture within a given microstructure. This approach consists of the following main steps: (1) using Generalized Spherical Harmonics (GSH) basis functions to transform the orientation data, (2) determining Orientation Distribution Functions (ODFs) from the transformed data, (3) integrating the ODFs to calculate the texture index, and (4) using regression-based machine learning models to relate the texture index as a structural metric to processing parameters and microstructure properties. The major strength of this work is the model's speed and extremely light computational load.

Keywords: Crystallographic Texture, Reduced-Order Models, Generalized Spherical Harmonics, 2-Point Statistics, Texture Index

# Effect of variation of composition on atomistic structure of ternary Cu – Zr – Al based BMG

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## Abstract

Bulk metallic glasses (BMGs) are known for their exceptional strength and corrosion resistance. They are used for critical structural applications and biomedical engineering. The glass-forming ability (GFA) of elements is considered while making BMGs. A combination of Cu, Zr, and Al are found to have excellent GFA and therefore are used for making BMGs. It has been observed that by altering composition and optimizing cooling rate, stable structures, and improved mechanical properties can be achieved. In this work, a ternary Cu – Zr – Al-based BMG is taken into consideration and the impact of varying composition on the amorphous structure of BMG is studied. The presence of Full Icosahedra (FI) clusters in BMGs promotes the stability of the glassy amorphous structure and indicates better GFA. Molecular dynamics-based modeling and simulation have been carried out to have an atomistic insight-based detailed analysis on the variation of composition on the formation of FI clusters. In general, a total of 36 samples have been taken into consideration by ranging Zr from 40 at % to 60 at. % with step size of 4 and Al from 5 at. % to 10 at. % with a step size of 1. Initially, glass transition temperatures (Tg) are determined, and then annealing is carried up to 0.9Tg to determine the number of FI clusters in the system.
It has been observed that by keeping the cooling rate at $10^{11}$ K/s, the number of FI clusters increases with an increase in Al whereas the number decreases with an increase in Zr or a decrease in Cu. This gives valuable insights about the stability of BMGs.
Keywords: Full icosahedra, Glass forming ability, Glass transition temperature, Molecular Dynamics

# Computational Analysis of Alumina-Aluminium Armour Plate

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## Abstract

The study investigated the influence of various aluminium series backing layers on the ballistic resistance ability of bi-layer ceramic-metal targets through three-dimensional numerical analysis using the ANSYS/AUTODYN explicit solver. The ceramic front layer used was 95% alumina, and the metal back plate layers included 1100-H12, 2024-T3, 6061, and 7075 aluminium. The study involved an ogive-nosed projectile made of 4340 steel, with impact velocities of 493, 820, and 1200 m/s. The materials' strength and failure modes under impact were modelled using the Johnson-Holmquist (JH-2) model for alumina and the Johnson-Cook (JC) model for steel and aluminium. Among the aluminium series, 7075 aluminium exhibited the highest ballistic resistance, while 6061 aluminium had the lowest. Both 1100H12 and 2024-T3 aluminium showed comparable ballistic performances. These materials failed to withstand the projectile impact at the specified velocities despite differences in material properties. The findings indicate that the choice of aluminium series significantly affects the ballistic resistance of bi-layer targets, with 7075 aluminium providing the best resistance to penetration at all tested velocities.

Keywords: ballistic analysis, Johnson-Holmquist, aluminium, projectile

# Elastic constants of non-stoichiometric palladium hydride: A first-principles study

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## Abstract

This work delves into the feasibility of using Pd for hydrogen storage by conducting extensive computations of its elastic characteristics at different hydrogen concentrations. First-principles Density Functional Theory (DFT) calculations were employed to investigate the elastic constants of $PdH_X$ for varying hydrogen concentrations in both interstitial sites. The findings indicate that the octahedral structure exhibits higher elastic constants than the tetrahedral structure. An increase in hydrogen content in both structural configurations results in a reduction in stiffness. The chemical strain due to increasing hydrogen content follows a linear behaviour, adhering to Vegard's law. Overall, this work provides valuable insights into the mechanical stability, deformation, and resilience of $PdH_X$, underscoring its potential for efficient hydrogen storage.

Keywords: Hydrogen storage, Elastic properties, Vegard coefficient, DFT calculations

# Investigation of Phase Stability and Stacking Fault Energy in Fe50Mn30Cr10Co10 Alloy: A Computational Approach

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## Abstract

High-entropy alloys (HEAs) or complex concentrated alloys possess exceptional strength-ductility combination in addition to thermal stability, corrosion resistance, and malleability, rendering them attractive for structural applications. It is attributed to the presence of twinning-induced plasticity (TWIP) and transformation-induced plasticity (TRIP) effects in some of the HEAs. Here, we have chosen the $Fe_{50}Mn_{30}Cr_{10}Co_{10}$ alloy, which exhibits these phenomena. The objective of this study is to evaluate the structural and mechanical properties of the of this alloy, particularly focusing on its dual-phase microstructure and the TWIP and TRIP effects. By using ThermoCalc (TC) and spin-polarized Density Functional Theory (DFT) calculations, this study aims to understand the thermodynamic stability of different phases and stacking fault energy variation with temperature on which the TRIP and TWIP effects are very much dependent.
Thermo-Calc calculations predict that below 300 K the HCP phase has a lower Gibbs free energy than the FCC phase, indicating its greater thermodynamic stability at lower temperatures. Thermo-Calc also predicts the presence of a BCC equilibrium phase in contrast to the literature experimental results. This discrepancy is attributed to the non-equilibrium cooling in experiments. DFT simulations suggest that, for both spin-polarised and non-spin-polarised calculations, the HCP phase has a lower energy than the FCC phase at 0 K. For spin-polarised calculations of the FCC phase, the antiferromagnetic arrangement of the magnetic moment causes volume expansion and energy reduction, taking it closer to that of the HCP phase energy. For the HCP phase, the effect of spin-polarisation on energy is very small. At 0 K, the non-magnetic BCC phase (non-spin-polarized DFT computation) is not stable, whereas the magnetic BCC phase is stable and shows a substantial ferromagnetic moment. To study the stability at high temperatures, the Gibbs free energy with temperature is computed using phonon dispersion calculations. These showed a transition from magnetic HCP to magnetic FCC at around 580 K. However, the energy difference between these two phases is very small, which implies the potential formation of a dual-phase structure. Our findings from the AIMD simulation indicate that Mn-Co, Cr-Co, Fe-Co, Fe-Fe, and Fe-Mn can form short-range orders, as confirmed by existing literature. The calculations of stacking fault energy with and without spin polarisation reveal a very strong dependence of the SFE on the magnetic effects of the elements. The SFE with spin-polarization remains consistently low at both 0 K and around room temperature, which is beneficial for enhancing the transformation-induced plasticity (TRIP) effect in the alloy.

Keywords: Stacking fault energy, phase stability, TRIP, TWIP, High Entropy Alloys.

# Orientation selection in alloy dendritic evolution at high velocity: A phase-field study

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## Abstract

Investigations of directionally solidifying melt pools during additive manufacturing (AM) processing of metal alloys reveal that the resulting columnar structures often grow along preferred growth orientations different from the temperature gradient direction, some of which are not even along preferred crystallographic directions. It is well-known that microstructure orientation results from the growth competition between the heat flow direction and preferred crystallographic orientation. Specifically, the competition between interfacial anisotropy and process anisotropy (pulling speed and thermal gradient) leads to symmetric dendrites, tilted dendrites and other unsteady morphologies, including seaweed patterns. The selection mechanism of such patterns remains unexplored at high velocity in the frame of AM. To understand the underlying physical phenomena, we study the tilted growth of cellular arrays as a function of the misorientation angles ($\theta_R$) between the directions of thermal gradient and crystal lattice and other relevant control parameters. For this purpose, we use an alloy phase-field method to explore the tilted growth of cellular arrays of a directionally solidified binary alloy at high velocity in two dimensions. We characterize the effects of varying the thermal gradient, growth velocity, the solutal concentration of the melt, and surface tension anisotropy on the growth direction of the resulting interface morphology and the associated primary arm spacing, constitutional undercooling, and microsegregation phenomena during directional solidification. Our work provides a detailed yet concise presentation of the tilted growth of dendrites for a broad parameter space and in the whole accessible range of directions for establishing the orientation selection maps, that is, to identify the relationships between growth directions and relevant variables. Our simulation results reasonably agree with experimental measurements and should have qualitative relevance to microstructure formation in metal castings and weldments of commercial alloys.

keywords: Phase-field, tilted dendrites, microstructure, microsegregation

# High Throughput Phase Prediction of High-entropy Alloys

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## Abstract

The phase stability of high-entropy alloys (HEAs) or multi-principal element alloys (MPEAs), which are composed of more than three elements, poses a significant challenge due to compositional complexity. The combinatorial explosion due to the multicomponent nature of such alloys warrants newer methods for simulation. Considering the above, the present talk will discuss computational tools such as the Genetic Algorithm Based Atomistic Sampling Protocol (GAASP) and the Order Parameter Engineering for Random Systems (OPERA) approach. The GAASP approach can be used for atomistic sampling of HEAs to generate thermodynamically relevant (i.e., low-energy) structures. In addition to this, we will present an approach to generate chemical short-range order (CSRO) without explicit energy calculations. The combined GAASP and OPERA approach can efficiently generate atomistic configurations for determining the thermodynamic properties of HEAs.

**Keywords**: High Entropy Alloys, Simulation, Phase Stability, Chemical Short-Range Order.

# Unveiling glass forming ability patterns in bulk metallic glasses via advanced machine learning approaches

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## Abstract

In the present study machine learning (ML) models were used to predict the Glass Forming Ability (GFA) of various bulk metallic glass (BMG) systems. A careful feature selection procedure was employed to identify important parameters that exert influence on glass formation. Linear Regression (LR), Random Forest model (RF), Support Vector Regression (SVR), and K-Nearest Neighbours (KNN) were used to estimate the compositional dependencies through numerous physical, thermodynamic, and topological characteristics on the GFA. Important parameters affecting the glass formation were selected utilising the rigorously curated feature subset RF model yields in Maximum R-squared value amongst all the models showing good predictability of $D_{max}$. Further, three key features, Mismatch entropy ($\Delta S_\sigma/k_B$), electronegativity difference ($\Delta\chi$), and $P_{HSS}$ were identified which shows the highest $R^2$ value (0.749) of $D_{max}$ prediction. The model was further validated using twenty distinct BMGs, resulting in an $R^2$ value of 0.82, indicating that the majority of the BMGs are in alignment with the model. Hence, this model has pinpointed the ideal glass-forming characteristics. The results obtained through the study will help to provide a better understanding of BMGs and their future development.

**Keywords:** Bulk metallic glasses; Glass forming ability; Thermodynamic parameter; Random Forest model; Machine Learning

# Phase Field Modelling of phase separation in FeCr using MicroSim

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## Abstract

Microstructure is the link between processing and properties. Hence, simulating the microstructure helps decide the processing route and parameters for desirable properties. Phase-field modelling is one such modelling technique which uses a diffused interface approach to simulate microstructural evolution. Microstructure is represented by phase-field variables which are continuous functions of space and time. Differential equations involving these variables are solved numerically for evolution of microstructure. Unlike sharp interface models, there is no need to keep track of interfaces; therefore, complex morphologies can be simulated. To get the quantitative results, thermodynamic information from CalPhad (Calculation of Phase Diagram) method can be coupled with phase field. This coupling is crucial for using phase field models in ICME (Integrated Computational Materials Engineering) platforms.

MicroSim (Microstucture Simulator) is a software stack consisting of various phase field codes developed under the National Supercomputing Mission. We are using the Cahn-Hilliard module in MicroSim to simulate spinodal systems. To do the same for real systems like FeCr, thermodynamic data generated from CalPhad method made available by Thermocalc is imported in MicroSim using TC-Python SDK. Gibbs free energy description in Thermocalc is used as input in the phase field as bulk Gibbs free energy.

In this presentation, we will present microstructures that are generated for composition Fe-35 at. % Cr and we will compare the same with published FeCr experiments involving APT and SANS technique. Specifically, we will compare the characteristic parameters of spinodal decomposition, namely, wavelength of phase separation, amplitude of phase separation and volume fraction of second phase. We will also discuss the modifications that might be needed in the model and the implementation such as composition dependent gradient energy coefficient for quantitative comparison of modelling and experimental results.

**key words** : Phase-field modelling, CALPHAD, Microstructure, spinodal decomposition

# The Effect of Heating Rate on Grain Growth and Mechanical Properties in 100Cr6(Bearing Steel)

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## Abstract

This research investigates the effect of heating rate on grain growth and mechanical properties in 100Cr6(Bearing Steel). 100Cr6, a high-carbon, chromium-containing steel, is widely used in bearing applications due to its excellent hardness, wear resistance, and fatigue strength. The heating rate during heat treatment processes is an important parameter that can significantly influence the microstructure of the material and, thereby, the mechanical properties. To understand this relationship, we conduct a series of controlled heat treatments at various heating rates, complemented by Phase-Field Simulations to model grain growth dynamics.

In the experimental stage, the 100Cr6 steel samples are subjected to different heating rates, followed by quenching to preserve the microstructures attained at different stages of the heat treatment process. The heat-treated samples are then characterized using Optical Microscopy, Scanning Electron Microscopy (SEM), and Electron Backscatter Diffraction (EBSD) to observe the grain morphology and measure the grain size distributions. Additionally, hardness tests are performed to evaluate the mechanical properties corresponding to each heating rate.

Parallel to the experimental work, Phase-Field Modelling is employed to simulate the grain growth behaviour under different heating rates. Phase field Modelling is a powerful computational tool that allows for the prediction of microstructural evolution by solving the governing equations of Thermodynamics and Kinetics. The simulations incorporate relevant material properties and process parameters, such as Diffusion Coefficients, Interface Energies, and Thermal Gradients, to accurately capture the grain growth dynamics in 100Cr6 steel.

Rapid heating rates lead to Heterogeneous grain growth, characterized by a mix of fine and coarse grains, which can detrimentally affect the material's mechanical performance. Slow heating rates result in uniform and fine grain growth. These fine grains impede dislocation movement, with enhanced mechanical properties, such as increased Hardness and Yield Strength. However, excessive grain refinement can lead to brittleness, reducing the material's toughness. The optimal heating rate is identified by balancing these competing effects.

Keywords: 100Cr6, bearing steel, heating rate, grain growth, phase field modelling

# A Phase-Field study of Field-Assisted Sintering

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## Abstract

This study develops a phase-field model to simulate Field-Assisted Sintering Techniques (FAST). The model integrates some key physical processes of solid-state sintering, such as rigid body translation, particle rotation, grain growth via boundary migration, and various diffusion mechanisms. It calculates local current density distribution to analyse electrical conductivity variations and verify Joule heating. Additionally, it accounts for heat conduction and losses due to radiation and convection, updating diffusivities dynamically with temperature changes. The model's predictions for densification curves and Joule heating are validated, showing enhanced diffusivities from the applied electric field, leading to higher particle densification and faster sintering rates. This model offers insights into Field-assisted sintering processes, optimizing sintering parameters, and improving material properties. The model predictions are used to delineate the contributions of Joule heating towards Field-Assisted Sintering.

Key words: Phase-Field Modeling, Field-Assisted Sintering, Joule heating

# Modelling for Enabling First Time Grain Oriented Electrical Steel Rolling (CSP-Route) in India

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## Abstract

Demand for Electrical steel is expected to grow to 200 kT by 2030, backed by 30-40% EV penetration. New charging stations will lead to increase in Cold Rolled Grain Oriented (CRGO) demand. Currently in India, 100% CRGO grades are imported, and existing domestic suppliers are unable to cater to this EV segment. The future scope for Electrical steel is increasing and thereby it’s important to explore the possibility of high-quality mass production in this segment.

Electrical steel is of two types. First one is Cold Rolled Non oriented (CRNO) which is used in electrical motors. The second one is Cold Rolled Grain oriented (CRGO) which is used in transformers. With increase in Electrical vehicles & charging stations, the consumption is expected to increase significantly. Though few CRNO steel grades are produced in India, 100% CRGO grades are imported in India, and they are heavily protected with patents both on the process route and chemistry. CRGO exhibit best magnetic property in one direction.

Keywords: Quality, Hot Rolled Coils, GRGO, Simulation, Rolling Simulator

# Effect of Hydrogen Injection in a COREX Gas Based DRI Furnace using a CFD Model

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## Abstract

With increasing push towards carbon and emission reduction in steel plants, it has become inevitable for iron and steel plants to look for cleaner alternatives for iron making other than the BF – BOF path. With ease of operation and shorter maintenance time, gas based DRI making furnaces have gained attention of researchers all around the world. Hydrogen has been reported as a better and cleaner reductant for iron ore, however, a DRI plant being run completely on hydrogen is yet to be realized practically. In this regard a gradual transition towards hydrogen based reducing gas is envisioned as a cost effective route. Hence industries have taken up hydrogen injection in existing plants to reduce carbon emission and evaluate their process for transportation and handling of hydrogen. A CFD model was built to asses the operation of a COREX gas based DRI furnace along with injection of pure hydrogen. The increased productivity and the impact on bed temperatures has been studied through the CFD model. With increasing hydrogen injection, the $H_2/CO$ ratio of the reducing gas reaches 1 which leads to a transition from an exothermic operation to an endothermic operation leading to lower top gas temperatures. The present study aims to benefit the plant scale trials of hydrogen injection in COREX gas based DRI plant at JSW Vijayanagar Works.

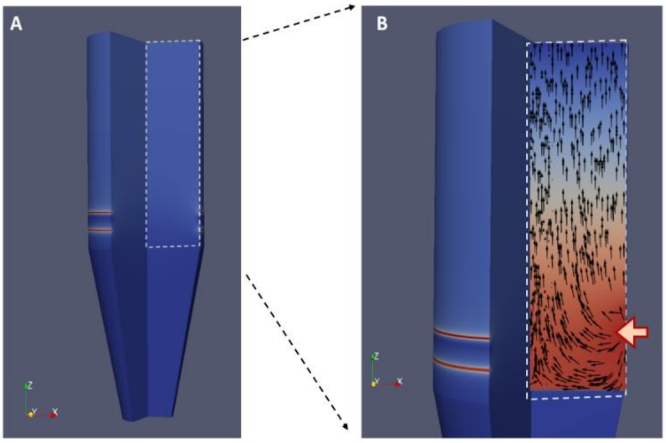


Fig. 1: Illustrative diagram of DRI shaft with velocity vectors of reducing gas

**Key words** : Direct reduced iron, Computational fluid dynamics, Hydrogen Injection, OpenFoam, Process modelling.

# Enhancing Surface Wettability Predictions of the Textured Surfaces Using Machine Learning

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## Abstract

The study of surface wettability is important for several reasons across various fields, including physics, chemistry, materials science, biology, and engineering. Surface wettability plays a significant role in biological systems, including cell adhesion, protein adsorption, and biomaterial compatibility. Understanding and controlling surface wettability are essential for designing biocompatible materials, medical implants, and drug delivery systems. Analysis of surface wettability with different surface properties and energies is very important to characterize the surface or materials. However, it is computationally very expensive to simulate a model to analyze the wettability and characterize the surface. In this paper, we developed and validated a model using the Pseudo-potential multiphase lattice Boltzmann method to generate training data for the machine learning algorithms. Support vector regression, decision tree regression, Extreme gradient boosting machine, Random forest regression, and Adaptive gradient boosting machine models were developed to predict the surface wettability and identify the correlation between surface and fluid properties with surface wettability. The proposed models can make a surface wettability prediction for arbitrary surface and fluid properties. The R2 score, RMSE, and MAE metrics are used to evaluate the performance of the models. The comparison between numerical results and ML model predictions showed a good agreement of more than 98%.

**Keywords:** Surface wettability, Machine learning, AdaBoost, $R^2$ score, RMSE

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# Plant Simulation of Blast Furnace using Aspen Plus

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## Abstract

Blast furnace remains the cornerstone of the iron and steel industry, more so in the Indian context. It contributes to about 65–70% of total $CO_2$ emissions during the steel production from iron ore. To address increasing concerns on emissions and prioritize sustainability, this study uses Aspen Plus, a process simulation tool, to model and simulate blast furnace operation under different operating conditions and study the impact on emissions. The model mimics the important chemical reactions occurring in the various zones of the blast furnace using the RIST model. The blast furnace model is also integrated with other ancillary units like hot blast stove and PCI unit. The model captures changes in input parameters like the raw material composition, and gas flow rates, and operating conditions like the pressure and temperature. For the development of the plant simulation model, this work includes the development of a mass and enthalpy balance model based on Excel using the data of the JSW plant. Finally, the model will be validated with the plant data of BF-4 of the JSW Steel plant. A scenario analysis will be performed to investigate the impacts of injection of auxiliary reducing agent, increase in PCI rate, increment in the $O_2$ enrichment rate and injection of $H_2$ at different rates as well as at different temperatures. Based on the scenario analysis, the replacement ratio of coke and coal will be obtained, which will guide in the estimation of possible reduction of $CO_2$ emissions from the blast furnace.

**Key words** : Blast Furnace, $CO_2$ reduction strategy, Aspen Plus, Simulation.

# Computational Alloy Design of Cr-modified Fe-Mn-Al-Si-C Lightweight Steel Through Calphad and Machine Learning Approaches

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## Abstract:

The steels used in the automobile sectors must reach an attentive balance between strength and ductility to maintain the structural integrity of vehicles and achieve intricate designs. Moreover, there is a continuous drive in the automobile sector to reduce the weight of the passenger car to reduce the carbon footprint. However, passenger safety remains the top priority in such material selection processes. Using high-strength steels as traditional weight reduction approach is subjected to its own limits. A new austenitic lightweight steel has therefore been developed in the present study with a composition range of Fe-(10-30) Mn-(1-12) Al-(0.4-1.8) C primarily for the automotive applications. The stacking fault energy (SFE) is an important parameter for determining the deformation process and optimizing the mechanical properties of austenitic steels. Aluminum (Al), carbon (C), and manganese (Mn) are chosen as alloying elements to increase the SFE of the alloy. Chromium (Cr) and silicon (Si), on the other hand are selected mainly to enhance the corrosion resistance. The use of chromium (Cr), silicon (Si) and aluminum (Al) help to reduce the density of the alloy as well. In this study, we used a thermodynamic model considering sub-regular solution approach and also different machine learning (ML) techniques to forecast the SFE for over 614 austenitic steels. The comparison emphasizes the need to enhance the CALPHAD (CALculation of PHAse Diagrams) databases and interfacial energy prediction techniques to improve the accountability of thermodynamic models. The objective of the ML approach is to create a prediction model which can analyze the correlation between chemical composition and SFE. When comparing several ML algorithms, it is found that the Extra Trees (ET) model exhibits the highest level of prediction accuracy, with an $R^2$ value of 0.98 and lowest Mean Absolute Error (MAE) values (train=0.89 and test=5.88 $mJ/m^2$). In addition, the SFE values predicted using these models were compared with the experimental values reported in the literature. The current models present new changes that correlate better with experimental findings.

Utilizing these models, we have developed a Fe-Mn-Al-Cr-Si-C steel that can form an austenite phase stable within the 920-1200 oC temperature range. The SFE of the alloy was estimated to be 61.47 mJ/m2 and 61.71 mJ/m2 using thermodynamic and ML models, respectively. Whereas, the SFE, as determined by the XRD microstrain method is 62.68 mJ/m2. The newly designed alloy has a yield strength (YS) of 426 ± 4 MPa, an ultimate tensile strength (UTS) of 744±15 MPa, and an elongation (TE) of 75±3%.

Keywords: Stacking fault energy, Machine learning, Extra trees, Lightweight steels, CALPHAD

# Framework to optimize texture and enhance magnetic property of electrical steel processed by repetitive bending under tension

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## Abstract

Electrical steels are used in various soft magnetic core applications like electric motors, generators, alternators, etc. Electrical steels are steels that have high amounts of silicon (up to 3.5%) which reduces eddy losses and increases magnetic permeability. More than 90% of the soft magnets are made of electrical steels out of which major contribution is from non-oriented electrical steels. Non-oriented electrical steels (NOES) have similar magnetic properties in all directions (magnetic isotropy) whereas grain oriented electrical steels are anisotropic. Improving the magnetic properties of NOES through optimization of crystallographic texture has been an on-going research activity since long. Any small improvement leading to a small increase in efficiency would lead to a significant impact in the overall energy consumption. Traditional sheet metal processes to manufacture NOES includes hot rolling followed by annealing and cold rolling. Recent experimentations have shown that a recent sheet metal deformation method, i.e., Repetitive bending under tension (R-BUT), as opposed to cold rolling promotes the cube texture which is desirable for improved magnetic properties. It also increases the formability of the material by which large strains are attained without reaching the fracture limit of the material. This is evident from Figure. 1 which compares the load-displacement curve of specimen under simple tension and R-BUT process. This happens because plastic flow occurs in this mechanism which prevents necking. This work focuses on developing a finite element model to simulate the R-BUT process in Ansys and explore the effects of different process parameters on the final texture obtained. The deformation gradients are extracted from the FEM model, then used by crystal plasticity models to predict crystallographic texture.

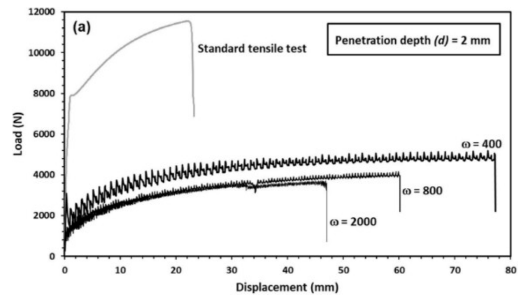


**Figure. 1**: Load displacement curve for R-BUT sample process and simple tensile test.

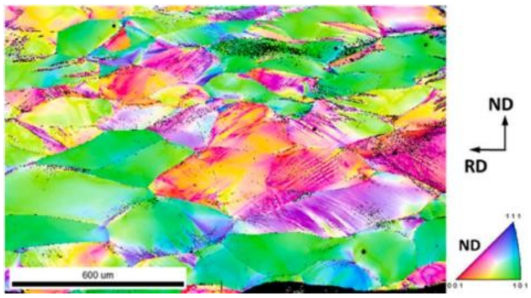


**Figure. 2**: Inverse pole figure map for surface after R-BUT process

Key words: Electrical steels , Repetitive bending under tension, crystallographic texture

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# Finite Element Analysis of Scanning Strategies in Dissimilar Metal Additive Manufacturing Process

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## Abstract

Multi-material hybrid components such as copper-steel with enhanced thermal conductivity and high strength are attracting attention for their superior performance. Cladding of Copper onto steel using laser-directed energy deposition (L-DED) is a viable option. However, the process is challenging due to differences in the material thermo-physical properties, resulting in residual stresses and distortion. In this study, a coupled thermo-mechanical analysis has been performed using Finite Element Method (FEM), where SS316 steel is taken as the substrate, and copper is the deposited part. The study is performed for six scanning patterns: raster, zig-zag, alternate line, out-in spiral, in-out spiral, and S scan. The anisotropic heat transfer behaviour during steel-copper cladding necessitates selecting scanning strategies that promote homogeneous thermal distribution by minimizing the number of deposited elements in contact for optimal heat transfer performance. The zig-zag scan path is found to be an ideal choice for the dissimilar cladding of copper on steel since it shows less residual stress and distortion, a weaving pattern, and a continuous path.

Keywords: Additive manufacturing, Scanning path, Numerical Modelling, Thermal Analysis,

Finite Element Methods

# FEA Simulation of Automotive B-Pillar component for High Strength Automotive Steels

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## Abstract

Automotive industry has been on a continuous journey to reduce weight for fuel efficiency and increase safety by using high strength structural components. With every new model, automotive designers have been changing the structural components and material specifications to augment its efficiency and safety limits. One such component is the B-Pillar which forms the vertical roof support structure located between the front and rear doors on a typical vehicle and its properties determine the safety of the vehicle's passengers in the event of a site impact or rollover. With the development of different high strength steels with varying formability, it becomes imperative to study and identify the best grade of steel for this critical component. The FEA based models offer a cost-effective solution for determining the most suitable and cost-effective grade of steel for a specific applications. In this study, a finite element analysis (FEA) model was developed using Simulia Abaqus simulation package to simulate the forming of B-Pillar. The FEA model was used to carry out forming simulation of the b-pillar component using six different advanced high strength steels (AHSS) commonly used in the automotive industry namely LA380, DP590, DP780, DP980, DP1180 and CP780. Developed model was used to predict and compare the possible crack locations, major & minor strains, stress distribution and thinning profiles for the selected grades of steel. It was found that DP590 shows more wrinkling tendency and DP980 & DP1180 grades show cracking tendency at the bend section due to lower formability. DP780 and CP780 were found to be ideal for the selected b-pillar design. However CP780 would require higher blank force compared to DP780. The model can be utilized for the development of new steel grades and checking design specific suitability offline, thereby reducing the need for physical experiments.

**Key words** : FEA simulation, B-pillar, cold forming, AHSS, dual phase steels, complex phase steels

# Experimentally Informed Micromechanical Modeling of Deformation Behavior of Structural and Technological Alloys

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## Abstract

Experimentally informed micromechanical modeling of materials can be instrumental and in fact unavoidable for the faster and cost-effective design and development of materials with desired properties. In recent years, micromechanical material modeling techniques have achieved a tremendous success due to their ability to systematically investigate complex phenomena such as dislocation mediated plasticity, dislocation-precipitate interaction, temporal and spatial evolution of stress and strain during deformation, phase transformation, mechanical twinning, damage and fatigue and so forth. These modeling techniques require an appropriate selection of material dependent constitutive model to describe the elasto-plastic deformation on the crystal scale, a well suited representation of the underlying microstructure to be analyzed (mostly coming from experimental observations) and a numerical technique to solve the partial differential equations describing the modeling phenomenon. Here, crystal plasticity finite element method (CPFEM) provide a powerful solution scheme for modeling the deformation behavior of different structural and technological alloys used by the manufacturing industries.

In the present work, we have developed experimentally informed micromechanical models based on the concepts of Crystal Plasticity (CP) finite element method. We showcase the power and versatility of these CP models through couple of different cases of material and phenomenon specific modeling. These different examples of modeling of TRIP assisted high strength steels, Al alloys, Mg alloys and Ni-based superalloys, sets the pathway for design and development of new structural and technological materials including the solutions to the existing challenges in the mechanics of materials community. In addition, these examples also points out the importance of modeling and simulation in the industrial context. The glimpse of scientific work presented in these examples are the excellent combination of experiments and simulations following the framework of integrated computational materials engineering (ICME).

Keywords: Crystal Plasticity Finite Element Method, Dislocations, Microstructure, TRIP effect, Structural Alloys

# Detailed study on unbalanced force emanating from stored elastic energy from quasi- static DEM simulation in granular packing

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## Abstract

Traditional understanding suggests that the load on granular materials is unevenly distributed, primarily along force chains, while other particles experience minimal force. However, the concept of unbalanced forces and its impact on transitioning from quasi-static to non-quasi-static states remains inadequately explored, especially in discrete simulations of granular packing. We conducted systematic analysis, inspired by common tests in the mining industry such as the wall friction test, through simulation to comprehend the behavior of unbalanced forces within the system. Contrary to expectations, we observed sharp peaks of unbalanced forces even under quasi-static conditions. By identifying particles with maximum unbalanced forces and scrutinizing their dynamic behavior and surrounding environment, we gained valuable insights. Our study elucidates that sudden peaks in unbalanced forces are attributable to the storage of elastic energy within particles, followed by sudden or gradual release. This fundamental exploration of unbalanced forces and their relationship with stored elastic energy fills a notable gap in the existing literature.

Identifying instability in particulate ensemble is at the core of many important phenomena, such as the Shear Transformation Zones (STZs) in metallic glasses, identifying tiny but non-trivial configurational changes at the onset of glass transition as well as for its relaxation behavior, origination of specific structural features (say, origin of stacking faults) in High Entropy Alloys (HEAs), kinetic instability induced symmetry breaking in granular media, Self-Organized Criticality (SOC) induced avalanching in granular systems etc. For example, it is still an open challenge in the glass community to elucidate the reasons for relaxation behavior of small atomic clusters and their displacements during deformation. Although, the role of unbalanced force index into those phenomena is not thoroughly explored to the best of our knowledge, the findings of the present article drop an interesting hint about its suspected role as a common thread behind such diverse and seemingly unconnected phenomena, which warrants a thorough investigation. In that case, the unbalanced force index can turn out to be a very important metric for analyzing the configurational instability of particulate ensemble for quasi-static and static conditions.

**Keywords:** Discrete element modelling, Granular material, Unbalanced force, Wall friction test, Iron ore, Quasi-static

# Multi-objective multi constrained optimization of copper alloy compositions for targeted properties using genetic algorithm

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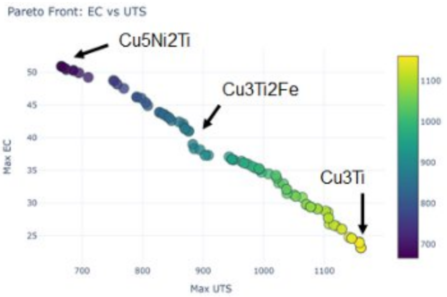
## Abstract

Copper alloys are pivotal in various industrial applications due to their excellent electrical and thermal conductivity, corrosion resistance, and mechanical properties. The performance of copper alloys is significantly influenced by their composition and processing parameters, which presents a complex, multi-dimensional optimization problem for alloy design. Traditional approaches to alloy design often rely on empirical methods and trial-and-error, which are time-consuming and inefficient. Machine learning and genetic algorithms has become increasingly efficient with the advent of increased computational power and therefore are used for design of alloys with novel compositions and properties. Machine learning serves as the starting point for the integrated computational materials engineering approach which facilitates optimisation of targeted properties. In this study, we explore the optimization of copper alloy compositions and processing parameters to maximize ultimate tensile strength (UTS) and electrical conductivity (EC) using machine learning models. A dataset of over thousands of alloy compositions is used for training machine learning models. Random forest model was chosen as the best model for optimisation among many based on evaluation metrics performance. A genetic algorithm is employed for the optimization process, leveraging a random forest regressor as the predictive model. Non-dominated Sorting Genetic Algorithm II (NSGA-II) is employed using a fast non-dominated sorting approach and an elitism strategy to ensure the convergence towards the Pareto-optimal front. The optimization adheres to constraints ensuring the sum of composition of alloying elements to 100% and individual elements stay within the specified bounds. The Pareto front solutions highlight the trade-offs between these properties and provide a range of optimal compositions for further investigation. Our results reveal critical insights into the composition-property relationships and highlight the significant factors affecting UTS and EC. For example: Three compositions based on Cu-Ti having different combination of UTS and EC are shown in Fig. 1. Two of these compositions have been melted, processed and characterized to validate the results. There is good match between prediction and experimental data.




| Compositions | UTS (Mpa) | EC (%IACS) |
|---|---|---|
| Cu3Ti | 1170 | 21 |
| Cu3Ti2Fe | 985 | 35 |
| Cu5Ni2Ti | 665 | 50 |

Fig. 1: (a)Pareto-optimal front of UTS and EC for copper alloys (b) selected compositions

Key words : Multi objective optimisation, genetic algorithm, random forest regressor

# Mitigation of Galvanizability Issue in Advanced High Strength Steel Sheet and its Time Evolution Corrosion Performance

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## Abstract

Continuous hot dip galvanizing of advanced high strength steel grades is fraught with problems arising out of the surface selective segregation and subsequent oxidation of the alloying elements during the coating process. In the present work, the galvanizability of DP 980 steel grade has been improved through an application of Fe-based pre-layer on steel surface prior to the application of a galvanizing coating. Furthermore, the influence of high content of Al and Mg, addition of alloying elements and the change in the microstructure of the coating were studied in order to mitigate the issue of the formation of brittle hexagonal $MgZn_2$ phase in the coating. Finally, the relationship between the coating microstructure and corrosion performance has also been analyzed.

Keywords: Galvanizability, Advanced High Strength Steel Sheet, Time Evolution Corrosion, Zn-Al-Mg coating, brittle hexagonal $MgZn_2$ phase

# Prevention of Pin Rust formation in Cold Rolled Steel Sheets

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## Abstract

The surface quality of cold-rolled steel sheets is crucial for drum and barrel applications, especially when using Dioctyl Sebacate (DOS) oil, which is intended for storing food grade oils/goods. However, DOS oil is lighter than rust preventive (RP) oil. The corrosion rate is influenced by factors such as atmospheric temperature, humidity, pollutants, and surface residues. This often results in pin- type rust formation in cold-rolled continuous annealed (CRCA) coils. The defect appears as small rust spots that develop randomly (rust nucleation).

To improve the product's corrosion resistance, the problem was analyzed in three steps: enhancing the base material, optimizing storage and aging and improving the self-life of DOS oil. For base material improvement, process parameters were examined to identify the most significant factors affecting corrosion resistance, which included H2 concentration in the annealing furnace, strip temperature in the last section of the annealing furnace, and material chemistry (micro alloy addition during slab casting). These parameters were optimized and results were validated using Electrochemical Impedance Spectroscopy. The data analysis shows relation between ageing from CAL production time to material use at the customer. Accordingly, Statistical analysis of consumption patterns and production timelines was conducted to optimize order placement and dispatches, reducing the overall aging of coils. By implementing these measures, pin rust formation in CRCA material with DOS oil was successfully controlled. Next, the quality of DOS oil was enhanced by adding approved substances in existing oil, thereby changing the morphology of oil to improve its self-life for corrosion resistance capacity from the existing self-life. This was done in close coordination with the oil supplier. The different formulated oils were applied on CRCA sheets and testing's like humidity, SST were done to identify the most suitable formula.
In conclusion, enhancing the base material, improving DOS oil, and optimizing storage and aging successfully controlled pin rust formation in cold-rolled and annealed steel sheets.

Key words : Pin Rust, DOS Oil,

# Electricity Generation Using Organic Materials

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## Abstract

In this paper, some fundamental investigations are established to demonstrate the potential of harvesting electrical energy from living plants. The energy is harvested by embedding electrodes into the plant to allow flow of ions and hence generate electricity. Multiple random tests have been conducted using different types of electrodes and plants or soil as an attempt to determine the characteristics of the harvesting system. It is found that voltages are produced to greater extents by all tests where combination of special rod and every plant produces the highest voltage. In addition, it is shown in this paper its ability to light up Light Emitting Diodes (LED). By using a multimeter to test the value of voltage max=1.89V generated by a single cell of plant and soil generate max voltage =2.10V by using 20g of soil. which grants it a potential to be used for low power electrical consumption appliances in the future. We can also convert the dc current into AC current for use in large appliances.

Fig. 1: Electricity generating using aloe vera

Key words : renewable energy; organic energy; higher energy source; energy generate system: Unwanted living plants, Special plate, anode, cathode rod, sulphur acid,

# Enhancing Aluminium-Air Battery Performance: Suppression of Hydrogen Evolution Reaction via Electrolyte Modification

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## Abstract

Aluminium-air batteries stand out as a promising alternative for energy conversion technology, offering sustainability and environmental benefits. It is characterized by its high specific capacity of 2.98 $Ahg^{-1}$, energy density of 8.1 kWh $kg^{-1}$, lightweight design, safety and cost-effectiveness. However, similar to other battery types, the development of aluminium-air batteries faces significant challenges, particularly due to the inherent parasitic hydrogen evolution reaction (HER) at the aluminium anode. This reaction, driven by severe corrosion, results in low anode utilization, reduced discharge capacity, and poses safety risks due to hydrogen gas accumulation. The hydrogen gas is produced from free water molecules not solvated by cationic species in the electrolyte, leading to deprotonation at the anode surface. To mitigate HER on the aluminium anode, reducing the water activity at the anode surface is crucial.

In this study, a strategy is used to modify the hydrogen bond network of the electrolyte to reduce parasitic reactions. By adding low-cost, eco-friendly sodium glycinate molecules, which contain nitrogen and oxygen atoms, the solvation structure of the traditional NaOH electrolyte is significantly altered. This approach reduces the number of free water molecules and effectively suppresses the hydrogen evolution reaction (HER) at the aluminium anode.

**Key words:** Aluminium air battery, Electrolyte, Corrosion, HER

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# Water-Powered Spercapacitors: From Aquatic Irrigation to Energy Fulfillment

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## Abstract

The rapid depletion of fossil fuels is observed worldwide thus, there has been a growing demand for renewable and sustainable energy sources [1]. As a part of development of a sustainable energy source, supercapacitors are the promising candidates. They can be the alternatives to existing batteries for various applications. Supercapacitors show features such as high-power delivery and fast charging capability. Supercapacitors use thin dielectric film and high surface area electrodes, due to which they show high energy storage capacity. Simultaneously, low cost is also the benefit since they use carbon-based materials. To add the benefit of efficiency and sustainability to supercapacitors, biomass sources are used. The biomass-derived carbon sources can be also be biodegradable, which is an advantage over traditional dielectric materials which are used in the existing supercapacitors. Water hyacinth, an invasive aquatic weed, presents a viable raw material for carbon synthesis [2].Water hyacinth is the weed, having excess growth and has led to significant ecological issues, including oxygen depletion in water. In the present work, attempts are being made to use the stems of water hyacinth as the precursor for supercapacitor electrode fabrication. The local sample of water hyacinth is used, which was collected from the Ambazari Lake, Nagpur, Maharashtra, as a precursor for supercapacitor electrode fabrication. The stems of water hyacinth are first carbonized at 300°C and subsequently graphitized at 800°C to in order to obtain the porous structure. It is found that the carbon electrodes exhibit excellent performance. The electrodes have achieved a specific capacitance value of 129 F/g at 0.5 A/g and good cycle stability even after 1476 cycles of charge-discharge at a current density of 4 A/g. It is reported in literature that the biocompatibility, flexibility, and porous nature of cellulose present in water hyacinth are able to contribute to the effectiveness of water hyacinth-derived carbon in supercapacitor applications [4]. This work meets the dual purpose of eliminating the ecological problems caused by the pervasive water hyacinth and using it for building the supercapacitor application [3].

Key words : Water Hyacinth, Biomass-derived Carbon, Supercapacitors, Sustainable Energy Storage Devices, Hierarchical porous structure.

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# Preventing Oxidative Staining in Continuous Pickling Lines: Efficacy of Plus 10 B Alkaline Inhibitor

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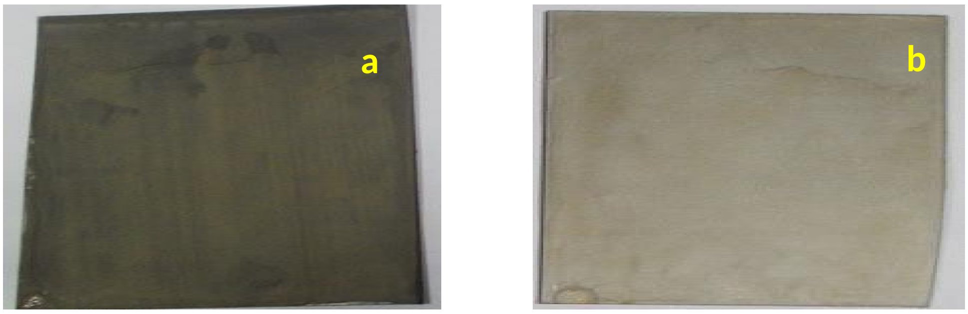
## Abstract

In continuous pickling lines, steel strips often develop stain marks during line stoppages due to reactivity with the environment. A trial was conducted using Plus 10 B, an alkaline stain inhibitor to prevent this issue.

In the present investigation the inhibitor was tested on hot-rolled (HR) samples (3" x 15") under laboratory conditions. To simulate the pickling conditions, the samples of hot rolled strips were pickled in 15% HCL solution at 70-80°C temperature for 28 seconds, followed by rinsing in deionized water with and without Plus 10 B at varied concentrations (0.2%, 0.3%, 0.4% V/V) at 65°C for 5 minutes and 1 minute. The results demonstrated that samples treated with Plus 10 B exhibited no stains during periods of stillness, regardless of the duration, while untreated panels showed brown-black stains. This study confirms the efficacy of Plus 10 B in preventing oxidation staining on steel strips during stoppages in continuous pickling lines, highlighting its chelating functions that inhibit stain formation.

Fig. 1: a.Without Inhibitor b.With Inhibitor




Key words : Stain marks, Plus 10, concentrations, Temperature, chelating

# Hydrogen's Impact on the Microstructure and Mechanical Characteristics of Post-Weld Heat-Treated Pipeline X60 Grade Steel

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**Abstract**

Since hydrogen is a renewable and sustainable energy source, it is essential to achieving net zero emissions globally by 2050–2070. Currently, attempts are being undertaken to transport hydrogen in combination with natural gases or in its pure form. When considering transportation choices, pipeline systems (with a capacity of 100,000 kg/hr and costing 0.1-1.0
$/kg/km) seem to be a better option than trucks and ships. When hydrogen and pipeline steel interact, a major problem known as hydrogen embrittlement (HE) can occur. This can seriously impair the mechanical qualities of the material, including elongation and fracture toughness. Less emphasis has been paid to welding, despite it being a crucial step in the pipeline transportation of hydrogen. When pipelines are welded, the effects of hydrogen embrittlement are more severe.

In this investigation, pipeline steel of X60 grade was welded using the manual metal arc welding (MMAW) procedure and then exposed electrochemically to a hydrogen atmosphere. Utilizing SEM (including EBSD) and hardness/tensile testing, the microstructure and mechanical characteristics of the as-received, welded, and post-welded steels have been assessed. It was discovered that the steel's hardness increased following welding, but that it decreased following heat treatment. The ductility of X60 steel was reduced by 40–50% and 80–85%, respectively, before to and following welding, as a result of hydrogen charge. When compared to the welded condition, post-weld heat treatment shown an improvement, with a 60–70% reduction in ductility following hydrogen charge. The existence of cleavage characteristics following hydrogen charge was verified by fragmentography analysis. The present study aims to investigate the correlation between the mechanical characteristics of X60 steel, both before and after hydrogen charging, and its microstructure, including phase fraction and grain size.

Keywords: X60 steel, MMAW process, Hydrogen embrittlement, Microstructure, Mechanical properti

# Development of multi-principal mixed metal oxide impressed current anodes for cathodic protection

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## Abstract

Cathodic protection (CP) plays a crucial role in preventing corrosion of metallic structures, such as pipelines, storage tanks, and offshore platforms. Impressed current cathodic protection (ICCP) is widely employed due to its longer service life and ability to deliver higher output current density. The effectiveness of the ICCP system depends on the higher efficiency and lower consumption rate of the anode material, which is guided by the electrochemical activity and stability of the anode. Conventionally, mixed metal oxide (MMO) coated Ti anodes are utilized for the CP of buried and undersea structures. The MMO comprises a mixture of noble and electrochemically active metal oxides deposited on the Ti substrate. The $IrO_2$ -$Ta_2O_5$ (70:30) MMO-based impressed current anode is frequently utilized commercially due to its high activity for oxygen evolution reaction (OER) and lower consumption rate. However, the higher cost, scarcity of these noble metals and unavailability of an alternative anode material possess major limitations to the widespread utilization of these anodes. Recently, multi-principal metal oxides (MPMOs) comprising noble metal-free transition metals have emerged as an efficient electrocatalyst for OER during water splitting in both acidic and neutral environments. The MPMOs exhibit a highly disordered structure with stabilized entropy, which generates more active sites for the catalysis of OER. These materials also effectively tune the electronic and valence structure, which shows remarkable activity and stability for OER. The major challenge is to design the composition as per the application and synthesis of these oxides as coatings on the metal substrate. It is noteworthy that these materials have not been reported for their use as an impressed current anode and their attractive electrochemical properties could pave a path for the development of an alternative low-cost impressed current anodes. In the present work, a series of MPMOs with the composition $NiCoTiTaIr_x$ (x = ….) has been deposited on the Ti substrate using the thermal decomposition method, and their electrochemical stability and activity were evaluated in $H_2SO_4$ and $Na_2SO_4$ solutions.

Keywords: Corrosion, Cathodic protection, Mixed metals oxides, Oxygen evolution reaction.

# Corrosion behaviour of electrodeposited aluminium coating on copper from ionic liquid applying direct and pulse reverse current methods

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## Abstract

This study explores the development and characterization of high corrosion resistance aluminum coatings applied via electrodeposition from ionic liquids. Aluminum, is known for its light weight and high strength to weight ratio, which is used as protective coating for its excellent corrosion resistance. However, the traditional electrodeposition of aluminum in aqueous solutions poses significant challenges due to hydrogen evolution and the formation of unstable aluminum hydroxides. To address these limitations, this research employs ionic liquids as an alternative electrolyte medium, offering a stable, water-free environment conducive to the deposition of high- purity aluminum. The experimental procedure involved the use of a novel ionic liquid composed of an aluminum chloride (AlCl3) and 1-n-Butyl-3-Methylimidazolium Chloride ([Bmim]Cl) mixture. The Aluminum coating was successfully done using both direct current (DC) and pulse reverse current (PRC) methods. Various parameter such as temperature, current density, and deposition time, were optimized to achieve uniform and adherent aluminum coatings. The coatings were characterized using scanning electron microscopy (SEM), X-ray diffraction (XRD), and energy-dispersive X-ray spectroscopy (EDS) to assess their microstructure, phase composition, and elemental distribution. Electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization tests were conducted to evaluate the corrosion resistance of the aluminum coatings.

In conclusion, the electrodeposition using PRC method exhibited fine grain size, smooth and homogenous coating surface and superior corrosion resistance compared to DC method.

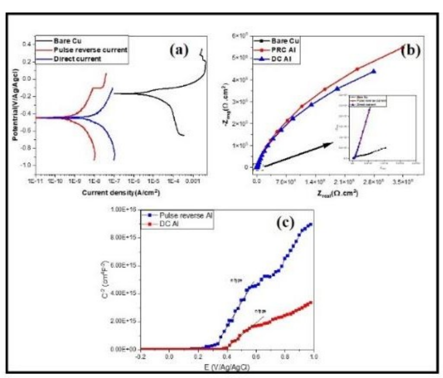


Fig. 1: Electrochemical measurements (a) LP, (b) EIS and (c) Mott-Schottky analysis of samples Keywords: Electrodeposition, ionic liquid, direct current, pulse reverse current, microstructure

# Recent development in hot-dip coatings on advanced high strength steel

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**Abstract**

In recent years, there is a significant increase in the use of thinner gauge advanced high strength steel (AHSS) sheet in structural applications including automobiles to produce lightweight components without compromising the safety. Moreover, the use of thinner gauge steels in the structural parts demands improved corrosion protection and therefore, galvanizability is crucial. The aforementioned factors are the driving force behind the fabrication of high quality hot dip coatings on AHSS substrates to impart better corrosion protection. However, selective oxidation of minor alloying elements on the steel strip surface during inter-critical annealing prior to hot dipping in liquid Zn-alloy bath impose significant challenges, which results in undesirable quality defects on the coated surface in the conventional hot dip process line available in industries. In addition, complex thermal cycle is required to be optimized for desired microstructure of AHSS, which might not be compatible with the existing industrial process parameters.

With recent advancements in hot dip coating process, a number of promising methods are now available to produce good quality galvanized (GI) and galvannealed (GA) coatings on AHSS. The present study highlights the various opportunities and challenges pertaining to fabrication of high quality hot dip coatings on high strength steel utilizing state-of-the-art hot dip process simulator (HDPS) available at CSIR-National Metallurgical Laboratory (CSIR-NML) Jamshedpur. Various approaches to develop high quality GI and GA coatings on AHSSs will be discussed, including dew point control and application of pre-coat. In addition, hot dip Zn- Al-Mg-X coating with better resistance to corrosion, surface blackening and powdering will be highlighted. Further, development of new composition based on hot dip Al-Si-X coating suitable for hot forming and high temperature applications will also be discussed.

key words : Hot Dip Coating, Galvanized, Galvannealed, Al-Si Coating

# Ceramic Primer for Direct Application on Rusted Steel

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## Abstract

Rust is good! Yes, for the rust converter ceramic primer developed at CSIR-National Metallurgical Laboratory, Jamshedpur; the presence of rust on the mild steel surface is beneficial, unlike for other market-available primers and paints which require a rust-free surface before paint application. This water-based, odorless rust converter primer reacts with rust to make a ceramic coating strongly adherent to the metal surface and prevent the onset of corrosion underneath the paint layer. So whether painting is required on a newly constructed mild steel structure or a painted but corroded steel structure, use of the rust converter ceramic primer ensures corrosion protection of the painted steel structures for long durations. Forget about the time-consuming and costly surface preparation steps (sandpapering, shot blasting) and apply the rust converter ceramic primer directly on the rusted surface. The USP of the ceramic primer are:

- Direct application on rusted steel surface
- Eliminates costly and tedious surface preparation processes
- Prevent paint delamination and paint failures
- Reduce maintenance costs and increase the life of steel structures
- Can be applied by brushing or spraying (Field applications)
- Water-based coating (Environment friendly)
- High Temperature Resistant (Up to 500-degree C)

Fig. 1: Ceramic Primer application on rusted steel

Key words : Ceramic coating, Rust converter, Primer, Rusted Steel

# Corrosion Study on Selective Laser Melted Al-Mg-Sc-Zr Alloy with low Sc/Zr ratio in marine conditions.

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## Abstract

Generally, Al-Mg-Sc-Zr alloys prepared through additive manufacturing have Sc/Zr ratio greater than 1. In this study, we investigated the electrochemical corrosion behavior of commercially available additively manufactured Al-Mg-Sc-Zr alloys with a Sc/Zr ratio less than 1 in marine conditions. We prepared the Al-Mg-Sc-Zr alloy using the laser bed powder technique, resulting in a composition of 3.98 wt.% Mg, 0.3 wt.% Sc, and 0.7 wt.% Zr. The X- ray diffraction pattern analysis confirmed the Al matrix with face centered cubic and secondary phase $Al_3(Sc, Zr)$ with $L1_2$ crystal structure, respectively. Microstructure study of the alloy revealed fish scales morphology in parallel to the built direction with the core consisting of columnar grains and equiaxed grains along the scale boundaries, this bimodal grain size distribution varies due to thermal gradient and grain refinement. Linear sweep voltammetry (LSV) and electrochemical impedance spectroscopy (EIS) tests performed in 3.5 wt.% NaCl showed that the alloy had better corrosion resistance compared to alloys with Sc/Zr ratio greater than 1, corresponding to lower corrosion current density ($I_{corr}$) and less negative corrosion potential ($E_{corr}$). Higher corrosion resistance is attributed to fine grains due to heterogeneous grain refinement and a stable protective layer due to higher Zr content.

Keywords: Additive manufacturing, $Al_3(Sc, Zr)$, $L1_2$ crystal structure, LSV, EIS, $I_{corr}$, $E_{corr}$

# Effect of Ageing Heat Treatment on Mechanical and Stress Corrosion Cracking Behaviour of 7075 Aluminium Alloy

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## Abstract

Aluminium alloy (AA7075) is an alloy with zinc and magnesium as the primary alloying. The typical composition is Al - 5.6–6.1% Zn - 2.1–2.5% Mg - 1.2–1.6% Cu - and less than a half percentage of Si, Mn and Cr. It has excellent mechanical properties such as high strength-to-weight ratio, reasonably good ductility, toughness, resistance to fatigue, and machinability. It is one of the most commonly used aluminium alloys for highly stressed structural applications and has been extensively used in aircraft structural parts. This alloy is produced in many tempers like under- (T4), peak- (T6), over-aged (T7).

Our research aims to improve the corrosion resistance as well as mechanical properties of 7075 Al-alloy by the suitable ageing heat treatments that controls the size, distribution and volume fraction of the second phase precipitates within the grains, along the grain boundaries and precipitate-free zone (pfz) width. The alloy will contains that the ageing treatments lead to the precipitation of fine semi-coherent η' ($MgZn_2$) particles within the matrix, and equilibrium η ($MgZn_2$) precipitates within the grain boundaries. The fine semi-coherent η' ($MgZn_2$), precipitates improve the alloy's strength property, and corrosion property (mainly, IGC and SCC etc., resistance) seems to controlled by equilibrium η ($MgZn_2$) precipitates.

Various ageing heat treatments include isothermal (low-high and high-low), non-isothermal, retrogression and reageing (RRA), and interrupted ageing etc., will alter/vary the size, distribution and volume fraction of the second phase η' ($MgZn_2$) and η ($MgZn_2$) precipitates. After isothermal ageing, the various alloy states under-(T4), peak-(T6) and over aged (T7) tempers are produced. The age hardening behaviour shows that the peak aged (T6) temper has maximum hardness, but it is seem to be more susceptible to SCC, and over aged (T7) temper seems to exhibit greater stress corrosion cracking (SCC) resistance, with the expenses of 10- 15 % loss in hardness and strength compared to T6 tempers

.

**Keywords**: Ageing, Isothermal, Retrogression and ageing, stress corrosion cracking

**References**:

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# Optimization of NMC based cathode coating for Li-ion batteries

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## Abstract

Commercial cathode coatings are typically produced using a PVDF binder dissolved in NMP solvent. However, NMP is highly toxic and evaporates during the drying of the electrode, necessitating a solvent recovery system for environmental protection. Additionally, NMP is expensive, further increasing production costs. An aqueous slurry manufacturing approach for NMC cathodes could address these issues, yet cathode active materials are prone to react with water, introducing additional complexities. Li+ ions leach from the lattice of the cathode active material, accompanied by the oxidation of transition metal cations and a loss of charge capacity. This leaching raises the pH of the slurry due to LiOH formation, causing increased interface resistance, hydrogen gas evolution, and large cavities in the electrode layer. In this study, we attempt to produce NMC coatings using an aqueous approach with PAA (Poly Acrylic Acid) as a binder. PAA offers the unique advantage of in-situ formation of LiPAA upon mixing with the NMC cathode and maintains the slurry pH around 7.5, addressing the issues of corrosion and Li+ leaching in water contact. This method demonstrates a promising pathway to environmentally friendly and cost-effective NMC cathode production.

Key words: NMC, NMP, Li-ion batteries, PVDF, Poly Acrylic Acid (PAA), Cathode Coating.

# Generation of Electricity by using Organic Materials

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## Abstract

In this paper, some fundamental investigations are established to demonstrate the potential of harvesting electrical energy from living plants. The energy is harvested by embedding electrodes into the plant to allow flow of ions and hence generate electricity. Multiple random tests have been conducted using different types of electrodes and plants or soil as an attempt to determine the characteristics of the harvesting system. It is found that voltages are produced to greater extents by all tests where combination of special rod and every plant produces the highest voltage. In addition, it is shown in this paper its ability to light up Light Emitting Diodes (LED). By using a multimeter to test the value of voltage max=1.89V generated by a single cell of plant and soil generate max voltage =2.10V by using 20g of soil. which grants it a potential to be used for low power electrical consumption appliances in the future. We can also convert the dc current into AC current for use in large appliances.

Fig. 1: Electricity generating using aloe vera

Key words : renewable energy; organic energy; higher energy source; energy generate system: Unwanted living plants, Special plate, anode, cathode rod, sulphur acid,

# Microstructural influence on corrosion properties and mechanism of a commercial purity AlCuFeMn medium entropy alloy

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## Abstract

Equimolar AlCuFeMn medium entropy alloy prepared from high purity metals (referred to as high purity alloy) demonstrates favourable mechanical and corrosion properties and possesses potential for structural applications. Consequently, AlCuFeMn medium entropy alloy was prepared envisaging practical use by employing commercial purity metals (hereafter referred to as bulk AlCuFeMn) through arc melting and casting in a copper mould. The microstructure of the bulk annealed alloy exhibits copper and iron-rich regions. Further, room temperature characterization revealed that the iron-rich regions constitute Face-Centered Cubic(FCC) phase of lattice parameter 5.81Å , while the copper-rich region exhibits a Body- Centered Cubic phase of lattice parameter 2.91Å. Potentiodynamic polarization tests on the bulk alloy indicate lower aqueous corrosion resistance compared to high purity alloy. Additionally, the presence of a positive cyclic hysteresis loop suggests a tendency to pitting corrosion. Electrochemical impedance spectroscopy tests, in conjunction with corroded surface microscopy, support that the principal corrosion mechanism is localized corrosion. EIS studies suggest that $R_{ox}$ decreases with immersion time indicating a continuous passive layer breakdown. Experiments utilizing energy dispersive spectroscopy on the oxide surface cross- section reveal the formation of a copper oxide-enriched layer on the surface. Further analysis through corroded surface XRD and Raman spectroscopy confirmed the predominance of copper oxide along with other metallic oxides.

Key words: Medium Entropy alloy, Microstructure, EIS, Pitting corrosion

# Comprehensive Evaluation of UC-555: A Versatile PU Acrylate Water-Based Coating for Enhanced Corrosion Resistance

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## Abstract

This study investigates the effectiveness of UC-555, a PU acrylate water-based coating manufactured by Sreechem Resin Ltd., designed for universal application across various surfaces, including metals, plastics, plywood and concrete. The National Test House (ER) in Kolkata conducted comprehensive evaluations to ascertain the coating's effectiveness in corrosion resistance and durability. Key tests included salt spray tests, chemical resistance tests, impact resistance tests, and scratch hardness tests, following ASTM and IS standards. The results demonstrated that UC-555 offers excellent adhesion, corrosion resistance, and durability, making it suitable for both preventive and emergency applications in industrial and commercial settings. The coating exhibited no signs of corrosion, rusting, or blistering after extensive testing periods, ensuring reliable protection against environmental elements. The product is noted for its fast-drying nature, ease of application and cost-effectiveness.

Key words : Corrosion Resistance, PU Acrylate, Water-Based Coating, Universal Coating, Industrial Application

# Degradation of Structural Materials due to Corrosion at Hooghly Met Coke

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## Abstract

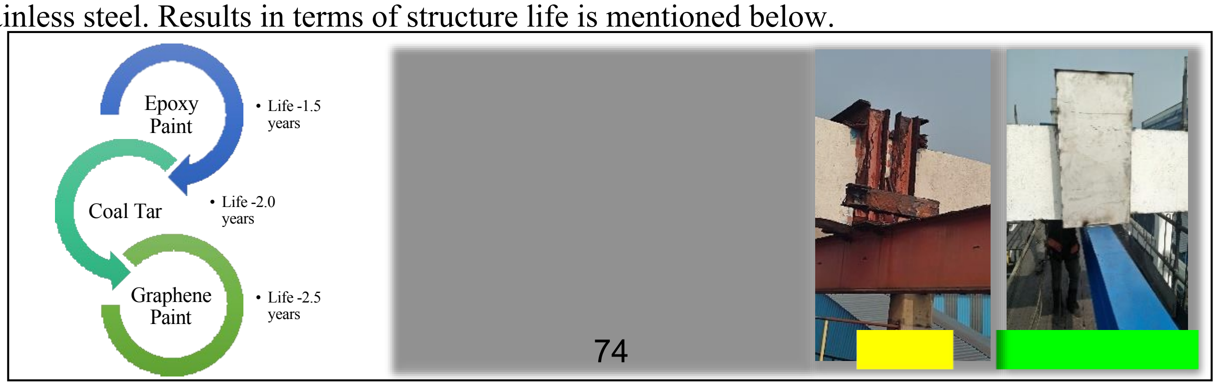
Corrosion is the degradation of materials usually metal owing to chemical reaction with the environment which depends on the concentration of environment, stress, erosion, and the temperature. It not only increases the costs of maintenance but also responsible for life losses and safety hazard. It is an irreversible damage of metal surface in conversion of a pure metal to its chemically more stable form such as sulphides, oxides, hydroxides, etc. in a corrosive environment. The corrosive environment may be of any type i.e., may be solid, liquid or gas. These environments are generally known as electrolytes. These electrolytes allow the transfer of ions (cations and anions) and form two reactions (anodic and cathodic). This process is called a half cell oxidation reaction or the anodic reaction and is represented as

$$2Fe \longrightarrow 2\,Fe^{++} + 4e^{-}$$

These electrons remain in the steel and flow to sites called cathodes, where they combine with water and oxygen of the atmosphere. The reaction at the cathode is called a reduction reaction. To maintain electrical neutrality, the ferrous ions migrate through the painted surface pore water to these cathodic sites where they combine to form iron hydroxides or rust. This initial precipitated hydroxide tends to react further with oxygen to form higher oxides. The increase in volume leads to internal stress within the steel that cause metal loss.

At HMC, the steam generated from quenching of hot coke consists of $SO_X$, $NO_X$ etc, these come to the surface of steel structures and chemically attack them in getting corroded. The load bearing structural members near to quenching station are getting highly corroded where the thickness of members is getting reduced up to 40% of its original thickness within a span of 2 years, which may lead to major catastrophic structural failure. Also, it has been observed that the fine particles of coal and coke from ambient air are forming a thin layer over the painted surface of structural members. While in presence of moisture it is chemically reacting with the paint layer and deteriorate the paint thickness, which allows the quenching steam to encounter metal surface and helps the structural corrosion process faster. In quenching process Tata Power blowdown water is used (chloride content is 3000 ppm). This atmospheric chloride is increasing the rate of corrosion in presence with water and oxygen.

As the root cause i.e., quenching steam cannot be eliminated as the process remains same, some of the enablers are taken here to mitigate the rate of corrosion like painting steel surface with Coal Tar, Graphene paints in place of normal Epoxy paint and lining small structure with stainless steel. Results in terms of structure life is mentioned below.



Before After – 4 years

Fig. 1: Grab bucket monorail beam life Comparison

key words : Corrosion, Quenching Steam

# Effect of aging temperatures on pitting corrosion behavior of hot rolled high nitrogen high manganese austenitic stainless steels in natural seawater condition

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## Abstract

In the present work, hot rolled High Nitrogen high manganese austenitic Stainless Steels (HNSS) were solution annealed and aged at 700°C, 800°C and 900°C for 14 hours. Precipitation kinetics at the Grain Boundaries (GB) of HNSS was studied using TC- PRISMA simulation and SEM analysis. Pitting corrosion behavior of HNSS at solution annealed and aged conditions were studied using anodic polarization and Electrochemical Impedance Spectroscopy (EIS) analysis. TC-PRISMA simulation results showed that equal volume fraction of chromium nitride ($Cr_2N$) precipitates was observed in grain GBs of austenite in all three aging conditions. However, large size precipitates were observed in samples aged at 900°C compared to samples aged at 700°C and 800°C. SEM investigations showed the presence of lamellar $Cr_2N$ at the GBs and coarse lamellar austenite in regions adjoining the GBs in samples aged at 700°C aging temperature. Disc type $Cr_2N$ precipitates were observed in GBs of austenite in 900°C aging temperature. Besides, sample aged at 900°C exhibited relatively stable and homogenous layer compared to solution annealed and samples aged at 700°C and 800°C.

Keywords: High Nitrogen austenitic Stainless Steels, precipitation kinetics, chromium nitride, pitting corrosion, anodic polarization.

# High Entropy Oxide (HEO) on different carbon substrate for Hydrogen Evolution Reaction (HER)

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Designing and developing superior and cost-effective electrocatalysts for the hydrogen evolution reaction (HER) via water splitting is crucial for advancing industrial-scale electrolysers. However, a significant challenge lies in fabricating these materials with the optimal morphology and composition. Herein, we aim at synthesising high entropy oxide (HEO) nano-catalysts as functional materials through facile single step aqueous electrodeposition procedure on various carbon substrate (carbon cloth and graphite sheet) using transition metal elements. The comparative study has been performed to examine the role of substrate over the catalytic efficiency towards HER performance. The synthesized materials were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), X- ray photoelectron emission spectroscopy (XPS) to study the morphological feature and formation of phases at different current density used for electrodeposition. The electrocatalytic properties of these HEOs are evaluated for HER through LSV, CV, EIS, and chronopotentiometry technique and the evaluated properties are comparable with the standard Pt/C catalyst.
The results indicate that the material-substrate combination significantly influences the catalytic efficiency. Notably, HEOs at higher current densities on both substrates exhibit low overpotentials and high stability, suggesting promising potential for scalable HER applications. The promising results of HEO on different carbon substrate pave the way for future development in hydrogen production technologies.
Keywords: Hydrogen Evolution Reaction (HER), Electrocatalysis, High Entropy Oxide (HEO).

# Dross Management in manufacturing of 55%Al Zn alloy coated steel at Tata Steel Khopoli

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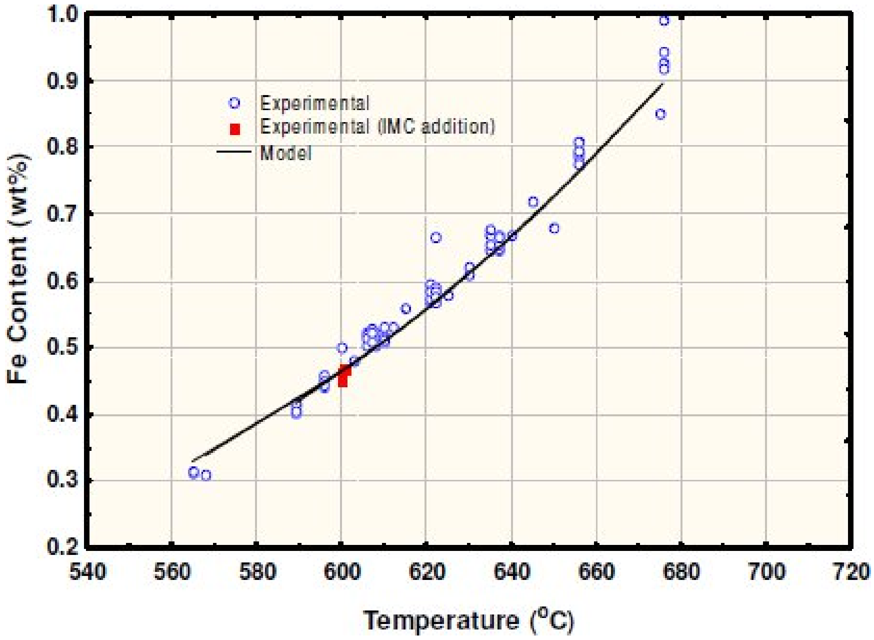
## Abstract

In any hot dip coating process, Intermetallic Compounds generation is inevitable. In metal coating operation, Intermetallic Compounds form, when the solubility limits of the elements at get exceeded at the operating temperature. These Intermetallic Compounds (IMCs) are commonly called dross. These are very hard particles and detrimental for the good quality product.




When the liquid metal (Molten Zn/ Galume alloy) becomes supersaturated with iron, Intermetallic Compounds, IMCs, precipitate as dross. The dissolution of iron from the steel surface when it encounters the coating alloy is the source of iron in the bath. The solubility of Fe in 55%Al Zn alloy is given as follows.

Iron Solubility Curve

Dross is of two types, namely Top dross, and Bottom dross. This is due to density of the IMCs wrt the molten metal. The bottom dross is worse as it sinks to the bottom.

In case of 55% Al -Zn alloy coated steel production, IMCs that form, cannot be managed chemically. In case of manufacturing of 55%Al Zn alloy coated steel, there are two mechanisms to manage the dross. These are given below.

1. To ensure minimum thermal and chemical gradient
2. To keep the size of IMCs very fine as possible by keeping the bath stirring

To make good quality product, TSM Khopoli has taken many initiatives to control the generation and manage its management.

The paper discusses the reasons of dross generation and the various steps taken to control it in

Tata Steel Khopoli, Maharashtra.

**Key Words**: - Solubility, Intermetallic Compounds (IMCs)

**References**

BIEC Technology Manual

Recent evolution & refinement of 55%Al Zn alloy coated steel, Darren Thompson, BSL Australia

# Studies on Cavitation Erosion – Corrosion Behaviour of Low Nickel Containing Austenitic Stainless Steel

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## Abstract

Due to their optimized mechanical and corrosion characteristics, low nickel austenitic stainless steels (ASS) are gaining attention in shipbuilding, marine, defence, petroleum, nuclear, chemical equipment, and power generation. The present work investigates the effect of exposure time on cavitation erosion and corrosion behaviour of AISI 202 ASS in solution annealing (SA) condition. Initially, the AISI 202 ASS samples are sectioned and subjected to SA treatment, i.e., 1100° C for 2h + water quenching and followed by metallography to observe the microstructure. The cavitation erosion studies are carried out using an ultrasonic probe sonicator under two environmental conditions i.e., distilled water and a 3.5% NaCl with an exposure duration of 2h, 4h, 6h, and 8h. The eroded samples are evaluated for microstructure and hardness using optical microscopy and microhardness tester. Further, potentio-dynamic polarization (PDP) studies are performed to understand the corrosion resistance on the eroded sample for 8h and non-eroded samples in a 3.5% NaCl and distilled water environment using a basic three-electrode electrochemical system. From the above work, it is found that the optical microstructure of AISI 202 ASS in the SA condition resulted in an austenite grain matrix along with concurrent twinning. The cavitation erosion studies show that as the time duration of cavitation erosion increases, the micro-crack growth increases, increasing weight loss in both environments. Also, more weight loss, higher microhardness and poor corrosion resistance were observed in the 3.5% NaCl environment compared to distilled water. This may be attributed to the higher impact force with the denser NaCl medium.

Keywords: Low nickel austenitic stainless steels (ASS), Cavitation Erosion, Potentio-dynamic Polarization (PDP), Distilled Water, Sodium Chloride (NaCl).

# Development of Chemical Passivation for Zn-Mg-Al alloy Coated Steel

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## Abstract

Hot dip galvanizing is an effective and economical industrial process for producing coated steels. Zn-based metallic coatings over steel substrate protect steel by sacrificial corrosion but are prone to white rust upon environmental exposure. White rust is a localized and rapid corrosion attack on Zinc which appears as a white voluminous deposit over the coated steel surface. The rapid corrosion can completely remove Zinc at a localized area and reduce component life. Corrosion resistance properties of Zinc-based alloy-coated steel can be enhanced by the formation of a tightly adherent thin film of corrosion product known as the passivation layer. Over the years various coatings have been developed & engineered to protect steels for different applications. This work focuses on developing & establishing chemical passivation solutions for Zn-Mg-Al coated steel. The 2 types of solutions viz., Trivalent- Chrome & Chrome-Free from 3 different suppliers were applied on Zn-Mg-Al coated steel substrate using roll coaters & taken in the furnace at the desired peak metal temperatures. The quantity of the solution over the substrate is measured using an X-Ray fluorescence analyzer. The chemical passivation-protected & unprotected coated steel samples were exposed to the neutral salt spray (5% NaCl) environment (SST) and observed for onset & growth of white rust for different exposure times. Before and after exposure samples were also studied using the characterization methods of scanning electron microscope (SEM), and X-ray diffraction (XRD) & results were compared and co-related to the corrosion resistance performance with the various passivation solutions over Zn-Mg-Al coated steel for white rust. Trivalent-Chrome solutions in 30-55 mGSM and Chrome-Free solutions in 0.8-1.2 µm layer thickness shown good results from 3 suppliers. The material with these chemical passivation was also performed well in secondary processing of tube making and roll forming for component manufacturing.

Key words : Chemical Passivation, Zn-Mg-Al alloy coatings, Continuous Hot- dip galvanizing, White Rust

# Hydrogen Induced Cracking Susceptibility of API Linepipe Steels for Application in Sour Environments

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## Abstract

A sour service environment, characterized by high levels of hydrogen sulphide ($H_2S$), poses a significant risk of material failure due to cracking or corrosion. Such environments are commonly encountered in oil and gas production wells, transmission pipelines, and refinery equipment. For steel to be considered suitable for these challenging conditions, it must comply with the API 5L Annexure H requirements. One critical test for assessing the suitability of these steels is the Hydrogen Induced Cracking (HIC) test.

In this research, the HIC phenomenon in pipeline steel was thoroughly examined. The HIC tests were conducted on high-strength low-alloy (HSLA) steels with varying alloy compositions. These tests were performed in a sour environment, where hydrogen sulphide was continuously bubbled through the test solution for a duration of 96 hours, adhering to the NACE TM0284-2016 standard. The investigation found that precipitates played a crucial role in increasing the susceptibility of the steel to HIC, resulting in intergranular fractures. The initiation of cracks was predominantly linked to the presence of large precipitates, such as Nb- Ti carbonitride. This detailed analysis highlights the importance of understanding the role of precipitates in the performance of pipeline steels in sour service environments.

Key words: Linepipe steel, HIC, Energy dispersive spectroscopy (EDS), Precipitates, Crack propagation

# Effect of Grain Size on Corrosion Behaviour of Rolled Pure Magnesium

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## Abstract

Grain refinement is one of the most widely used processing techniques for enhancing the strength and ductility of metals and alloys. This grain size variation impacts the electrochemical characteristics of the system. Systematic research on the impact of grain size on corrosion is lacking in the existing literature. Prior studies address the impact of grain size of pure Magnesium on corrosion behaviour without separating the effect of texture and localized stresses. The impact of grain size on corrosion has been investigated using pure magnesium that has been rolled and annealed while maintaining a consistent texture. A wide range of grain sizes was considered while keeping localized stresses and texture consistent. The corrosion rate was calculated and the corrosion behaviour was studied using potentiodynamic polarisation testing, electrochemical impedance spectroscopy, and corroded surface characterization to get a broader insight into the corrosion mechanisms. It has been noted that as grain size decreases, the corrosion rate increases. This study contributes to the systematic and thorough understanding of the impact of grain size on the corrosion behaviour of pure Mg.

Key words: Corrosion, Magnesium, Grain size

# Impact of Micaceous Iron Oxide and Silicon Oxide Addition on the Corrosion Resistance of Epoxy Coating on Mild Steel

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Abstract

Epoxy based coating is commonly used on metal to prevent rusting. It shows toughness after curing, good adhesion to metal substrate, and durable hardness. The Micaceous Iron Oxide (MIO) with epoxy contains lamellar like iron oxide particles that align parallel to the substrate (mild steel), creating a layered barrier. This structure greatly enhances durability against moisture and chemical corrosion, particularly in environments with salt exposure. On the other hand, inclusion of $SiO_2$ increases the epoxy's strength and scratch resistance, making it more resilient against mechanical wear. Additionally, it improves the epoxy's thermal stability, enabling it to retain its properties at higher temperatures. The composite of MIO + $SiO_2$ with epoxy resin, acting as an anticorrosion coating on mild steel substrate, has been investigated in the present study.

The surface morphology and elemental analysis of the sample have been examined using SEM (scanning electron microscopy) and EDS (energy dispersive X-ray spectroscopy), respectively. Tests for corrosion have been carried out, including immersion tests in 3.5 per cent by weight NaCl solution for different periods of time. The immersion test at different time has been performed to analyse the corrosion rate of MIO, $SiO_2$, and MIO + $SiO_2$ composite with epoxy. Potentiodynamic polarization testing of the coated sample has been used to evaluate the effect of MIO, $SiO_2$, and their composite (MIO + $SiO_2$) on the epoxy coating's corrosion protection performance. It is expected that the composite MIO + $SiO_2$ with epoxy will enhance corrosion resistance of substrate. The corrosion investigation of composite of MIO + $SiO_2$ with epoxy coating on mild steel has opened the window to researchers for protection of railway wagons from harsh environments.

Key words: Epoxy resin, Corrosion rate, Composite of $SiO_2$ + MIO

# An Ultra-Fast and Facile Fabrication of Turbostratic Holey Graphene and its Electrochemical Behaviour

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Abstract

Scalable production of turbostratic holey graphene (tHG) with high energy density and power density is essential but challenging for flexible and compact supercapacitors. Herein, we demonstrate an efficient, rapid, cost-effective and kilogram-scale method for fabricating the twisted multilayer holey graphene using an atmospheric plasma spray. The twisting of graphene layers reduces electronic interactions between them, increasing the spacing between layers and consequently enhancing the graphene's effective specific surface area. The fabricated tHG electrode exhibits the highest specific capacitance of ~250 F $g^{-1}$ at 0.5 A $g^{-1}$, an energy density of 28.54 Wh $kg^{-1}$ and a power density of 280 W $kg^{-1}$ in the three-electrode system. Furthermore, the electrode exhibits outstanding electrochemical stability, retaining about 94% of its capacitance after 10,000 cycles. These characteristics position the tHG as an auspicious material for next-generation high-performance supercapacitors.

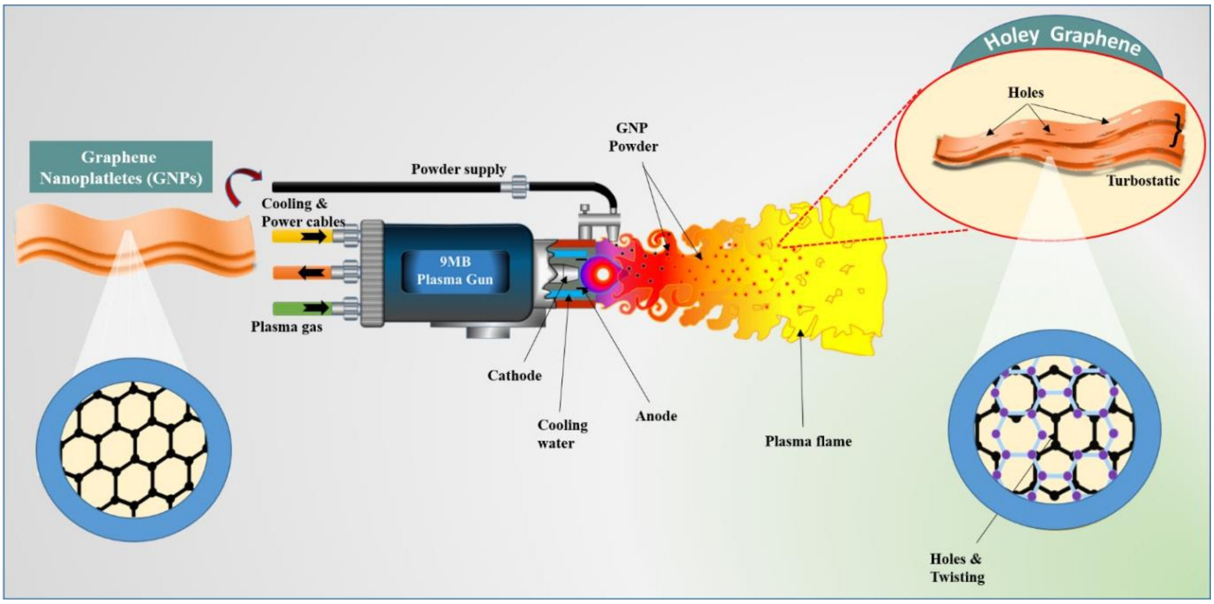


Fig. 1: Schematic demonstrates the mechanism of turbostratic holey graphene via age-old plasma spray technique.

Keywords: Holey graphene; Turbostratic graphene; Electrodes; Supercapacitor; Plasma spray

# Improvement of Corrosion resistance in the Austenitic stainless steel 304 grade in the No.4 finish

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~~Abstract~~

Austenitic stainless steel, particularly the 304 grade, is renowned for its excellent corrosion resistance, formability, and toughness, making it a preferred material for applications ranging from architectural elements to consumer products. This is primarily due to its composition of iron with chromium (18-20%) and nickel (8-10%) as the main alloying elements. The chromium provides exceptional resistance to oxidation and corrosion, while the nickel enhances formability and toughness. The No. 4 finish, known for its fine, brushed appearance, is favored for its aesthetic appeal and is used in kitchen appliances, automotive trim and architectural facades.

However, the mechanical processes involved in producing the No. 4 finish, such as grinding, often result in increased surface roughness, which can compromise the corrosion resistance of the material. This study aims to enhance the corrosion resistance of 304 stainless steel with a No. 4 finish by investigating and optimizing the process parameters. It begins with a detailed analysis of the surface characteristics of 304 stainless steel, employing advanced surface characterization techniques such as scanning electron microscopy (SEM). A comprehensive evaluation of process parameters, including grain size, in-process lubricants and polishing compounds used, the grit of grinding paper, and surface roughness measured after surface grinding were meticulously monitored and assessed for their impact on corrosion resistance, as evidenced by their performance in salt spray tests.

Results indicate that grinding generates surface macroscopic tensile residual stresses along the grinding direction, which can lead to the initiation of micro-cracks during exposure to corrosive environments. Furthermore, the grain size of the 304 stainless steel significantly impacts its corrosion resistance; specifically, a decrease in grain size tends to increase the corrosion rate. This is due to the concentration of defects at grain boundaries, where an increased grain boundary surface area from grain refining can lead to the destabilization of the passive film, thereby reducing general corrosion resistance. This study offers insights into the correlation between grinding parameters, grain size, and corrosion resistance, providing recommendations for optimizing these parameters to minimize adverse effects and enhance the performance of 304 stainless steel in demanding applications.

Key words: Corrosion Resistance, 304 Stainless Steel, No. 4 Finish. Reference:

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# Thermodynamic, Chemical and Electrochemical Studies of Musa Paradisiaca Linn. Pseudostem Extract as a Naturally Developing API 5L Corrosion Inhibitor in the Oil Industry

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## Abstract

The effectiveness of Musa paradisiaca linn pseudostem extract as an ecologically friendly inhibitor for corrosion prevention in an oil industry environment was evaluated in this work. The pseudostem extract was produced by maceration under ambient temperature using a mixture of methanol and water. The electrochemical studies show that the extract has a noteworthy capacity to slow down electrochemical reactions causing corrosion of API 5L steel in an oil environment. As one raises, the inhibitory efficiency (IE) increases with increasing concentration. Derived from the Musa paradisiaca linn pseudostem extract, the extract is obtained. The analysis of the corrosion products' morphology was conducted using a scanning electron microscope (SEM). The functional and structural groups of this were characterised using EDS, AFM, Raman spectroscopy, etc. The electrochemical experiments demonstrate that the extract has a significant ability to decrease the corrosion rate. The degradation of API 5L steel in oil conditions is due to electrochemical reactions. The inhibition efficiency (IE) rises as it increases the density. The corrosion inhibition efficiency is approximately 85% (potentiodynamic polarisation and electrochemical impedance spectroscopy), which is considered optimal. The value of 200 mg L was acquired through addition. One sample was taken at a temperature of 310 K. In addition, as the concentration increases The higher the concentration of pseudostem extract, the larger the activation energy required. Ea), with the maximum activation energy value of 45.50 kilojoules per mole. The concentration is 200 mg $L^{-1}$. On the other hand, raising the temperature and increasing the time of exposure decreases the values of corrosion inhibition effectiveness (IE); the optimal period of exposure duration of the experiment was 20 minutes, during which the concentration of IE was 85% and the concentration of the substance was 200 mg $L^{-1}$ at a temperature of 300 K. The process of corrosion inhibition involves

The adsorption process of Musa paradisiaca linn pseudostem extract bioactive on metal surfaces with a mixed inhibitor leads to the achievement of desired results. The mechanism involving both physisorption. The smoother surface morphology of the steel treated with Musa paradisiaca linn pseudostem extract verified this finding compared to the steel treated without it. This experiment revealed that Musa paradisiaca linn pseudostem extract has the capacity to serve as an eco-friendly corrosion inhibitor in the oil industry environment.

Key words- Green inhibitor, API 5L steel, SEM, potentiodynamic polarization, EIS, SEM, Raman spectroscopy

# $PbCl_2$ as a negative electrode for Lithium-Ion batteries

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## Abstract

The world needs more power in everyday life, preferably in a clean and renewable form of energy. Sun, wind and tides have huge potential in providing us with electricity in an environmental-friendly way. Energy storage will enable this adoption by enabling a constant and high-quality electricity supply from these systems [1]. Battery technology may be the keystone of the energy transition. Our energy-storage strategies are currently shaped by Lithium-ion batteries; batteries employing Lithium chemistry have been intensively investigated because of their high energy attributes, which may be deployed for vehicle electrification and large-scale energy storage applications. Another important direction of battery research for micro-electronics, however, is relatively less discussed in the field but growing fast in recent years [2]. Then many efforts have been put to further improve the performance of Li-ion batteries, achieved certain significant progress. To meet the increasing demand for energy storage, particularly from increasingly popular electric vehicles, intensified research is required to develop next-generation Li-ion batteries with dramatically improved performances, including improved specific energy and volumetric energy density, cyclability, charging rate, stability, and safety [3]. However, commercially available Lithium-ion batteries based on graphite anodes cannot meet this aggressive demand due to their low theoretical capacity (372 mAh). Therefore, there is an urgent need for new promising anode materials that have at least twice the theoretical capacity of graphite.

Lead and Lead compounds anodes ensure next-generation Lithium-ion batteries, thanks to their high theoretical efficiency, low cost and full operating capacity [11]. Pb based alloys have their large volumetric capacity (6452 mAh/cc) and gravimetric capacity (569 mAh/g) and appears to be a potential alternative to graphite anode. However, Pb based alloys, while lithiation has an enormous volume expansion and large volumetric stress, are subjected to pulverization [4-5].

Using "active-active" (combinations of two or more active Lithium elements) and "active-inactive" (combinations of one Lithium active and one inactive elements) alloys strategies has long been adopting methods to reduce volumetric strain. Due to the refined particle size, the diffusion length of Lithium is reduced, which makes lithiation/delithiation faster and helps to accommodate strain through the nanocrystalline structure. Examples of “Active-active” alloys strategy such as $Ag_4Sn$ and SnSb will lithiate under different voltage plateaus (characteristics of each element), helping to reduce the rate of volumetric stress while lithiation [6-7]. Examples of “active-inactive” alloy strategy types include intermetallic compounds such as $Ni_3Sn_4$, $Cu_2Sb$, and $Cu_6Sn_5$. The conductive inactive phase (Ni, Cu, and Fe) buffer the volume expansion at a unique potential while lithiation (growth) happens [8-10].

Therefore, in this work, the development of Lead-based anode $PbCl_2$ as a negative electrode has been done. Negative electrode $PbCl_2$ gives around 2.5 times more volumetric capacity than the graphite even after 50 cycles. In addition, it also clearly demonstrates that lead chloride anode has good structural stability and electrochemical reversibility by XRD and SEM observation. This can be used as a promising anode material for lithium-ion batteries after further modification.

key words : Lead (Pb), Lead Chloride, Anode material and Lithium-ion battery

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# ORR Catalyst on Ni-Coated Stainless-Steel Mesh Substrate: A Cost-Effective Air Cathode for Fuel Cells and Metal-Air Batteries

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## Abstract

This study presents the development of a cost-effective air cathode utilizing an ORR (Oxygen Reduction Reaction) catalyst, specifically $MnO_2$ nanoparticles, deposited on nickel-coated stainless steel (SS) mesh, designed for fuel cells and metal-air batteries. The nickel coating was applied through an electroless deposition process, which not only ensures a uniform and adherent layer but also enhances the electrical conductivity of the substrate without requiring an external power source. The resulting Ni-coated SS mesh provides a conductive, porous, and durable substrate for the $MnO_2$ nanoparticles, crucial for improving catalytic activity and overall cell performance.

The porous nature of the nickel coating facilitates enhanced mass transport, which is particularly advantageous for ORR applications. This structure allows for better oxygen diffusion and a more effective utilization of the $MnO_2$ nanoparticles compared to traditional substrates like nickel foam, carbon paper, and carbon cloth. Moreover, the increased electrical conductivity offered by the Ni coating improves the overall efficiency of the electrochemical reactions at the cathode. In our polarization studies, the $MnO_2$ nanoparticle-coated Ni-SS mesh demonstrated significant improvements in the specific capacity and stability of the air cathode, underscoring its potential for long-term applications in fuel cells and metal-air batteries. Fig. 1 shows the fabrication of an Aluminum-Air Battery reactor utilizing $MnO_2$ Nanoparticle-Coated Ni-SS Mesh for polarization studies.

Specific capacity tests revealed that the $MnO_2$ nanoparticle-coated Ni-SS mesh achieved an anode utilization rate of up to 92.6% under a 50mA load, showcasing efficient material use and consistent performance. These findings suggest that the $MnO_2$ nanoparticle coating, supported by the conductive and porous Ni-SS mesh, not only enhances the durability and efficiency of the air cathode but also provides a compelling alternative to conventional materials such as nickel foam, carbon paper, and carbon cloth.

This study underscores the potential of $MnO_2$ nanoparticle-coated Ni-SS mesh as a scalable, cost-effective solution for air cathodes in fuel cells and metal-air batteries, offering an optimal balance between performance, stability, and economic viability.

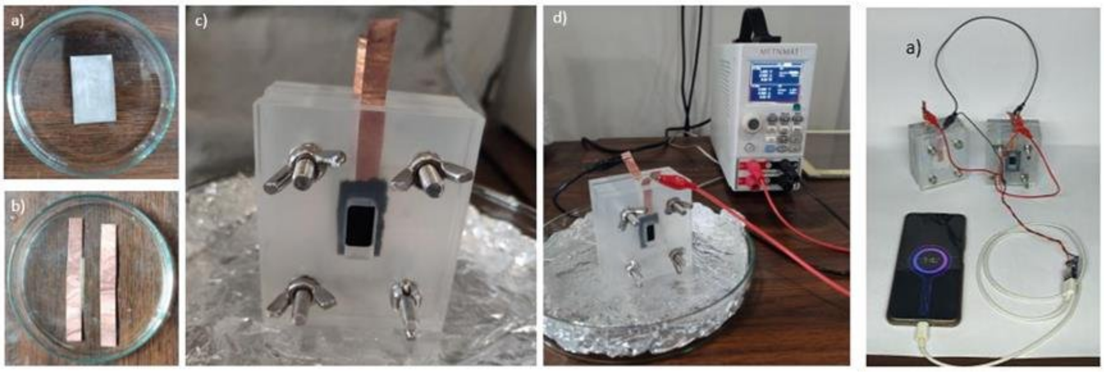


Fig 1: Fabrication of an Aluminum-Air Battery reactor utilizing $MnO_2$ Nanoparticle-Coated Ni-SS Mesh for Polarization Studies

Keywords: ORR catalyst, $MnO_2$ nanoparticles, Nickel-coated stainless steel, Fuel cells, Metal- air batteries

# DEVELOPMENT OF ANTI-CORROSION COATING FOR STAINLESS STEEL USING PANI-EPOXY RESIN MIXTURE

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## Abstract

Metal corrosion is a significant problem in many industries, leading to huge economic losses. One common method for protecting metal surfaces from corrosion is to use polymeric coatings. Epoxy-based coatings are particularly popular due to their superior chemical resistance, mechanical strength, and ability to adhere to metal substrates. To enhance the anti-corrosion properties of epoxy coatings, polyaniline (PANI) conducting polymer can be added as a filler. This improves the ability of the organic coating to act as a barrier against corrosive substances and also provides electroactive performance characteristics. The presence of PANI creates a passive film on the metal substrate, further protecting it from corrosion. Our project aims to develop a filler using polyaniline and incorporate it into epoxy coatings at varying concentrations to achieve optimal corrosion resistance. These coatings will be characterized using a range of techniques, including Scanning Electron Microscopy and Fourier Transform Infrared Spectroscopy.

Key words: Corrosion, PANI, Epoxy coatings, Filler

# Developing High-Performance Anode Supported Solid Oxide Fuel Cell using Ti-doped SrFeO3 Electrodes.

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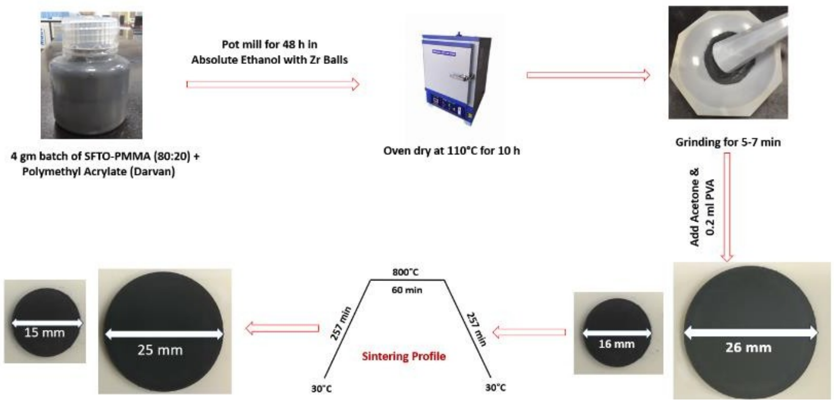
## Abstract

Solid Oxide Fuel Cells (SOFCs) are electrochemical devices that efficiently convert chemical energy from fuels such as CO, $H_2$, $CH_4$, and other hydrocarbons into electrical energy. They feature a dense electrolyte sandwiched between two porous electrodes the cathode and anode. SOFCs are recognized for their high electrical efficiency (over 60%), and their ability to operate directly on wide variety of hydrocarbon fuels. This study focuses on the development and performance evaluation of an anode-supported SOFC with Ti-doped $SrFeO_3$ (SFTO) as a symmetrical electrode and $Gd_{0.1}Ce_{0.9}O_{2-\delta}$ (GDC) as an electrolyte. The cell microstructure will be studied using a scanning electron microscope, and its electrochemical performance will be tested using Solartron at different temperatures. Previous studies have shown that Ti-doped $SrFeO_3$ electrodes deliver high power density of 509 mW.cm$^2$ and maintain stable operation at elevated temperatures (700-800°C), Demonstrating significant potential for future commercialization in energy conversion. It was seen from the study that highest power loss was observed due to thick electrolyte (~300$\mu m$) contributing to high ohmic resistance. Hence by using anode supported SOFC where anode acts as a porous support & dense electrolyte is coated over the anode which will substantially reduce electrolyte thickness.




Key words: Solid oxide Fuel Cell; Strontium Iron Titanium Oxide; Gadolinium Doped Ceria; Electrolyte Support; Anode support SOFC; Symmetric Electro.

# High pressure extrusion briquettes of solid wastes to reduce the coke rate in Blast Furnace

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## Abstract:

TATA Steel Jamshedpur has commissioned an Extruded Briquetting Plant of 50 tph capacity to cater the problem of utilization of process solid waste generated across the iron and steel making process. Three major solid wastes generated during iron and steel making process are blast furnace flue dust, Gas Cleaning Plant sludge and LD Sludge. These wastes are utilized by mixing it with cement and bentonite with required moisture and processing it under high pressure extrusion process to form cylindrical briquettes. After an ambient air curing of these briquettes, it is sent for physical and chemical analysis. The major parameters defining the strength of these briquettes are proportion of the raw material mix, addition of cement and bentonite, moisture content of the green mix, pressure of the extruder, diameter and thickness of the die and curing period of the briquettes. Once the required tumbler index is achieved, it is sent to blast furnace to replace the iron ore with 3% of briquettes in burden. These briquettes have contributed to reduce the coke rate consumption at blast furnace by 10 kg/ton hot metal. During the commissioning and start-up of this plant many challenges were faced like frequent jamming of die, breaking of product briquettes, uneven feeding of binders through Loss in Weigh feeder, improper mix of raw materials, etc. These challenges were overcome by some innovative design modification, fine tuning input raw material mix, optimizing the process parameters to reduce interruptions and analysis of the data to improve the binder addition in the raw mix for desired physical and chemical quality. Encouraging result was observed like interruption free run, production level achieved @300TPD with good strength (Tumbler Index +6.3mm ~ 70)

**Keywords:** Briquetting, Binder, Extruder, Green Mix, Tumbler Index, Loss in Weigh feeder

# Sustainable Tableware Production using bagasse with IoT Cloud Platform

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## Abstract

Sustainable product design is getting more recognition in the present day as it considers environmental, social, and economic parameters for the development of new products. The environmental disadvantages of conventional plastic and metal plates are emphasized through a thorough literature analysis, underscoring the pressing need for sustainable alternatives. This research investigates the viability and advantages for the environment of using bagasse, a byproduct of processing sugarcane, in the creation of sustainable plates. As bagasse is plentiful and biodegradable, it offers a viable substitute for traditional materials in food service items and promotes circular economy. The process of bagasse-based tableware manufacturing is explained in detail and tableware produced are tested and compared with already existing alternatives. Furthermore, the importance of Internet of Things (IoT) technology in supporting data-driven decision-making is emphasized, especially when it comes to supply chain management, manufacturing processes, and material selection optimization. By utilizing IoT for real-time tracking and analysis, manufacturers may increase energy efficiency, reduce waste, and guarantee environmentally sustainable production methods. The research lays the groundwork for a more ecologically conscious and circular approach to the production of tableware by recommending the adoption of bagasse in conjunction with IoT-driven sustainability strategies.

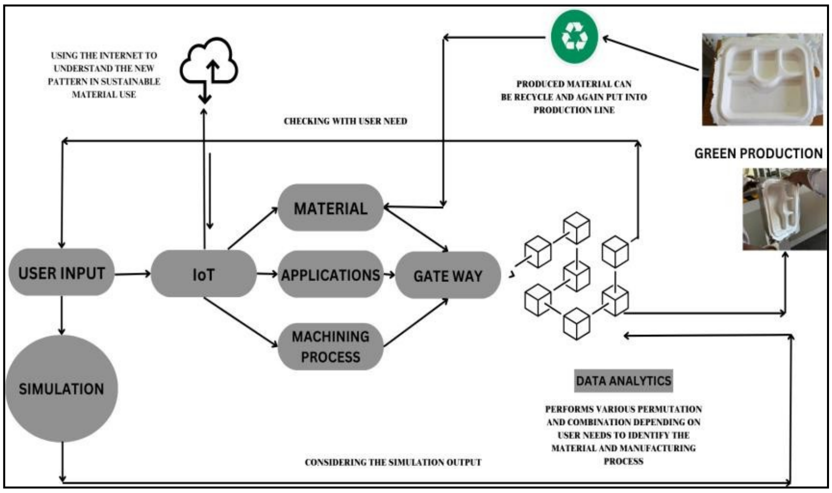


Fig. 1: IoT Architecture for Sustainable Material Selection (Author's own work)

key words : Sustainable Tableware, Circular economy, Bagasse, Internet of Things

# Imperishable recovery of critical metal from end-of-life lithium ion battries by using sulphuric acid

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## Abstract

The rapid increase in Electric Vehicles as well as portable electronic device (Mobile and laptop) sales blazed an explicit discussion regarding the availability of critical metals. An appropriate approach/technique is required to the upcoming emerging threat related to waste LIBs that contains heavy metals and other hazardous materials pose, to the environment and public health.

Generally, spent LIBs are composed of 20-25 wt. % Co, 5-10 wt. % Ni, 3-5 wt. % Li, 10-15 wt. % Mn, along with aluminum, copper, Iron and plastics. These end-of-life LIBs have the option of being recycled, which can ultimately lower the cost of producing new LIBs which benefits the ecomonic, preventing the environmental pollution from harmful components, conserving and preserving natural resources. Hence the recycling of these end-of-life lithium ion batteries has attracted significant attention in recent years.

The recycling processes for lithium ion batteries mainly include mechanical treatment, Pyrometallurgy, hydrometallurgy and bio treatment, among which hydrometallurgy dominates all the approaches being optimal, environmental friendly and recover high purity metals with low energy consumption as compare to Pyrometallurgy process due to loss of Li, Al and Mn in slag. Hydrometallurgical processes involve various acids like organic and inorganic as leaching agents. This Paper mainly focus on recovery of these critical metals from waste lithium ion battery by using sulphuric acid as leaching agents, followed by solution purification, precipitation, and solvent extraction techniques. However, with organic acids, there has been evidences of selective recovery of metals which can be extracted under reducing environment; however separation turns out to be tedious task.

We aim to present the current demand and supply of these critical metals, the recycling technologies of spent lithium-ion batteries, and there impact on environment, in vogue.

Key Words: Critical metals; End-of-life LIBs; Hydrometallurgy; Leaching; Recycling

# Leveraging Life Cycle Assessment for environmental sustainability in steel industry

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## Abstract

Life cycle assessment (LCA) is a crucial analytical tool used within the steel industry to evaluate and mitigate its substantial environmental impacts. The steel production process, particularly iron-making, is notably energy-intensive, contributing significantly to global energy consumption and environmental degradation. By applying LCA, steel producers can systematically assess and improve their manufacturing processes, aiming to reduce their environmental footprint. Conducting a comprehensive LCA requires a detailed life cycle inventory (LCI) that encompasses the entire steel life cycle. This includes stages such as raw material extraction, production, use phase, and end-of-life processes. Gathering accurate and comprehensive LCI data is foundational to identifying and quantifying the environmental impacts associated with each stage of the steel life cycle. LCA evaluates various environmental indicators relevant to the steel industry, such as climate change, ozone depletion, acidification, and eutrophication. These indicators provide a multifaceted view of the environmental burdens imposed by steel production. For instance, climate change metrics quantify greenhouse gas emissions, while acidification indicators assess the release of acidic substances that can harm ecosystems. Understanding these impacts allows steel producers to implement targeted strategies to mitigate their environmental footprint. A key aspect highlighted by LCA in the steel industry is the issue of abiotic resource depletion. Steel production heavily relies on several non-renewable minerals, including iron ore, copper, manganese, and nickel. LCA offers a comprehensive understanding of current production trends and the potential future shortages of these vital metals. By assessing the depletion rates and availability of these resources, LCA provides critical insights for strategic decision-making regarding resource management and sustainability. Beyond its environmental benefits, LCA also serves as a foundational framework for various certification and rating schemes. Certifications such as Environmental Product Declarations (EPD), GreenPro, and CDP rely on LCA data to validate the environmental performance of steel products. These certifications not only enhance the market credibility of steel products but also promote transparency and accountability within the industry. Furthermore, LCA provides valuable insights into process efficiency and operational parameters. By conducting LCA on an annual basis or comparing it across similar units, steel producers can identify inefficiencies and areas for improvement. Continuous monitoring and assessment through LCA enable the implementation of process enhancements that reduce environmental impacts and optimize resource use. Despite its benefits, LCA is inherently a complex and resource-intensive process. It involves extensive data collection, analysis, and interpretation, requiring significant time and effort. However, the comprehensive insights gained from LCA make it an indispensable tool for the steel industry. It underpins various certifications, reporting schemes, process improvements, and strategic decision- making, ultimately contributing to the industry's sustainability goals.

**Key words** : LCA, LCI, Sustainability, cradle to gate, end of life

# Characterization of charcoal for its utilization in Blast Furnace

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## Abstract

Charcoal is used as a replacement of pulverised coal in blast furnace. Due to the challenge for $CO_2$ mitigation, interest for charcoal use as a renewable energy source is rising in steel industry. Physical, chemical and reactivity characterization of charcoal is important for its utilization in Blast furnaces.

Due to unorganised sector for lump charcoal production, it is supplied by multiple vendors with different carbonization process for lump charcoal production. It leads to variation in charcoal quality parameters; hence it is important to characterize each incoming lot before utilization in blast furnace. This paper explains different characterization techniques for charcoal i.e., Size fraction analysis, Bulk density, % Moisture, Hard groove grindability index, Calorific value, Proximate and Ultimate analyses.

There was a challenge to characterize all incoming lots of lump charcoal due to its increased utilization in blast furnace. This paper also describes measures taken for development and implementation of mechanized sample preparation and testing facilities for charcoal at laboratory. Measures taken to control dust emission during screening of charcoal samples have been also addressed in this paper.

Keywords: Charcoal, Blast Furnace, Characterization, Mechanization

# A Case Study on Steel Recycling Ecosystems

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## Abstract

Since its inception, significant developments have improved the steelmaking process, aiming to achieve optimal quality and cost. Steel has evolved into a crucial component of daily life due to its versatility and ability to deliver superior performance across a wide variety of applications. The recycling ability of steel stands out as a sustainable practice, proven very effective in maintaining quality across multiple recycling cycles without degradation. This study investigates two primary themes: the comparative environmental impact of different steelmaking routes in global and Indian contexts, and the circular economy dynamics of steel recycling. The analysis contrasts the carbon emissions associated with various steel production routes namely Induction Furnace, Electric Arc Furnace, and Basic Oxygen Furnace and highlighting significant differences. The findings reveal that the Electric Furnace route emits approximately one fifth of the carbon compared to the BOF route.

This study furthermore investigates into the unique practices at Polaad Steel, particularly our innovative scrap segregation techniques. This approach enables the efficient recycling of more than twelve different steel grades, encompassing comprehensive pre- and post-processing stages. The research estimates that Polaad Steel's recycling operations involve a vast ecosystem comprising over 1,00,000 individuals and 1,200 vehicles, contributing in the production of approximately one million tons of finished steel (rebar) annually. Additionally, the economic aspects of steel recycling are explored, encompassing the logistics from scrap collection to recycling units, as well as the financial implications of steel recovery from recycling processes. This comprehensive analysis emphasizes the all-around benefits and sustainability of steel recycling as a key component of modern industrial practices. This discussion summarises the relationship between technological advancement, environmental keeping, and economic viability within the steel industry, positioning recycling as a foundation for sustainable development in global steel production.


Fig. 1: Different types of scrap

Key words: Recycling; Sustainability; Circular economy; $CO_2$ emission; Rebar.

# Utilization of Agro-wastes for Versatile Engineering Applications: A brief Glimpse

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## Abstract

Agricultural wastes are menace leading to soil pollution and air pollution. But the wastes could be managed scientifically by extracting important constituents replacing the inorganic constituents generally synthesized from minerals. There is a focus on development of light weight composite without sacrificing strength, hardness and compatibility with different environment. Thus, proper utilization of agricultural wastes is a highly plausible solution addressing environmental pollutions as well utilization of natural resources without stressing on mineral exploitations. Different agricultural wastes like coconut ash, rice husk ash, cassava peel ash are noted to be very beneficial and compatible for light weight metal matrix composites using aluminum as the main matrix. Coconut shell ash is noted for producing highest amount of activated carbon amongst the major agro-wastes. Coconut nut shell ash is also noted to be useful for metal matrix composites, concrete reinforcement fillers, water purification, heavy metal removal and others. Similarly cassava peel ash is also noted for partial replacement of cement in concretes, for activated carbon production and others. Rice husk ash is also noted for contributing Silica, alumina from agro-wastes to Al based metal matrix as reinforcing agents, as partial replacement in cement/concrete, producing micro-fine silica, soil ameliorants and others. Thus, the present paper focuses on different agro-wastes, their utilization and some methodology of incorporation to produce light weight composite materials.

Key words: Agro-wastes, light weight composites, rice husk ash, coconut shell ash, cassava peel ash

# Valorization of Steel Waste: A Sustainable Solution for Steel Making

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## Abstract

Ladle Furnace (LF) slag is a byproduct produced during secondary steel making process. Slag generated from Al-killed steel has relatively high CaO-$Al_2O_3$ content that can be recycled and used at LF as an alternative to calcium aluminate synthetic slag and fluorspar. However, owing to finer size fraction of the LF slag post metal recovery, they are ground dumped which is a sheer waste of valuables as well as an environmental concern. With stringent environmental norms, an approach was adopted to recycle the LF slag thereby reducing ground dumping. The current paper outlines the research on reutilizing LF fine slag in steel production by dosing with suitable compounds to improve slag fluidization. Finer LF slag fraction, which was ground dumped, is briquetted into a suitable size fraction that can be used at ladle furnace, while larger LF slag lumps are used in their as-is condition. Trials were conducted at steel shops by usage of this re-engineered slag to help in early slag formation that will facilitate desulphurization. The impact of trials on lime consumption, fluorspar consumption, desulphurization rate and processing time at ladle furnace were studied. The trials had encouraging results with good desulphurization rate and reduced fluorspar as well as lime consumption at ladle furnace. The study helped to eliminate dumping of LF slag by recycling it thereby reducing lime and fluorspar consumption at plant.

Keywords: Al-killed steel, recycling of LF slag, briquetting, ladle furnace, fluorspar.

# Utilization of carbon neutral fuel in iron ore agglomeration

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## Abstract

Iron ore sintering is an energy and pollution intensive stage in an integrated steel plant. The majority of the energy consumed in sintering is solid fuels, like coke breeze and anthracite. The combustion of fossil fuels has been widely known as the main source of $CO_2$, SOx and NOx, and studies have verified that substituting fossil fuels with clean and renewable bioenergy in sinter making was an effective strategy to reduce the emissions of $CO_2$, SOx, and NOx. The combustion of coke breeze contributes to a majority proportion of direct $CO_2$ emissions in sintering. Sustainability efforts viz., heat recovery from waste gas recirculation, natural gas/oxygen injection in the top layer of the sinter bed, reducing recirculation of sinter fines etc. have been widely adopted across the world to improve the energy efficiency of the process. Biomass sintering is an effective approach for low carbon sintering due to its carbon neutrality. Due to high moisture and volatile content, raw biomasses are not suitable for sintering as it adversely affects the sinter quality and in turn leads to an inefficient blast furnace operation. Hence, in this study, charcoal with fixed carbon basis was used as a replacement of coke breeze in iron ore sintering.

This study was carried out to determine the influence of using charcoal as a supplementary fuel on the quality of sinter. The primary fuel, coke breeze, was replaced with 5, 10, 20, 30 & 50% charcoal (with 16% Volatile Matter content) to produce sinter. Improvement in cold strength (Tumbler Index) of sinter is observed upto 20% replacement of coke breeze. Beyond 20% replacement of coke breeze by charcoal led to decreasing cold strength of sinter due to decrease in sintering time. The Reduction Degradation Index was largely within the acceptable range as the lattice distortion due to crystalline transformation from hematite to magnetite is restricted due to the formation of increased number of pores. For a plant scale trial, the procurement of charcoal with consistent quality is a challenge as the supply chain is currently evolving. Nevertheless, it is a promising alternative to the traditional fossil fuels currently being used in the sintering process.

Key Words : iron ore sintering, charcoal, cold strength

# Application of BOF Slag as Effluent Sorption Media for Coke Oven Effluents

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## Abstract

During coal carbonization and by-product recovery processes, a significant quantity of effluent is generated. These effluents contain various pollutants such as phenol, cyanide, ammonia, oil and grease, tar, polycyclic aromatic hydrocarbons, etc., and need to be treated before discharge or recycling. These effluents can be treated in an Effluent Treatment Plant by various methods such as coagulation, filtration with coagulation, aerobic and anaerobic biological processes in different stages, adsorption/sorption, ozonization, ion exchange, and reverse osmosis. However, many of them have high operational cost and needs significant investment. In view of the need of cost and efficiency optimization, aerobic biological treatment has been adopted as core treatment process of integrated steel plants of SAIL.

The effluent received for treatment by biological process in aeration tank, contains high loads of pollutants that hinders growth of microorganisms, resulting in insufficient biological treatment. Considering high level of contaminants, an improved pre-treatment method (sorption process) by in house generated Basic Oxygen Furnace (BOF) slag was envisaged as a possible sorption media for pre- treatment of coke oven effluent.

BOF slag is a waste material generated when steel is produced through the BOF steel-making route. For every tonne of steel produced, 120–150 kg of slag is generated. The grains of the generated BOF slag are partly dense and partly porous, having a high surface area and rough surface texture. In view of these, exploration of BOF slag as an economical sorption medium for the removal of toxic constituents from the coke oven effluents was planned. Further, BOF slag can increase the alkalinity of wastewater, which enhances the effectiveness of biological treatment.

In this work, trials were carried out both in laboratory and industrial scale using BOF slag of different sizes for pre-treatment of coke oven effluent. The BOF slag of ≤ 10 mm size has been found to be more effective in reducing the cyanide concentration & ammonical nitrogen and increasing total alkalinity in coke oven effluent.

Key words: Coke oven effluent, Sorption, BOF slag, Cyanide & ammonical nitrogen

# Optimizing Gas Mixing Schemes for Reheating Furnaces to Reduce Coal Bed Methane Gas Consumption

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## Abstract

This paper details the development of a modified gas mixing scheme for Reheating Furnaces (RHF) at an integrated steel plant in India, aimed at reducing consumption of costly Coal Bed Methane Gas (CBMG) in RHFs by utilizing surplus in-house Basic Oxygen Furnace Gas (BOFG). The existing mixing station, initially designed to mix Blast Furnace Gas (BFG), Coke Oven Gas (COG) and CBMG, was redesigned to integrate BOFG, thereby lowering the usage of expensive CBMG in RHFs. In the proposed system, different mixing schemes with all available gases (BFG, BOFG, COG and CBMG) were worked out. In all the mixing schemes, efforts were made to keep Wobbe index of the proposed Mixed Gas (MG) and heat loads of the system same as the existing, ensuring minimum modifications in the existing combustion system of RHFs. The proposed design incorporates both automatic and manual operational controls, with a control philosophy ensuring proper gas mixing and flow rate adjustments. After implementing the proposed mixing scheme, the average consumption of BOFG in RHFs increased from zero in 2022 - 23 to 8 $Nm^3$/ t charge weight in 2023-24, leading to reduction in consumption of costly CBMG in RHFs by 2 $Sm^3$/ t charge weight.

Key words: By product gases, Reheating furnace, Coal Bed Methane gas, Basic Oxygen Furnace gas

# "Turning Trash into Treasure: Advancing Sustainability through Direct Utilization of Solid Secondary Waste in Steel Plant"

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## Abstract

Integrated steel plants have been significant contributors to solid waste generation, containing valuable constituents such as iron, calcium oxide, silica, and alumina. While on the other hand posing hazards to health and the environment as it also contains some trace elements. JSW Steel Dolvi, situated 100 km from Mumbai, operates as an integrated steel plant with a capacity of 10 MTPA. The Dolvi premises generate approximately 7500 tons of solid waste on daily basis comprising BF Dust, Sludge, SMS Slags (EAF Slag, BOF Slag, KR Slag, LHF/LF Slag), Mill Scales, and SMS Dust. Out of this 7500 tons of solid waste 4200 tons of materials were consumable*.

Initially, Dolvi faced hurdles in utilizing these waste fully due to its fine texture, chemical composition, and concerns about its impact on product quality. Major challenge was to distribute these materials among the consumers (2 Sinter and 2 Pellet plants) based on their texture, size, chemical composition and their impact on the final product of these units. However, through strategic distribution planning and incorporating mechanical solutions, JSW Dolvi has overcome these challenges. Today, it stands out as a leader by achieving 100% consumption of its internal solid waste (consumable*), a feat accomplished with minimal changes in existing facilities. By directly using these secondary materials into sinter and pellets plants, JSW Dolvi has improved its economic efficiency by replacing IBRM partially by these solid waste. JSW Dolvi is also consuming 100tons/day of material which are considered non consumable, in its own Cement Plant. It is also reducing carbon consumption as well as carbon emissions, thus contributing to environmental sustainability. This innovative approach not only benefits Dolvi's bottom line but also sets a new standard for environmentally responsible industrial practices.

JSW Dolvi's journey showcases the power of innovation and commitment to sustainability in transforming waste into opportunity, paving the way for a cleaner, more efficient future in steel production.

*these materials are getting consumed in few places in the world.

Key words: Secondary Waste, JSW Steel Dolvi, 100% Waste consumption, Waste Management, Sustainability, KR Slag, BOF Slag, EAF Slag, LHF Slag.

# Investigation into Stabilization of Expansive Properties of BOF Slag

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## Abstract

Significant quantity of by-product is generated during steel production in integrated steel plants. Typically, 120-160 kg of BOF slag is produced per tonne of steel. A part of the slag is recycled within the steel plant and the majority remains unused due to its high phosphorous content. This poses substantial ecological and economic challenges. The continual dumping of BOF slag is unsustainable, necessitating the exploration of its potential applications, particularly in the construction of highway embankments. However, its high swelling potential and alkalinity have limited its use, as these properties can compromise structural stability and cause environmental issues through leaching. The study was aimed to investigate the expansive properties of BOF slag to determine its suitability for various applications. An Indian standard, IS 383:2016 was referenced to develop a slag expansion test apparatus, which was used to measure the expansion potential of both weathered and unweathered slag from thee different integrated steel plants of SAIL. The BOF slag was weathered artificially in an in-house developed hot water bath facility for slag conditioning, where it was submerged in hot water controlled at 70 - 80°C for 72 to 80 hours. The study also examined various size fractions of the slag to provide a comprehensive understanding of its expansive behavior. The test method was followed to calculate the volumetric expansion ratio for the evaluation of the potential expansion of steel slag aggregates due to hydration reactions. The study revealed that the expansion potential of both composite slag and its size fractions exceeded the acceptable range of 2%, rendering it unsuitable for direct use in road construction and related applications. This finding highlighted while BOF slag has potential applications in construction, particularly in highway embankments, its use requires effective stabilization treatments to mitigate its expansive properties and environmental concerns. The study identified a five-day heating and cooling cycle as an effective method for slag stabilization. This treatment significantly reduced the expansion potential of the slag, making it more suitable for practical applications. The findings of the study contribute to the broader efforts to improve solid waste management in the steel industry, emphasizing the need for sustainable practices and innovative solutions to enhance the utilization of by-products like BOF slag. However, further research and development are necessary to optimize these treatments, refine stabilization techniques, and explore additional applications in order to ensure for safely and effectively use of the BOF slag in various construction applications. This will reduce its environmental impact and contribute to more sustainable steel production processes.

Keywords: BOF slag, steelmaking, expansive properties, stabilization, road construction, recycling, environmental impact, IS 383:2016

# Development of Environment Friendly Colour Coated Products Without Chromate Conversion Pretreatment with class-3 Durability.

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## Abstract

Hexavalent chromium is widely recognized as hazardous substances due to their toxicity, sensitizing properties, and carcinogenic potential. In response to the growing environmental and health concerns, there is increasing interest in developing alternative coating technologies that eliminate the use of chromate conversion pretreatment while maintaining product quality and performance.

This study focuses on the development and evaluation of the environment friendly coating formulations suitable for industrial applications, with Class-3 durability standards. Traditional coating processes often rely on chromate conversion pretreatment at the Colour Coating Line (CCL) to enhance adhesion, corrosion resistance, and overall durability. However, these processes pose significant environmental and health risks, requiring stringent regulatory compliance such as EU RoHS directives.

The objective of this research was to formulate and assess coating systems that can achieve comparable performance without the need for chromate conversion pretreatment. Key parameters evaluated include adhesion strength, corrosion resistance (through salt spray and humidity tests), colour stability, and gloss retention over extended periods. The coatings were applied using standard industrial methods to ensure practical applicability.

Experimental results demonstrated that the developed coatings met the performance criteria set by industry standards. Paint Adhesion tests revealed robust bonding characteristics, while corrosion resistance tests, including salt spray and humidity exposure, showed promising results comparable to traditionally treated coatings.

Additionally, colour stability and gloss retention remained within acceptable ranges throughout accelerated weathering tests, confirming the coatings' durability under simulated environmental conditions. Importantly, the formulations developed in this study were designed to comply with EU RoHS regulations, thereby supporting sustainable manufacturing practices and reducing hazardous chemical usage in industrial operations. By eliminating chromate conversion pretreatment, this approach not only enhances environmental sustainability but also offers potential cost savings by streamlining production processes.

In conclusion, the findings of this study underscore the feasibility and effectiveness of the developing environment friendly coatings without chromate conversion pretreatment. These advancements contribute to advancing sustainable practices in the coating industry while maintaining high standards of product performance and regulatory compliance.

Keywords: Chromate Conversion Pretreatment, Class-3 Durability, Hexavalent Chromium, Environmental Sustainability

# Ironmaking Using Biomass as a Reductant: Pathways Towards Green Steel Production"

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## Abstract

The steel industry is a significant contributor to global $CO_2$ emissions, necessitating the development of sustainable ironmaking technologies. This review explores the use of biomass as a reductant in ironmaking, emphasizing its potential to lower carbon emissions and contribute to the concept of green steel. The paper examines various types of biomass, their preparation and processing methods, and the thermochemical mechanisms involved in iron ore reduction. It also assesses the technical, economic, and environmental aspects of biomass-based ironmaking, comparing it to conventional methods. Challenges such as biomass availability, consistency, and integration into existing steelmaking infrastructure are discussed. The review concludes by identifying future research directions and policy measures needed to support the transition to green steel production using biomass reductants.

**Key Words:** Biomass; Green Steel; Sustainable Steelmaking; CO2 emission

# Life cycle analysis and cost analysis of pelletization process for goethite ore substituting fossil fuel with rice husk

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## Abstract

In this study, the suggested modified procedure using different rice husk compositions was compared to the standard conventional pelletization process in terms of feasibility. Decreased carbon footprint and lower emission values verified environmental acceptability. Furthermore, an analysis of the modified pelletization process's economic feasibility revealed a 6.79% cost savings over the traditional approach. A Life Cycle Assessment (LCA) method was used as a decision-support instrument to assess sustainability. The analysis showed a measured decrease in COx and SOx emissions of 100% and 43.3%, respectively, demonstrating a notable advance over the traditional method. The suggested pelletization method using only rice husk is found to be sustainable. The comprehensive study was carried out to find the sustainable way to utilize low-grade goethite ore and rice husk, in the pelletization process to produce iron ore pellets. Sustainability was confirmed by making of economical and ecofriendly iron ore pellet that is suitable as one of the burden materials for the blast furnace. Presently, Coke consumption may be reduced by approximately 1.2 MTPA, and hence, the fossil fuel consumption may be reduced by 2.0 MTPA in India. This novel and potential approach may help integrated steel plants reduce carbon footprint significantly.

Keywords: Lifecycle analysis, Rice husk, Goethite ore, Pelletization, Carbon neutral

# Investigation on the Carbon Capture in BOF Sludge and its Recycling in Pelletization Process

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## Abstract

Integrated steel plants process iron ore, coal and flux to produce steel, through various unit processes. Each unit process produces one or other by-products. Although many of them are very rich in iron, flux and fuel values, a general term wastes or inplant wastes has been given to them. Presently, the environmental awareness and recognition of the mineral values in wastes have resulted in attempts to recycle them and recover their associated minerals up to the extent possible. Recycling recovers the mineral values, eliminates the disposal cost and preserves the environment. On the other hand, ore-based steelmaking generates a variety of residues including dusts, sludges, scales and slags. Recycling of these residues within the process or via other applications is essential for the sustainable production of steel. Domestic environmental legislation and the cost of raw material and energy continue to drive efforts toward increased recycling. Most of the BOF sludge generated in SAIL steel plants remains unutilized and treated as wastes. In this investigation, an attempt has been made to utilize BOF sludge in pelletization process.

In this study BOF sludge collected from SAIL plant has been characterized. The XRD analysis of the BOF sludge has also been carried out. In the present work, carbon capturing of BOF sludge has been conducted in auto-clave under a CO2 gas pressure of 5 kg/cm$^2$ in auto-clave. It has been observed that maximum 0.8 % weight gain is achieved after 1 h 40 m.

In another study, an attempt has been made to utilize BOF sludge in pelletization process. Green pellets with basicity 0.35 were prepared with the variation of BOF sludge (from 25-100%) replacing limestone into pellet mix. The green pellets were indurated in an electrical heating furnace at 1300°C. The Cold Compressive Strength (CCS) values were measured. It has been found that pellets made with 25% BOF sludge replacing limestone exhibit a CCS value of 212 kg/p. This result has been validated in the pilot pelletization system using 25% BOF sludge replacing limestone. The CCS value has been improved to 238 kg/p. The hardened pellets also exhibit very good RDI (11%), RI (65.5%), Swelling Index (14.6%) and Porosity (20.3 %). Hence BOF sludge may utilized in pelletization process with 25% replacement of limestone.

Keywords: BOF Sludge, Carbon Capture, Pelletization, Cold Compressive Strength, Porosity, Reducibility Index

# Green Solutions: CO2 Sequestration through Tree Planting in Iron Ore Mines of JSW Steel Ltd., Odisha

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## Abstract

There is a growing interest in the role of different types of land use systems in stabilizing the $CO_2$ concentration and reducing the $CO_2$ emissions. Tree plantation has been recognized as a means to reduce $CO_2$ emissions as well as enhancing carbon sinks. The mining division of JSW Steel Ltd located in the State of Odisha has four open cast fully mechanized mines which started its operation in 2020. We have lush green cover of approximately 3,40,122 plants of different native species like Sisham, Chakunda, Neem, Jamun, Karanj etc in our mines. Trees being the natural sink for $CO_2$ is the very acquainted form of carbon sequestration method adapted by JSW Steel in Mining Division. Trees absorb $CO_2$ during photosynthesis and store it as biomass (trunks, branches, leaves, and roots). Trees distribute this biomass in two primary compartments: Above-Ground Biomass (AGB) and Below-Ground Biomass (BGB). AGB encompasses the parts of the tree that are visible above the soil line and BGB consists of the roots.

The total weight of the biomass is estimated as 120% of the AGB value, based on the assumption that the BGB comprises of approximately 20% of the AGB. Therefore, BGB is calculated as: BGB = 0.2 × AGB. From these formulas, we can calculate the total biomass of a tree as: Total Biomass (TB) = AGB + BGB = AGB + 0.2 x AGB = 1.2 × AGB.

On an average, a tree consists of 72.5% dry matter and 27.5% moisture content. To calculate a tree's dry weight, we multiply the total weight of the tree by 72.5%. So, Total Dry Weight (TDW) = TB × 0.725.

Generally, for any plant species 50% of its biomass is considered as carbon i.e., Total Carbon (TC) = TDW × 0.5. For calculating $CO_2$ equivalent, total carbon was multiplied with a factor of 3.6663, which has the basis of atomic weight ratio of $CO_2$ to C is 44/12 = 3.67. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.67, i.e., $CO_2$ weight = TC × 3.67.

The calculation for the quantity of $CO_2$ sequestered by the green cover of the mines is done by using the above-mentioned methodology. The trees aged 5 years and above is accounted for the study. According to this study the aggregate amount of $CO_2$ sequestered by the plantation sums up to 96797 tonnes.

Restoration and Reclamation being the final stage of mining wherein afforestation is the predominant method for the same. There will be an amplified amount of plantation in every year which will indeed add on to the $CO_2$ sequestration in a progressive manner which can be assumed to be around 7000 tonnes per year.

Key words: $CO_2$ sequestration, Plantation, Above-Ground Biomass (AGB), Below-Ground Biomass (BGB), Total Carbon (TC)

# "MEROS and EOS Technologies: Optimizing Sintering with Reducing Fuel Consumption and Minimizing Dust Emissions"

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## Abstract

Sinter Plants play a vital role as a raw material for iron & steel production by agglomerating iron ore fines, flux, and coke into a product suitable for blast furnaces. Sinter Plants in JSW Dolvi works are equipped with ESP (Electrostatic Precipitator) for treatment of sinter off gas. The ESPs are designed to reduce dust emission below 50mg/m3, which can still pose environment threats in the coming days.

Steel plants in India are gradually moving towards European environmental standards, JSW group is also moving towards Green Steel concepts. These involves numerous technologies that are implemented for reducing dust emission in Compliance with European environmental norms. Sinter Plant-2 of JSW Dolvi has integrated technologies like MEROS (Maximized Emission Reduction in Sintering) and EOS (Energy Optimized Sintering) for the optimization of sintering process, reducing consumption of solid fossil fuel consumption and reduce off-gas emission. The adoption of MEROS and EOS transforms Sinter plants with high off-gas emission into emission and energy optimized sintering plant, achieving dust emission of less than 5mg/m3 as well as saving 5-6 kg/ton of solid fuel consumption.

This study explores operational challenges and quality deviations encountered after commissioning of MEROS and EOS and how Sinter Plant-2 successfully adopted these technologies to achieve energy and emission optimized sintering.

Key words: Sinter Plant, Dust Emissions Optimization, MEROS, EOS, Energy Efficiency.

# Carbon Dioxide Sequestration in Coal Seams

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## Abstract

The continuous increase in atmospheric carbon dioxide (CO2) after the post-industrial revolution is one of the primary causes of the rapid global temperature rise and other climatic imbalances. Currently, the atmospheric CO2 concentration is over 420 ppm, which has resulted in an approximately 1.2°C temperature rise compared to preindustrial levels. CO2 capture, utilization, and storage (CCUS) has been identified as one of the primary pathways for the abatement of anthropogenic CO2. According to the International Energy Agency, the world needs to implement about 6.2 gigatons of CCUS by 2050. However, even 50 years after the first CCUS projects started operating, there are only about 30 CCUS projects around the world, capturing only 42 mtpa against global CO2 emissions of 36 gtpa. Considering the scale of global CO2 emissions, CCUS needs to significantly scale up in an accelerated time frame to make a meaningful contribution to global decarbonization.

India has substantial geological sequestration potential in its basaltic rocks, coal seams, depleted oil reserves, deep saline aquifers, and sedimentary basins. The theoretical estimated storage capacity of CO2 in India is in the range of 400–600 Gt. One of the most attractive areas for the application of CO2 sequestration is in underground coal seams via enhanced coalbed methane (ECBM) recovery. Coal reservoirs contain pore spaces and natural fractures, which contain methane and act as potential sinks for atmospheric CO2 through ECBM. Injection of CO2 into coal reservoirs displaces methane from coal matrix pores, as CO2 has a higher affinity for adsorption in coal pores than methane. Considering India's vast reserve of bituminous and sub-bituminous coals, around 3.6–6.3 Gt of CO2 can be stored in these coalfields (Vishal et al., 2021). However, these assessments were performed on an aggregated basis, and did not assess this potential at a level of geographic, geologic, or economic disaggregation.

Tata Steel Group is among the top ten global steel companies, with an annual crude steel capacity of over 35 million tonnes per year. The company has five captive coal mines at the Jharia coal field. The company is also working toward achieving net zero for steel production. Therefore, a scientific study was carried out in collaboration with IIT Bombay to estimate the CO2 storage capacity in the deep-seated unmineable seams of the Jharia group of mines. This study involved laboratory tests that included ultimate analysis, rock-eval pyrolysis, thermogravimetry analysis, low-pressure gas adsorption, field emission gun scanning electron microscopy, other petrophysical and geo-mechanical studies, and numerical modeling to identify preliminary CO2 storage potential. From the scoping level study, it has been observed that, around 44 million tonnes of storage capacity over 10 years are at Jharia mines. Going forward, a prefeasibility study is to be done with one dedicated bore hole drilling for detailed characterisation of all the coal seams.

Key words: Carbon, Net zero, CCUS, sequestration

# Decarburization of Aluminium Sector Pathways

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## Abstracts

The aluminium industry generates more than 1.1 billion tonnes of CO2 e (carbon dioxide equivalent) emissions annually – around 2% of global anthropogenic emissions. As per Council On Energy, Environment And Water (CEEW) estimates, the total baseline emissions in the production of aluminium in India is 20.88 tonnes of CO2 (tCO2 ) per tonne of aluminium. This includes the emissions due to direct fuel use, emissions associated with the electricity consumed in the process, and the emissions generated due to the nature of the process itself, also termed 'process emissions'. **Electricity consumption accounted for 80 per cent of the total for aluminium sector**, **while process emissions and fuel consumption accounted for the rest**. In view of the projected growth in demand for aluminium, emissions need to be addressed to limit global warming to 1.5°C in order to curb climate change risks.

Added to this, India's aluminium exports to the European Union (EU) are set to become difficult due to implementation of the Cross-Border Adjustment Mechanism (CBAM). When the CBAM tariffs kick in from 2026, primary aluminium producers exporting to Europe will have to buy EU-ETS (European Union-Emission Trading System) certificates for the emissions, making exports to be unviable for domestic players. CBAM will lead to a significant 20% rise in prices due to the stark difference in emission intensities between key producing countries such as China, India and Europe. Given that 67% of the global power requirement for aluminium production is met by coal- or gas-based power plants, exports from all geographies to Europe are set come under intense scrutiny.

This Paper focuses on the importance of fostering the thinking of reducing the CO2 consumption in Aluminium for survival in the upcoming stringent guideline era. This Paper also focuses on the pathways that can be explored for the decarbonization of Aluminium Sector.

**Key Words:** Decarburization , CBAM,EU-ETS

# Recycling of Phenolic Resin used for metallurgical sample preparation.

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## Abstract

Material characterization and quality assurance of engineering components/products via destructive testing in steel industries necessitates meticulous metallurgical specimen preparation. This process is vital for analysing the metallurgical and mechanical properties of materials, whether new, used, or failed, in alignment with technical specifications. Each metallurgical test adheres to specific standards. Conventionally, phenolic resins, particularly Bakelite or Phenol Formaldehyde (PF) resins, are utilized in the hot mounting process for all types of metallic samples. These resins, the first commercial synthetic resins, can endure high temperatures and resist non-oxidizing acids, salts, and various organic solvents. They exhibit robust compact strength and abrasion resistance, facilitating easy polishing and surface preparation. Additionally, PFs' chemical inertness ensures they do not react with etchants during the etching process. Operating effectively at temperatures as high as 120°C, PF resins are globally employed for this purpose. However, phenolic compounds pose carcinogenic risks. A National Institute of Health, USA study indicated that phenolic compounds induced tumours in rats, leading to death within 23 months. Consequently, disposing of these compounds is challenging due to stringent governmental regulations prohibiting landfilling or casual disposal. To address this, a Reduce and Reuse strategy was adopted. Consumption was minimized by repurposing old Bakelite mounts as makeup pieces for general use. For reuse, material characterization of powdered old mounts versus fresh powder showed no significant differences. Subsequent experiments involved crushing old mounts into powder, mixing this with fresh phenolic resin powder in varying proportions, and using each mix for hot mounting. These mounts underwent rigorous quality checks, including abrasion, compactness, chemical reactivity, and hardness tests. The optimal proportion was identified, trialled multiple times, and consistently met all quality standards. Implementing this strategy reduced phenolic resin consumption by over 65%, cutting costs from approximately 48 lakhs to 16.8 lakhs. Additionally, metallic parts were recycled as scrap, optimizing resource utilization. This initiative significantly benefits the environment by reducing hazardous waste and promoting sustainability.

Key words: Phenolic resin, Phenol Formaldehyde, Bakelite, carcinogenic

# Extraction of copper and other precious metals from E-waste by using Induction Furnace

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## Abstract

E-waste, such as discarded PCBs, contains a variety of hazardous substances that can pose significant risks to the environment if not properly managed. Improper disposal or treatment of e-waste can lead to the release of toxic materials including heavy metals and persistent organic pollutants which can contaminate soil, water, and air. The most common mineral that we can find in PCBs is copper. Extracting copper and precious metals from PCBs is a crucial process in recycling and recovering valuable materials like gold, silver, platinum, etc. This study investigates the use of pyrometallurgical processing in an induction furnace to extract copper and precious metals from PCBs. The process involves the addition of a flux (FeSio2), which assists in separating and concentrating the target metals. the results of the study demonstrate the feasibility of this approach, with the induction furnace effectively melting the PCB materials and the FeSio2 flux facilitating the extraction of copper and precious metals. The next steps in the research process will focus on identifying alternative fluxes, such as borax, to enhance the efficiency and selectivity of the extraction process. The goal is to increase the purity of the extracted materials and maximize the amount of metals recovered while also ensuring proper accuracy and minimizing waste. This continued investigation will contribute to the development of more sustainable and effective methods for the recovery of valuable resources from electronic waste

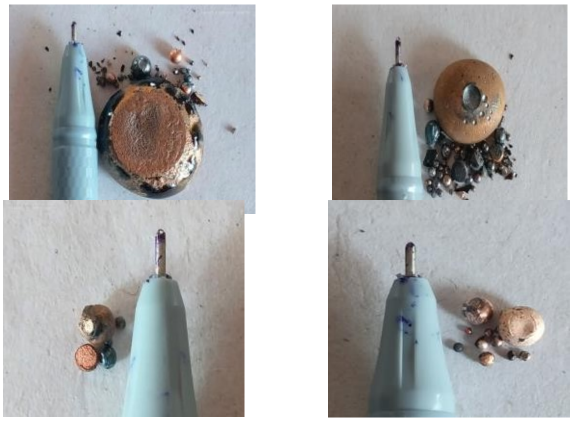

Figure 1. Pictorial representation of induction furnace.Figure (2,3,4,5). Images of samples collected during the extraction process (PCBs)

Keywords: pyrometallurgical processing, induction furnace, FeSio2 flux, borax, copper.

# Application of crushed coal overburden as an alternate to river sand for mortar

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**Abstract**

Tata Steel Ltd is operating opencast coal mines at West Bokaro to supply coking coal to its integrated steel plant. In an opencast coal mine, large volume of overburden (OB) is generated during coal mining (~9 tonne of overburden needs to be excavated for mining of 1 tonne of coal). Typically, the overburden is piled up in OB dumps within the mining lease area. The disposal or management of this waste material can lead to environmental issues and incur additional costs. On the other hand, there is a growing demand for sand for infrastructure development. Overexploitation of river sand has led to ecological, economic and social problems. Sand produced from overburden generated from coal mines may be beneficial for coal bearing areas & nearby cities, while also reducing the handling of OB dumps at coal mines. The manufacturing of sand from overburden will promote circularity in mining and sustainable practices.

IIT-ISM Dhanbad is entrusted to check suitability of crushed/washed overburden as replacement of natural sand in mortar/concrete. Test results have demonstrated that the crushed and washed overburden meets the requirements (gradation, density, soundness, deleterious materials, alkali aggregate reaction etc.) as per IS-383 for fine aggregates. It complied with the specifications of Zone-II sand (Fig.1) in IS-383 standards. Furthermore, the results of mortar tests are promising (achieving a compressive strength of 15 MPa after 28 days of curing), indicating its suitability for mortar applications (such as joining brick walls, plaster, etc.). The compressive strength test of M30 concrete designed as per IS 10262 could not achieve the target strength, suggesting that 100% OB sand is not a suitable alternative to river sand.

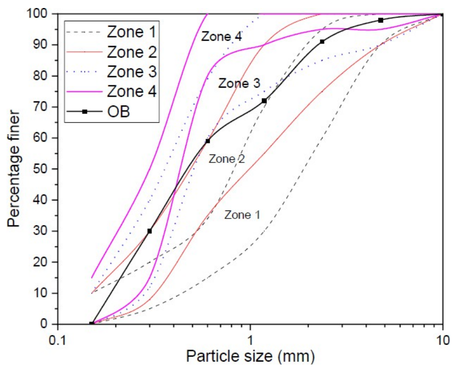


Fig. 1: Gradation of sand manufactured from overburden

keywords: sustainable mining, coal overburden, manufactured sand, cement mortar

# Zero Valent Iron based bimetallic nanoparticles for effective removal of antibiotics using photo-Fenton process

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## Abstract

The possibility of antibiotics to cause antibiotic resistance and disturb ecosystems makes their presence in water bodies a serious concern to the environment and public health[1]. To address this challenge, the utilization of advanced oxidation processes (AOPs) has gained considerable attention. Among these, the Photo-Fenton process stands out for its efficiency in degrading organic pollutants using nano scale Zero Valent Iron(nZVI). Even though nZVI has several advantages, its strong affinity for oxygen makes it unstable and restricts the applications it can be used for. To overcome this issue, herein we report an effective heterogeneous photo-Fenton catalyst nZVI/Cu bimetallic nanoparticle synthesized using the facile chemical co-reduction method. The photoactivity of this ZVI based bimetallic nanoparticle is analyzed through aging of materials. Post –aging revealed enhanced photoactivity for nZVI/Cu compared to nZVI. The phase formation and other structural properties of prepared nZVI and nZVI/Cu were investigated from the respective X-ray diffraction (XRD) pattern and particle morphology was studied from the Field emission scanning electron microscope (FESEM) micrograph. Further, the chemical properties such as elemental analysis, oxidation states of different elements were measured from X-ray Photoelectron Spectroscopy (XPS) analysis. The activity of nZVI and nZVI/Cu a is compared by the degradation of tetracycline, ciprofloxacin and antibiotic mixture using class AAA solar simulator which is further quantified using High Performance Liquid Chromatography (HPLC) analysis. The plausible degradation pathway and degradation intermediates were identified using LC-MS/MS analysis. The bimetallic nanoparticle showed higher removal efficiency (99%) when compared to bare ZVI.

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# Enhancing the Thermal Conductivity of Organic Phase Change Materials for Thermal Energy Storage

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## Abstract

Phase change materials (PCMs) are an ideal product for solar and waste thermal heat storage applications. This is because they can store and release latent heat energy during the process of melting and freezing i.e. changing from one phase to another. When such a material freezes, it releases large amounts of energy in the form of latent heat of fusion. Conversely, when the material is melted, an equal amount of energy is absorbed from the immediate environment as it changes from solid to liquid. Generally, thermal energy storage technologies can be categorized as latent heat with phase change materials (PCMs), sensible heat and those working based on reversible thermochemical reactions. However, the main drawback of PCMs is their relatively poor thermal conductivities that results in slow heat transfer rate in some applications. To overcome the drawback of low thermal conductivities of organic PCMs, several heat transfer enhancement techniques have been conducted in this temperature range, including adding fins, heat pipes, dispersing nanoparticles, microencapsulated PCM, carbon fiber, graphite composite and several other methods.

In the present work, several metal foams, wire woven cellular materials, graphene, graphite and other metallic/metal oxide nano-particles are used to increase the thermal conductivity of the resultant PCM composite. There has been an enhancement of 6 to 10 times in the thermal conductivity of the resultant composites. The best thermal conductivity enhancer in terms of cost and easier use is also identified in this study.

key words : phase change materials, metal foam, thermal energy storage, thermal conductivity enhancement, graphene, metal nano particles

# Advanced technological measures on fugitive dust emission control in logistic operations at Tats Steel Jamshedpur

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## Abstract

Fugitive dust emission during material handling is a major concern in an integrated steel plant. As the characteristic of raw materials viz coal, coke, iron ore and fluxes etc used in steel plant varies significantly, it is very difficult to handle fugitive dust emission with same source during material handling in bulk quantity specially during unloading at wagon tippler area. In this paper various air pollution control (APC) systems which are used at different stages of operations has been discussed. It was found that cold fog dust suppression (CFDS) system has an advantage over dry fog dust suppression system (DFDS) while handling calcined ore in tippler area. Use of CFDS in wagon tippler area has significantly controlled the dust emission during unloading of these raw materials. The paper also describes use of a new technique in track line cleaning which was used for the first time at Tata Steel Jamshedpur plant.

key words : Fugitive dust, Logistics operation, Air Pollution Control, DFDS, CFDS

# Decarbonization Initiatives in Blast Furnaces

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## Abstract

Decarbonisation is a very crucial step for the Indian economy. According to the survey, the Indian steel industry is one of the top $CO_2$ emitters, with an average of 2.15 $tCO_2$/TCS against 1.76 $tCO_2$/TCS, the global average. Iron making is the biggest contributor of carbon emissions. Currently, Tata Steel Meramandali Blast furnaces are contributing nearly 68% of total CO2 emissions in its steel value chain. BFs are working continuously in the diminishment of CO2 gas. High fuel rate operation was a concern for BF team as reduction in coke rate may increase furnace resistivity and disturb other critical parameters, which affect BF productivity. Fuel rate, as well as $CO_2$ emission was reduced with increasing pulverized Coal injection (PCI) from 156 kg/thm to 182 kg/thm & Hot blast temperature (HBT) enhancement to 1164ºC by optimizing process control through Level-2 Models & Advanced calculated parameters. To reduce carbon footprint, certain trials were adopted such as use of Super Absorbent Polymer (SAP) for reduction of coke moisture as well as dosing of Boric Acid to reduce slag rate by 32 kg/thm. Need of the hour is to adopt best of techniques and trials to suppress impact of $CO_2$ footprint and make green and sustainable iron making.

key words: Green House gas (GHG), Decarbonization, Super Absorbent Polymer (SAP), Pulverized Coal Injection (PCI), Hot blast temperature (HBT).

# Unlocking Value from Waste: Efficient Valuable Metal Recovery from Electric Arc Furnace Dust

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## Abstract

Electric arc furnace (EAF) dust is a significant by-product produced from melting of the scrap/DRI in Electric Arc Furnace during steelmaking process. According to industry and literature data, the EAF dust generation is approximately 15-25 kg per ton of steel production. EAF dust contains valuable elements such as zinc, lead, and iron, with 25-50 wt.% zinc and 22-45 wt.% iron being the principal constituents. This dust contains heavy metals and is between 20 and 100 microns in size. Land filling, dumping, or releasing this dust into the environment poses a serious risk to humanity. There are currently no accessible technologies for managing EAF dust that has been developed or practiced by industries. In this study, thermodynamic calculations were done to better understand the recovery of valuable elements from the dust using various biochar as reduction reagents.

Thermochemical software "FactSage 8.3" was used to assess the thermodynamic feasibility of metal extraction, such as Zn and Fe, under various industrial operating conditions. Thermodynamic calculations were also employed to better understand the intermediate phase transformations of key phases such as zinc-ferrite and iron oxide. By understanding these factors, this work aims to optimize the recovery processes, making them more efficient and economically viable. This not only contributes to metal recycling efforts but also addresses environmental concerns by reducing the hazardous waste generated by the steel industry.

Keywords : dust valorisation, metal extraction, thermodynamic simulation, steelmaking.

# Cost effective methodology for recovery of silver from end-of-life PV module

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## Abstract

In accordance with the Paris Climate Action Plan, the Indian government is promoting renewable energy and has set a target of 280 GW of solar energy capacity by 2030 [1, 2]. This means that the amount of waste generated by the waste solar panels in the coming years would be huge. Till day a cumulative capacity of about 69 GW solar panels has already been installed in the country and the capacity being continuously increasing with promotion of green energy production under multiple national schemes such as National Solar Mission and PM Surya Ghar: Muft Bijli Yojana. The present study is focus on attempts to recycle the end-of-life (EoL) solar PV modules for recovery of valuable contents. Silver (Ag) is one of the valuable contents present in EoL PV modules which amount to ~0.01 wt% of the panel. The study discloses a cost effective methodology recover the Ag metal content from EoL solar panels. Hydrometallurgical route is applied for selective extraction of Ag content and removal of Al, SiNx layer in single step etching reagent. The processing parameters including s/l ratio, time, temperature, acid concentration etc were systematically studied and optimized. The metals extraction and impurities concentration at various stages of processing were analyses through inductively coupled plasma atomic emission spectroscopy (ICP-OES) and Field emission scanning electron microscopy (FE-SEM). Ag metal content with ~98% purity was recovered in the current study.

Keywords: end-of-life solar panel; silver recovery, extraction, ICP-OES

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# AI in Sinter plant Sustainability

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## Abstract

Sintering is one of the agglomeration processes that converts iron ore fine into porous and lumpy mass with the application of heat and flux. In modern blast furnaces, sinter accounts 50-80% of the ferrous burden. Due to its superior quality any further replacement of lump ore with sinter improves blast furnace productivity and reduces coke rate and thus carbon footprint. However, Sinter Plant is significant contributors to environmental pollution, emitting large amount of dust, NOx and Sox including PM10 and PM2.5. These fine particles can penetrate deep into the lungs, causing respiratory problems, cardiovascular diseases, and even cancer. The Indian industrial landscape is undergoing a significant transformation driven by the rapid adoption of Artificial Intelligence (AI). AI-powered sensors and IoT devices can collect real-time data on environmental parameters such as air quality, water quality, and waste generation. This information can be used to proactively mitigate risks and prevent environmental incidents. It can also optimize energy consumption in industrial processes by analysing data on energy usage and identifying areas for improvement. AI has the potential to revolutionize Manufacturing Sector. This paper explores the potential of AI to enhance the sustainability of Sinter Plants. By integrating AI into various aspects of the Sinter plant operation significant improvements in environmental performance can be achieved. Tata Steel Meramandali (TSM) has implemented a number of digital initiatives at its sinter plants, including process optimization, emission monitoring, Resource optimization and waste management. The company has also developed a digital twin of its sinter plant, which allows it to test and optimize the process in a virtual environment. These initiatives are helping to make sinter plants more sustainable.

Key Words: Sustainability, AI, Optimization.

# Feasibility and Challenges of Aerogel-Palladium Composites for Hydrogen Storage: A Comprehensive Analysis

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**Abstract**

Aerogels, characterized by their remarkable porosity and expansive surface area, serve as an ideal matrix for hydrogen adsorption. Recent research has highlighted the potential of aerogel-palladium composites as high-performance hydrogen storage materials. By integrating palladium nanoparticles, which are known for their excellent hydrogen absorption capabilities, this study aims to enhance both the density and kinetics of hydrogen storage. The investigation is focused on the synergistic effects between the aerogel and palladium components, examining factors such as pore structure, palladium loading, and particle size distribution. It addresses challenges related to material compatibility, hydrogen diffusion, and desorption kinetics. Additionally, economic considerations and scalability are assessed to determine the commercial feasibility of this technology. The ultimate objective is to develop a thorough understanding of the factors affecting hydrogen storage performance in aerogel-palladium composites, thus advancing their potential application in clean energy systems.

**Keywords:** aerogel-palladium composites, hydrogen storage, composite materials, hydrogen adsorption and desorption kinetics, material compatibility

# Sustainability Initiatives for Green Environment at Hooghly Met Coke

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## Abstract

Sustainability is a rapidly expanding area of global research, becoming essential across all industries. This study at Hooghly Met Coke (HMC) explores various initiatives undertaken to promote sustainability initiative towards green environment. These efforts focus on sustainable practices such as water conservation, sustainable construction methods, and vermicomposting to support sustainable gardening. The findings demonstrate significant positive impacts on the environment and cost savings, providing valuable insights for policymakers and organizations aiming to enhance sustainability through green innovations and environmental awareness. The results indicate a clear pathway for other industries to achieve sustainable growth while mitigating environmental impacts.

About 2 acres land was occupied with civil & structural scraps generated during plant maintenance on every year, converted into garden which was enabler for increasing plant green area from 26% to 33%. The whole garden area is sustained with treated domestic wastewater through sewage treatment plant having capacity of 150 KLD. This sustainable water management benefits nutrient-rich fertilization, lower salinity, enhanced plant growth, reduce environmental impact. In HMC, Bed Method of Vermicomposting is followed. This helps plant gardening works such as developing roots of the plants, improving the physical structure of the soil, increasing water-resistance of the soil, helping in germination, plant growth, and crop yield, also nurturing soil with plant growth hormones such as auxins, gibberellic acid, etc. A storm water pond of capacity approx. 6500 cum has been developed during rain, the roof water from all building like ADM building / Store / Laboratory / pump house are collected in a common storm water drain and this water is collected in the storm water pond. The collected water is used in coke quenching and other purposes like gardening, water sprinkling on roads, etc. Generally, we provide guard wall/boundary wall to any property in terms of safety & to restrain unauthorized entry of any personal. For the construction we used Reinforced Cement Concrete (RCC) to make the guard wall. This idea is to make the guard wall using those old used Indian Rail & PSC sleeper. This will use the scarp materials; construction process is cost effective (Cost Saving – Rs 29.5 lakhs for 210 m wall making); Rapid Construction in comparison with conventional RCC wall; More sustainable construction process (73T less CO2 emission in terms of cement used in conventional RCC wall making process).


Fig. 1: Sustainability Initiatives at HMC

**key words** : Sustainable Garden, Vermicomposting, Sustainable Construction method.

# Recycling and reuse of GCP dust generated from SiMn production process.

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## Abstract

GCP dust storage and usage has been a great concern for ferro alloys industries. Addressing the waste generated during the production of ferro alloys is a huge respite for the plant as the GCP dust creates environmental hazards by increasing PM in the area apart from storage and handling issues.
Similar concern has been the issue for Ferro Alloy Plant Balasore during the production of SiMn alloys. The plant has two SAF of 16.5MVA rating, generating around 6-8 tons GCP dust per day. Also, these fines cannot be directly charged into the furnace as it may lead to safety hazards like shrinkage and eruption, thus is at present unutilized. To address this problem the GCP dust which contains 15-17% Mn was recycled back into the furnace in the form of briquettes as a potential source of raw material. To increase the metallic value of GCP dust briquette, medium grade Mn ore fines (-6mm) was added. Binder used for briquettes was cement (~10%) and bentonite (~2%) which provided a reasonably high cold compressive strength and furnace thermal stability during the operation. Nearly about 3% to 4% of the GCP dust briquette was added into the burden mix, which sufficed the total GCP dust generated per day from both the furnace, thereby 100% utilization of waste was considered. The furnace operation was monitored post briquette charging into the furnace which showed no deviation. Further the paper will encompass the percentage usage of briquettes along with theoretical comparison of various raw material for briquette production in the burden for sustainable and profitable production of SiMn alloy. Also alternative route of agglomeration was tried i.e. pelletization but the results was not so satisfying as much as briquetting route.

**Keywords:**
GCP dust, Briquette, Binder, Medium grade, pelletization.

# Reduction of Green House Gas Emission in Mini Blast Furnaces at JSW Salem Works

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## Abstract

Blast Furnace is one of the conventional technologies for producing liquid hot metal from Iron Bearing Materials viz Iron Ore lump, Sinter, Pellets and Direct Reduced Iron (DRI), using coke and pulverized coal as fuels. Sustainable iron making becomes imperative now-a-days since Blast Furnace iron making emits a significant amount of Green House Gas (GHG). Part of the coke requirement is replaced by injection of pulverized coal. JSW Salem works has two mini blast furnaces (BF#1 and BF#2) with the capacity of 402 and 640 $m^3$ respectively. The present Pulverized Coal combination is 67% non – coking coal and 33% Corex Coal fines. The emission factor for non – Coking coal and Corex Coal fines is 2.953 $tCO_2$ / MT.

As study was carried out to replace coal with sustainable bio-materials to reduce carbon footprint.
- Charcoal from various origins such as wood charcoal, coconut shell charcoal and cashewnut charcoal were studied for the suitability to replace coal. Based on the study, cashew nut shell charcoal having higher fixed carbon and low ash content was found better suitable for injection in the blast furnace. Trials were conducted with substitution of 1% Cashew nut shell charcoal in place of Corex Coal in the blend. The effect of use of charcoal in PCI unit and impact on the operation of Blast Furnace were analyzed. This study has shown substantial reduction in GHG emission and also resulted in cost savings.

Keywords: Pulverized Coal, Green House Gas, Metallurgical Coke, Cashew nut shell Charcoal
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# Recovery of rare earth from spent NdFeB based Permanent Magnets as an effective E-Waste management for creating a sustainable and circular economy.

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## Abstract

In the present climate, Neodymium (Nd) magnets are in high insistence for use in the manufacture of electric vehicle motors and medical equipment such as magnetic resonance imaging. In this study, we describe a new process for recycling Nd permanent magnets (PMs). Rare earth (RE) NdFeB magnets account for about two-thirds of the permanent magnet market. They have more significant advantages than other ferrite and (Sm–Co) magnets. Spent NdFeB magnets are a potential secondary source of rare earth elements (REEs), which are increasingly open to supply risks due to their scarcity and growing demand for consumption. The exceptional magnetic properties of miniature and lightweight NdFeB magnets, including high remanence, coercivity and maximum energy product, make them paramount in green energy technologies, such as NdFeB magnets used in wind turbines and electrical vehicles (EVs).There are various routes such as hydrometallurgical, pyrometallurgical and electrochemical to recycle spent NdFeB magnets and recover the REE's from it. In this research hard disk magnets were taken and demagnetised at Curie temperature and then the oxidised protected layer was removed by means of chemical treatment. Subsequently the magnets were subjected to communition and powder was collected. The communited powder was leached in HNO3 (69%-71%) and iron was precipitated with Ammonia, rest of the solution was treated with oxalic acid (99% pure) and RE oxalates were recovered. The RE oxalates were calcinated at high temperature (1223.15K) to convert RE oxide, in this we have recovered 99% of RE from spent NdFeB based magnets.

Keywords: Rare earth recovery, permanent magnet recycling, circular economy.

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# Development of slag based Geopolymers for high temperature applications

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## Abstract

Traditional cement production, a cornerstone of the construction industry, contributes significantly to carbon emissions and energy consumption. In response to these challenges, alternative binders, such as geopolymers, have emerged as promising contenders. Among the many of materials explored, Fly Ash (FA) and Ground Granulated Blast Furnace Slag (GGBFS), both industrial by-products, have gained considerable attention for their potential to form geopolymers with enhanced environmental credentials. Fly Ash, generated from coal combustion, and GGBFS, a by-product of the iron and steel industry, exhibit pozzolanic properties, making them suitable for geopolymerization. Geopolymers are inorganic binders formed by the chemical reaction between alumina-silicate sources and alkali activators, omitting the carbon-intensive process associated with conventional Portland cement production. In the present research work, different ratios of binders (Fly ash and GGBFS) have been tried along with varying molarity of alkali activators. Experimental observation reveals that the suitable combination cured at ambient temperature provide required strength gain for 1, 3, 7 and 28 days. Developed product also cured at elevated temperature ($60^0$C) and fast setting and higher 1day strength observed. There are advantages of using geopolymers in civil applications compare to conventional binders. This material can be cured at room temperature and can achieve 28day's strength in 7 days. Ordinary Portland cement (OPC) based material can sustain upto $300^0$C temperature and further fail or spall whereas geopolymer based construction material sustain upto $600^0$C comfortably and fail at more than $750^0$C.

This work aims to propel the development of sustainable construction materials, promoting the widespread adoption of fly ash and GGBFS-based geopolymers for a greener and more resilient built environment.

**Key words** : Fly ash, Geopolymer, GGBFS, Inorganic binders

# Optimization of coke oven gas recovery system using Aspen plus

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## Abstract

During coke making process, coke oven gas (COG) comes as a by product gas. This is one of the most valuable gases as it contains higher proportion of hydrogen ($H_2$) and methane ($CH_4$), both of which can serve as a fuel. In order to utilize this gas, there is need to separate the two major impurities, hydrogen sulfide ($H_2S$) and ammonia ($NH_3$) during COG recovery process. It is observed that with the increase in flowrate of weak ammoniacal water, ammonia and hydrogen sulfide scrubbing efficiency along with the increase in $P^H$. With the increase in sodium hydroxide solution, hydrogen sulfide scrubbing efficiency and $P^H$ increase. Hence, there is an opportunity for to optimize the flowrates of weak ammoniacal water and sodium hydroxide stream. An Aspen based model is developed to optimize the process using Aspen plus V14. As sodium hydroxide is one of the costliest chemicals in this process and increases the cost of further treatment, optimization of this stream may reduce the energy usage and operating cost for this process.

key words : Aspen plus; Optimization; COG recovery

# Antibacterial Response of Zinc Oxide Ceramics Processed via Cold Sintering

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## Abstract

Cold sintering is a green manufacturing technique to process ceramics extremely at low temperatures which has potential for electronics, energy storage, and biological applications.In the present work, almost fully dense ZnO ceramics obtained after cold sintering at very low temperature of 300 °C with application of 500 MPa pressure for 30 min. X-ray diffraction (XRD) patterns indicated presence of zinc oxide. In order to understand the bio-applications of the cold sintered ZnO, in-vitro antibacterial properties have been studied. The viability of Staphylococcus aureus (S. aureus)and Escherichia coli (E. coli) bacteria observed to reduce significantly.The statistical analysis reveal that all the unpolarized samples exhibit significant reduction in the optical density for both the bacteria.Furthermore, the cellular response also examined using MG-63 cells. Also, cellular response(for 3,5 and 7days, respectively) of ZnO reinforced with 20 wt% of SrTiO3 has been studied.The viability of the cells increases significantly with an increase in the duration of culture for the developed ZnO samples.The statistical analyses revealed that all samples exhibit significant increase in the viability of MG-63 cells in pure ZnO but not in the case of composite ZnO-20wt%SrTiO3.It indicates that ZnO is more biocompatible material than SrTiO3.

**Keywords:** Cold Sintering,Polarization,Cell Culture,Antibacterial.

# Ecofriendly production of low/medium carbon ferromanganese in electric arc furnace for sustainable steel industry

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## Abstract

The manganese ferroalloys viz. HC-ferromanganese and silicomanganese account for about 42% of total bulk ferroalloy. However, specific plant data on low-carbon and low-phosphorous manganese ferroalloy production is unavailable. The supply of low/medium-carbon manganese ferroalloys has been largely met through imports and low-capacity indigenous production. The low/medium carbon ferromanganese is often used to produce special steels with low carbon content. Hence, it is an indispensable ingredient in the unique steel-making process. In this endeavor, CSIR-NML developed a process based on the pre-reduction of ore followed by EAF smelting to produce low/medium-carbon ferromanganese. Lab scale test established critical parameters for pre-reduction of manganese ore in a rotary kiln. Thermochemical simulation of the pre-reduction process determined the required parameters for tests in a kiln. The effect of parameters was investigated to arrive at optimum conditions to obtain suitable ore for subsequent smelting. The smelting tests in 50 kVA EAF examined the suitability for reduction by silicomanganese. Subsequent smelting trials on a 1 MVA scale established the yield, specific power consumption (SPC), and optimum manganese recovery. The process was tested at TRL level-7 and is ready for demonstration in relevant conditions and on plant-scale equipment. This process is suitable for Pyrolusite and Braunite-type manganese ore. The SPC and recovery depend on the type and pre-treatment of the ore. The new process provides several advantages over conventional shaking ladle, aluminothermic, and AOD processes to produce low/medium-carbon ferromanganese. There were savings in raw materials, lower SPC, and increased manganese recovery when pre-reduced ore was smelted in EAF. However, depending on the silica concentration, a Pylousite yields better results than a Braunite. Several process parameters affect the outcome of the smelting. Ferromanganese with C = 0.2-2.0% and Mn = 70-80% could be produced, meeting IS grade specifications. The outcomes indicated the potential adoption of the process in the ferroalloy industry.

keywords: Ferroalloy; Ferromanganese; Energy-efficiency

# Enhancing Energy Efficiency and Reducing Emissions through Hot Air Utilization Optimization in Circular Cooler at Sinter Plant 2 in JSW Salem

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## Abstract

Sinter is a porous, solid mass formed by heating a mixture of iron ore fines, coke, and fluxes to a temperature just below their melting point. In a sinter machine, a mixture of iron ore fines, coke fines, anthracite coal fines, and recycled materials is layered onto a moving grate. As the mixture moves along the machine, it is ignited by a gas burner, causing the coke & coal fines to burn and generate heat. This heat partially melts the surface of the iron ore particles, causing them to fuse together. As the sinter cake cools, it solidifies into a porous mass. The finished sinter is then crushed, cooled through 4 nos of blowers in Circular cooler and screened before being used in a blast furnace for ironmaking. The utilization of hot air from the circular cooler blower presents a significant opportunity for energy conservation and cost savings in the sinter production process. The hot air, with an initial temperature range of 200 to 350°C, is increased to a more consistent range of 300 to 350°C through various modifications. These enhancements include the insulation of ducts, modification of sealing rubber height, reduction of hood and pallet gaps in circular cooler blower #1. By implementing these changes, an energy saving of 0.007 Gcal/ton of sinter has been achieved, translating into an annual cost saving of INR 1.58 crore. Additionally, this improvement has led to a substantial reduction in Greenhouse gas(GHG) emissions, specifically 10,657 tons of CO2

Key words :Sinter,

# Insights into recycling hazardous aluminium dross: A step towards sustainable circular economy

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## Abstract

The escalating global demand for aluminium has resulted in a concomitant increase in the generation of aluminium dross. It is a complex and hazardous by-product constituting upto 8 wt.% of total aluminium output per ton. In 2023, India alone produced over 3 million metric tons of aluminium, resulting in a substantial quantity of dross. Therefore, the recycling of aluminium dross to recover pure aluminium and generate valuable aluminium-rich products like $Al_2O_3$ is of critical importance. Various methods have been developed to recycle aluminium dross effectively and efficiently, thereby mitigating its environmental impact.

Pyrometallurgy presents a viable approach for aluminium recovery from dross, involving the melting of dross in a rotating furnace to break down complex formations and extract aluminium in its elemental form. However, the management of secondary waste generated by this method remains challenging.

In contrast, hydrometallurgical process offers promising alternatives to recycle aluminium dross. The hydrometallurgical approach involves leaching aluminium ions from dross using acids and alkalis, facilitating aluminium recovery without the need for high-temperature processing. Integrating these recycling techniques into a circular economy reduces the need for virgin aluminium, lowers energy use, and enhances the sustainability of aluminium production, making the process more resource-efficient and environmentally friendly.

Therefore, it is imperative to recycle aluminium dross as its rapidly increasing quantity poses significant environmental risks. Landfilling aluminium dross not only degrades soil and harms nearby flora and fauna but also leads to the loss of valuable aluminium resources. Thus, recycling aluminium dross not only mitigates environmental impacts but also recovers valuable aluminium, effectively turning waste into wealth. Furthermore, this recycling process supports sustainable practices by reducing waste, conserving natural resources, and lowering the carbon footprint of aluminium production. Consequently, it plays a crucial role in building a more sustainable and resilient industrial ecosystem.

Keywords: Aluminium dross, Hydrometallurgy, Pyrometallurgy, Recovery, Recycling

# Electrification of Process Heating in Steel Production

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## Abstract

In Today's world, how efficiently and sustainable way we use energy has become predominant. As in India, we venture towards Net Zero by year 2070, everyone is looking to reduce fossil fuel and that has become one of the key initiatives of the Industry. Someone said " a penny saved is a penny earned", Industry 4.0 is looking ways both to reduce energy cost as well as reduce utilization of fossil fuels. In coming days, Western World is becoming stringent and introducing carbon duty. If we in India are not able to course correct our path, our products especially for Steel Industry, we will become unviable.

One of the key energy consumer in Production is Heating Process (eg. Furnace) . Once we focus on making them energy efficient in a sustainable way, achieving Net Zero becomes easier.

Few ways to achieve the target is "Electrification of fossil fuel furnaces" and "Energy Efficient Furnaces". If we go as per market data, 20% of Industrial furnaces are electrical, 40% are gas fired and 40% are oil fired.

Key benefits of electric heating over fossil fuel fired furnaces are more energy efficient, less of $NO_X$ and $SO_X$, safer and quiter environment, better temperature control and reduction of $CO_X$ emission (zero if use renewable energy).

Due to above globally buzzword is "Future of heating technology is Electric".

**Keywords:** Net Zero, Electrical Heating, Sustainable, Environment Friendly, Low Maintenance, Cost Saving through energy efficiency, Increased productivity through higher operating temperatures.

# Multifunctional 3D Flexible Dandelion-like Foam: A Nature- inspired Wonder for Clean Tech and Wearable Device

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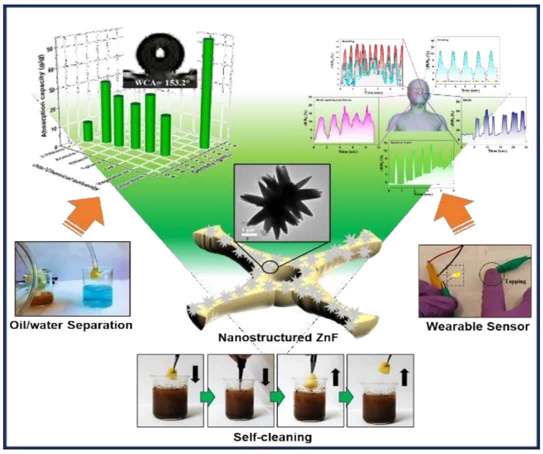
**Abstract**

Integrating 1D nanomaterials into 3D arrays or hierarchical structures is crucial for unlocking their complete potential in functional applications.[1] Here, we highlight that the morphological evolution of three-dimensional zinc oxide foams (ZnF) demonstrates profound influence of pH variations on surface morphology, leading to the formation of diverse structures with varying aspect ratios and dimensions. Our findings underscore the role of alkaline conditions in fostering the evolution of dandelion-like 1D nanostructures, attributed to intricate interplays of reaction kinetics and Ostwald ripening processes. Furthermore, ZnF explores its potential applications in self-cleaning, oil/water separation and human motion sensing. The ZnF, due to its high aspect ratio, is optimized to exhibit superhydrophobicity (water contact angle=153±2°) showcasing self-cleaning ability and enhanced oil-water separation performance following surface functionalization. Transitioning to wearable sensing, ZnF exhibits outstanding piezoresistive characteristics, precisely capturing a broad spectrum of human movements and tactile stimuli with rapid response times (~60ms). These movements encompass dynamic actions such as elbow bending, tapping, hand gripping, drinking, smiling, breathing, speaking, and mouth opening. Furthermore, ZnF exhibits stability over 10000 continuous tapping cycles, indicating the material's ability to maintain its piezoresistive properties over extended use. Overall, the multifaceted functionalities and versatility of synthesized ZnF paves the way in environmental remediation, sensor technology[2], and human-machine interfaces, heralding a new era of innovation in functional materials research.




Graphical Abstract

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# Steam Ageing of LD Slag at Tata Steel

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## Abstract

Tata Steel Plant generates huge amount of LD slag containing free lime (i.e.- 8-10%). The generated LD slag is sent to Metal Recovery Plant (MRP), where the metallic iron is separated, and the slag is crushed to smaller size fractions before being sent to their intended applications. The as is use of LD slag in applications such as road aggregates, railway ballasts etc. get inhibited due to the expansion property of LD slag. As per the available literature, volume of LD slag becomes three times of its original volume with the absorption of atmospheric moisture. This increase in volume results in the cracking of structures where as-produced LD slag is used without any treatment.

The current paper discusses about the Steam Ageing Facility setup in Tata Steel for accelerated ageing of LD slag with the application of steam. It was observed that there was a significant reduction in free lime content after the LD slag ageing process.

**Key Words**: LD slag, Free lime, Ageing, Weathering

# A review on Innovative Approaches to Sustainable Recycling of PET: Transforming Waste into High-Value Environmental Solutions

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## Abstract

Polyethylene terephthalate (PET) is one of the most widely used plastics globally, found in products ranging from beverage bottles to textile fibers. The global PET Bottles market size was valued at USD 18381.89 million in 2022 and is expected to expand at a CAGR of 4.84% during the forecast period, reaching USD 24412.43 million by 2028. During 2016–2021, the compound annual growth rate of PET has already achieved 21.93 metric tons, in India.
Despite its widespread use, the disposal of PET poses significant environmental challenges, as it is non-biodegradable and accumulates in landfills and oceans, contributing to environmental pollution. Sustainable recycling of waste PET is therefore critical to mitigating its environmental impact. This study explores innovative approaches to the recycling of waste PET, with a focus on developing valuable materials that have positive impact on environment.

The review investigates mechanical, chemical, and novel advanced recycling methods that convert waste PET into high-value products. Mechanical recycling, while widely practiced, often leads to diminished material quality and is constrained by contamination and polymer degradation, limiting the number of recycling cycles. In contrast, chemical recycling offers a more sustainable solution by breaking PET down into its fundamental monomers—terephthalic acid and ethylene glycol—allowing for the production of new PET or new materials supporting a closed-loop recycling system. One of the most effective methods of chemical recycling is the alcoholysis of PET in an alkaline medium. In this process, washed PET flakes are heated with alcohol (methanol or ethanol) and a base (sodium hydroxide or potassium hydroxide) in a reaction vessel. The resulting solution is then acidified and filtered to yield high-purity terephthalic acid and ethylene glycol, which can be used to synthesize new materials. Terephthalic acid proves to be a great candidate for the synthesis of metal organic frame works (MOFs). These metal organic frameworks are of considerable interest owing to their potential applications including gas storage, catalysis, luminescence, and electrochemical activity. Particularly, Cu based metal organic frame works are showing immense potential for carbon dioxide ($CO_2$) capturing due to their porous structure. On the other hand, ethylene glycol finds applications in antifreeze formulations and the production of polyethylene glycol, fiberglass etc.

In conclusion, the review provides a pathway for the development of environmentally sustainable recycling practices that can significantly reduce the environmental footprint of PET, ultimately contributing to a healthier and more sustainable planet.

Keywords: PET, Recycling, Monomers, Metal Organic Framework, Circular economy

# Recycling of metallic values from end-of-life capacitors

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## Abstract

The rapid advancements in technology and the availability and affordability of electronic devices have spurred the accumulation of electronic waste (e-waste). In 2022, about 62 million tonnes (Mt) of e-waste was generated globally and is projected to reach 82 million tons by 2030. India is the third largest e-waste contributor (4.1 MT), with recycling mainly carried by the informal sector. Printed circuit boards (PCBs) are an essential component (3-7 wt.%) of any electronic device, and their recycling is challenging due to their heterogeneity and complexity. PCB comprises a complex mixture of polymeric resin, metal foils, laminated layers, and electronic components (ECs). The ECs mounted on the PCB are a concentrated source of precious metals compared to primary ores and represent a higher weight fraction (~77%) than the basal plate. ECs of size range 1- 5 mm include capacitors (single-layered and multi-layered ceramic capacitors), integrated circuits, and resistors. The structure of multi-layered ceramic capacitors (MLCCs) consists of an alternate dielectric layer of BaTiO3 and internal electrodes (Ag-Pd), which are connected in parallel, while the end-electrode contains three layers of Ag, Ni, and Sn. The dissociation of the dielectric layer is a crucial step for the recovery of precious metals. The process flowsheet adopted for recovering precious metals (Ag, Pd) includes crushing, roasting, and three-stage leaching steps. The roasting process is carried out at a temperature of 700-1000 °C to form a fused product, which facilitates the breakdown of a stable dielectric layer. Subsequently, the roasted product is water-leached to dissolve the dielectric material, thus concentrating the precious metal content in the leach residue. Further, the water-leached residue is treated with 2 M HCl to dissolve Pd values (+2) and attain a recovery of 98%. The Pd is precipitated from the leach solution using NH4Cl to obtain a Pd salt. Further, acid-leached residue contains Ag values, which can be dissolved using thiosulfate solution at ambient conditions, with a silver extraction of 94%. In this process, Pd and Ag are selectively recovered and separated in the acid solutions. Moreover, the pre-treatment step of roasting effectively concentrates nickel and other metal values in the final leach residue, thus preventing a mixture of metal ions in the solution.

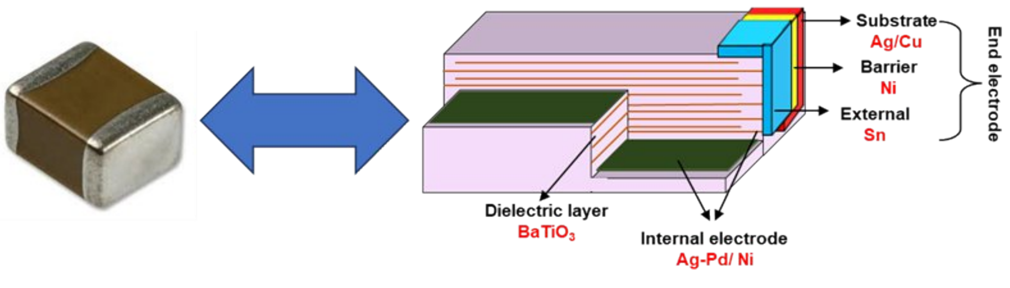


Fig. 1 Internal structure of the multi-layered ceramic capacitors

Keywords: PCB, recycling, ceramic capacitors, silver, palladium :

# Production of Briquettes through Cold Extrusion process utilizing Gas Cleaning Plant (GCP) Sludge and Mn Ore Fines at Tata Steel Ferromanganese Plant, Joda

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## Abstract

Tata Steel Ferromanganese plant, Joda generates manganese ore fines and Gas Cleaning Plant (GCP) sludge as a by-product of ferromanganese production. Due to fine size and high moisture, these materials cannot be sold off directly into commercial market and had no potential usage in the plant. Hence, a huge amount of space was required for the storage of these materials. A novel process has been designed to make use of GCP sludge and Mn Ore fines in a value-added manner by transforming it into Briquettes using the Cold extrusion process. These briquettes are utilized in Submerged Arc furnace as replacement of Mn Ore for Ferro manganese production. A significant amount of saving has been achieved after implementation of this project in terms of cost of raw material.
The current paper discusses about the Extruded briquette plant, which is set up for the first time in Tata steel, for utilization of Mn ore fines and GCP sludge.

**Key Words**: GCP Sludge, Mn Ore Fines, Briquetting, Cold Extrusion Process

# Enhancing Pickling efficiency and sustainability through advanced acid recovery in Acid regeneration plant

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## Abstracts

At Tata Steel Sahibabad, the acid regeneration plant stands out as a cornerstone of our commitment to innovation and sustainability. In an acid regeneration plant using fluidised bed roaster, the goal is to recover the Hydrochloric acid which is being generated as a byproduct of steel Pickling process. The waste pickle liquor which contains dissolved metals and acids, is processed in a fluidised bed roaster. In this unit, the roaster performs oxidation of the waste pickle liquor and metals. The high temperature inside the roaster and the presence of oxygen promotes the oxidation of the iron and the other metals to form metal oxides and regenerate the acids. The iron chloride (Fecl3) present in waste pickle liquor is converted back into hydrochloric acid and iron oxide. The regenerated acid is recovered from the gas phase through subsequent treatment stages. It involves the condensation of HCl gas vapour and separating them from fumes. The byproducts that are generated through ARP process are iron oxide and HCL fumes. Iron oxides are disposed and fumes are treated before releasing into the atmosphere. This process is efficient in recovering acids making it crucial for sustenance of any steel plant.

**KEYWORD**:
Acid regeneration plant, Waste Pickle liquor(wpl),Fluidised bed roaster, Hydrochloric acid, Iron chloride (Fecl3)

# Innovation in Recycling of Coke Dry Quenching Dust in Iron Ore Sintering

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## Abstract

Granulometry of solid fuel plays an important role in reduction of its specific consumption in iron ore sintering. Efficiency of solid fuel is reduced when it contains higher proportion of super-fines (-0.15 mm size fraction), as super-fines burn before the flame front zone during sintering process and do not have heat retention capacity. So, it fails to participate in sintering process as most of the heat passes through the waste gases and remains not fully utilised leading to the higher solid fuel consumption. Moreover, some of super fines in solid fuel passes along with waste gases and increases the stack emission in Sinter Plants.

With adoption of new technologies in any integrated steel plants, coke oven batteries are shifting to dry quenching of hot coke. This generates coke dry quenching dust (CDQ) as byproduct which contains fixed carbon more than 80% and can be utilised in iron ore sintering process. But CDQ dust contains super-fines (-0.15 mm size fraction) more than 70% with remaining size fraction below 1.0 mm. Therefore, several experiments were conducted to increase the mean size of CDQ dust by granulating it with the help of small drum pelletiser in lab and micro pellets of CDQ dust were prepared with addition of bentonite 2% and moisture 5%. The prepared micro pellets were finally used as partial replacement of coke breeze in pot sintering in lab. Experiment results established that good quality sinter can be produced with replacement of coke breeze with CDQ dust to the maximum 40%.

This paper elaborates the journey of innovations in developing techniques for efficient utilisation of super-fines CDQ dust in iron ore sintering which reduces the overall solid fuel consumption but also has the potential of controlling the stack emission at sinter plant.

**Key Words**: Recycling, Coke dry quenching dust (CDQ), Iron ore sintering, Sustainability

# Producing briquettes through extrusion process using plant solid waste at Tata Steel Ltd.

**Jamshedpur**

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## Abstract

A briquette plant was setup for the utilization of solid wastes such as BF sludge & Flue dust, LD sludge and in-plant dusts at Tata Steel Ltd., Jamshedpur. This is cold bonded briquetting technique which has zero direct carbon emission. During plant engineering, the optimization of civil and structural quantities of the proposed plant was conducted through value and process engineering and its details are presented in this paper. The proposed plant faced many operational challenges during initial conceptualization such as area constraints due to adjacent facilities, feeding of LD sludge through conveyors due to the high moisture and viscosity, possibility of spillage and material sticking on conveyor belts, develop optimum design which provides maximum value over the life cycle. To improve the value of the scheme over the life cycle, technical FAST was developed for basic function and different options were explored to develop new proposal with enhanced value. Value Engineering study resulted in optimization of productive area, optimization of civil and structural quantities with CAPEX saving of Rs. 13.24 crores & OPEX saving of Rs. 50 lakhs and ensuring safety through reduction in building height.

**Key Words:** Solid waste, Carbon emission, Customer FAST, Technical FAST, Function Resource Matrix, Value Study

# Implementing Sustainable Practices through Solvent Recovery at Tata Steel Sahibabad

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## Abstract

At Tata Steel Sahibabad, the continuous colour coating line is a subsequent process of galvanizing line producing a variety of colour-coated coils for various OEM customers. A key aspect of this process is the application of paint which significantly increases the longevity and resilience of galvanized products. Paint consists of four components: pigment, solvent, binder, and additives. During paint application, used solvent is a byproduct that is collected in a container, produced in each paint container cleaning after every colour change based on customer needs. So, we need to procure it frequently depending on the usage. This solvent (thinner) is considered as hazardous waste. To address this, a solvent recovery system, operating on a partial distillation principle, has been installed. This system efficiently recycles 85% of the solvent from the thinner, allowing the recovered solvent to be reused in production without adverse effects. This process enhancement reduces the need for new solvent purchases and improves overall efficiency. It is also a great step towards sustainability.

**Keywords:**

Paint, Sustainability, Colour Coating Line, Solvent Recovery, Partial Distillation

# An Innovative and Sustainable Approach to Enhance the Mechanical Properties of High-Strength Martensitic Spring Steels

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## Abstract

The pursuit of enhancing advanced high-strength steel's mechanical properties is unremitting. Heat treatment remains a cornerstone in this pursuit, wherein altering the austenitisation and tempering temperatures, plays a crucial role in modifying steel characteristics effectively. To address this challenge without increasing production costs, step tempering, a novel heat treatment method, emerges as a promising avenue. It involves controlled heating and cooling stages during tempering to optimise the steel's microstructure and properties. During this process, retained austenite decomposes, and the formation of transition or alloy carbides begins. Retained austenite, especially in the form of nanofilms, exhibits enhanced stability due to its fine morphology, being surrounded by harder phase martensite, and a higher percentage of carbon diffusion from the martensitic matrix during tempering. This retained austenite contributes to an increased strain hardening and improves the mechanical properties of the steel. Additionally, finely precipitated carbides throughout the steel matrix, further enhance its mechanical properties. This study employs step tempering to adjust the retained austenite content and fine carbide precipitation, effectively addressing the challenge of enhancing the toughness of high-strength martensitic spring steels while preserving their strength. Comparing this method with normal tempering highlights the advantages of this innovative approach. By examining the impact of step tempering on the microstructure and mechanical properties of martensitic spring steels, this research holds immense potential for advancing heat treatment processing and enhancing the performance of advanced materials in various applications.

Keywords: Step Tempering; Martensitic Spring Steels; Retained Austenite; Cementite carbides; Sustainable;

# Hydrogen Assisted Treatment for Recycling of EoL NdFeB Permanent Magnets

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## Abstract

The automobile industry is undergoing a revolution, where electric motor replaces the mechanical petrol or diesel engines. All the reputed four-wheeler manufacturing companies step forward to introduce their electric version in all models which is essential for their existence in the current market. In such a circumstance, indigenous development of $Nd_2Fe_{14}B$ magnet technology is essential for a country to be self-sustain in the automobile industry in near future. In the present scenario, availability of $Nd_2Fe_{14}B$ magnets is predominantly controlled by a few countries. The rare earth crisis in 2011 enhanced the demand of rare earth elements in the world market. The possibility of development of $Nd_2Fe_{14}B$ magnets are in two ways. First is from the primary raw materials which are directly from the mines. But the availability of rare earth elements and impact of mining on nature become question mark while planning for large scale production. The other option is from the secondary raw materials which includes the spent magnets from electronic devices including BLDC motors, hard disc drives, wind turbans, speakers, MRI machine etc,. The recycling of spent magnets can be performed in two methods. Extraction of individual elements from spent magnets followed by alloy making and further magnet fabrication is the first method. This is an effective method to produce rare earth source in our country. However, for recycling of $Nd_2Fe_{14}B$ magnets, this is costly and time consuming process. The second method is the repurposing of $Nd_2Fe_{14}B$ through Hydrogen treatment. Oxidation or corrosion is one of the major challenges during spent $Nd_2Fe_{14}B$ magnet recycling process. Conventional mechanical crushing for converting magnet to powder will results in huge oxygen uptake and also requires more efforts. Hydrogen Decrepitation (HD) is the best method for embrittlement of bulk and hard $Nd_2Fe_{14}B$ magnets in to fine powder. Hydrogenation can be effectively used to recycle the $Nd_2Fe_{14}B$ magnets through Hydrogen Decrepitation (HD) process in which at room temperature with Hydrogen pressure, the bulk $Nd_2Fe_{14}B$ magnets will be decrepitated into powder form without any additional energy. The resultant $Nd_2Fe_{14}B$ fine alloy powder can be directly used for the fabrication of new $Nd_2Fe_{14}B$ magnets. Here, we report the hydrogen decrepitation and dehydrogenation processes of spent $Nd_2Fe_{14}B$ magnets in bulk scale. Retaining of crystal structure, elemental composition and magnetic properties in the recycled $Nd_2Fe_{14}B$ alloy powder is confirmed through XRD, ICP-OES and VSM analysis. Morphology of recycled $Nd_2Fe_{14}B$ alloy particles is evaluated the FE-SEM images.

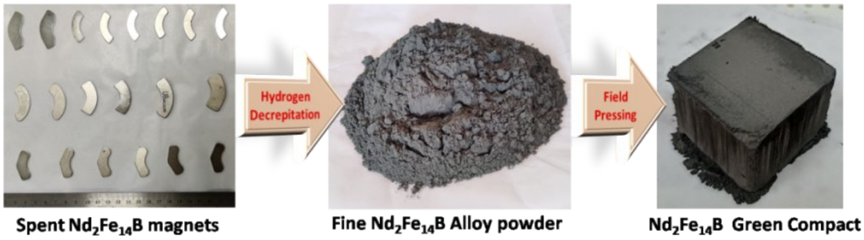


Fig.1: Recycling of NdFeB Magnets

Keywords: $Nd_2Fe_{14}B$permanent Magnets, Recycling, Hydrogen decrepitation

# A case study on Work Roll Spalling in Cold Rolling Mill, TSK

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## Abstract

In Cold rolling mills, premature failure of work rolls is a major concern. The in-service premature failure of rolls adversely affects the mill operation in two ways; firstly, the cost of rolls is huge and secondly, replacement of failed roll results in considerable loss of production due to shut down. The cold rolling mill consists of five strands wherein forged rolls are used. The present case study described on the failure investigation of strand 2 work roll spalling in cold rolling mill (CRM). A complete analysis was carried out on the spalled location. Roll was spalled on barrel area almost middle position. Total spall area is 1420 x 320 mm2. The roll was consumed just 1 mm from the initial diameter. Closer view of the spalled region revealed a central narrow track of 70 mm width with fatigue arrest marks or beach marks. The track of beach marks was propagated in the circumferential direction, opposite to the rotation of roll. Spalling characteristics indicated ''Ribbon Fatigue Spalling or Cat's Tongue Spalls''. Ultrasonic test was carried on the spalled rolled to study the crack propagation. Etched microstructure revealed fine carbide precipitation on tempered martensite matrix. No microstructural variation observed on the depth wise. There was no material abnormality observed in roll material. The study suggested that that, crack initiated from localised spalling on barrel surface. The strip breakage might be generated localised spalling on roll surface and crack might have initiated from that location.

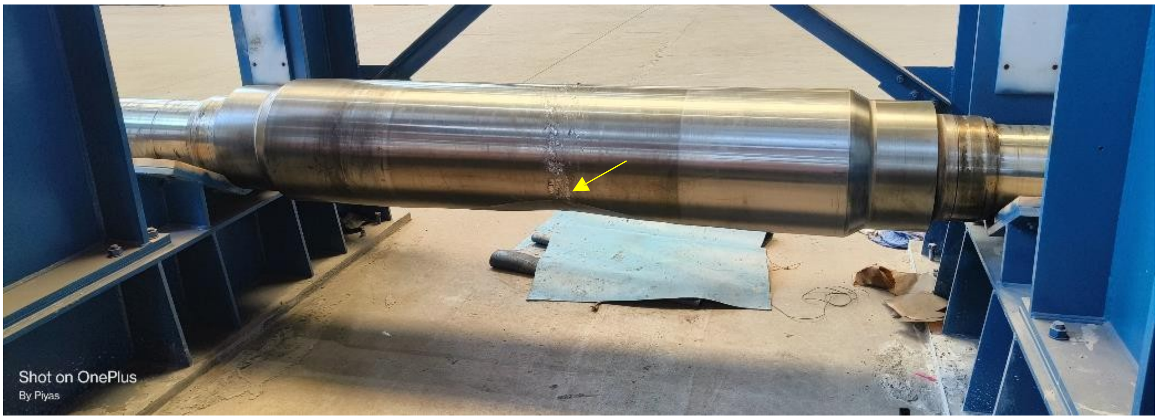


Fig. 1: Overview of failed roll shows the spall area key words: Premature failure, Spalling, Cat's Tongue spalls

# Metallurgical investigation into the causes of premature failure of high-carbon steel spring washer during production.

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## Abstract

A washer is a thin plate with a hole that is normally used to distribute the load of a threaded fastener, such as a screw or nut. The washer used in automotive engine component is of split or spring lock washer. A ring split at one point and bent into helical shape. The primary purpose of spring washers is to provide tension and preload in a joint assembly. This helps to maintain clamping force and prevent loosening or loss of tension due to vibration, thermal cycling, or other factors. The steel washer is one of the critical safety component for automobile engine and its failure may cause severe safety issue. Before subjecting to manufacturing the washer undergoes different process lines (Wire Rod >>> Drawing >>> Annealing >>> Pickling >>> Flattening >>> Spring Washer >>> Single Spring Washer). After manufacturing of washer toughness test is done to find out the metallurgical soundness and surface quality of the washer. In this toughness test the washer in a vice with the split ends free and straight above the vice jaws, a 90° segment of the free end is gripped with a wrench and bent. Washers should withstand twist test through a 90° angle without signs of fracture. The present paper highlights premature failure of automotive washer which failed during twist test. From the analysis, it has been observed that crack initiated due to presence of a slag entrapment in the matrix of washer. Higher extent of deformation at center might have aggravated cracking during coiling operation.

Key words: Spring Washer; Slag Entrapment; Twist Test; Deformation

# Case Study – Metallurgical Investigation of different causes of surface defect led to wire breakage during production

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## Abstract

The stress during wire drawing can lead to a particular type of internal mechanical damage, which is commonly termed as 'Centre Bursting'. Internal defect like Central bursting cause serious problem during final stage of drawing, because it is impossible to detect by means of a simple surface inspection during production and from these defect region crack initiate and resulting in failure during production. Since the occurrence of these kinds of defects is undesirable in industrial practice, it is important to predict the conditions, and by using this prediction it may be possible to monitor process conditions and to adjust the process to produce defect free products. Failure of steel wires during production due to breakage is a multifaceted phenomenon; wire breakages due to centre busting may be induced by improper input wire rod quality in terms of microstructure and cleanliness, inappropriate combinations of semi-die angle and/or lubrication break down on the wire surface. Thus metallurgical investigation of failed wire samples is therefore essential for pin down the genesis of failure. In this paper, a comprehensive investigation of three broken steel wires of different grades which cracked during production was investigated. Microstructural investigation of the broken wire samples revealed that failure of two wires caused by formation of hard and brittle phase (Bainite and Martensite) shows in Fig 1a and 1b on the wire samples. In the other case the failures of wire sample were attributed due to improper combination of semi die angle and reduction during wire drawing process.

Key words: Centre Bursting, Bainite, Martensite, Semi-Die angle.

# Addressing Weld Porosity Defects in Non-Oriented Electrical Steel 65C1000 at the Customer End

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**Abstract:**

Cold rolled non-oriented electrical steel grade 65C1000 is used for manufacturing core laminations for rotating machines, such as windmill generators. This material, supplied with a C5 class weldable, thin insulation coating, undergoes several processes at the customer site, including lamination punching, stacking, welding, drilling, painting, quality inspection, and dispatch. Welding is performed along the edge in the groove of core using an automatic MIG welding machine. During mass production, weld porosity defects were identified in some lamination stacks, causing non-conformity, production delays, and customer dissatisfaction.
To address this issue, a trial focusing on optimization of welding parameters at the customer site was conducted. Initial trials with varying welding parameters such as speed, current, voltage, Argon flow, and electrode gap but failed to correlate these factors with the defects. A comprehensive investigation was done by comparing good and defective coils by testing coating characteristics, which showed no significant differences. Further analysis of the annealing and coating process parameters, including coating thickness, line speed, and furnace temperature, revealed through binary logistic regression that coils with defects had marginally lower baking furnace temperatures. Validation trials with increased baking furnace temperatures resulted in defect-free performance at the customer site. This trial successfully addressed the weld porosity defects by optimizing the baking furnace temperature. The present work not only resolved the immediate issue but also enhanced the manufacturing process, ensuring long-term improvements in product quality and customer satisfaction.

**Key words** : Weld porosity defect, CRNO electrical steels, Insulation coating, Baking Temperature.

# Failure Analysis of Sprocket Mounting Bolts in an Apron Feeder used in Iron Ore Processing Plant

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## Abstract

Apron feeders or Pan Feeders are widely used in Iron Ore Processing Plants to transfer ore from surge piles or hoppers to conveyors/crushers for further processing. It is ruggedly constructed, consisting of a series of high carbon or manganese steel pans, bolted to strands of heavy-duty chain, which run on steel sprockets. The sprocket segments are mounted on a hub of the head shaft which is driven by a motor and gearbox.

This paper presents a comprehensive failure analysis of the sprocket mounting bolts in an apron feeder used in an iron ore processing plant. Apron feeders are critical in ensuring the consistent and controlled feed of bulk materials to crushers and conveyors. The failure of sprocket mounting bolts can lead to significant downtime and maintenance costs.

Investigation done for the root causes of the sprocket mounting bolt failures through visual inspection, material analysis, microscopic observation, and fractographic analysis. Visual observation of bolts revealed mechanical damage marks and plastic deformation towards the fracture end of shank portion. The results indicate that the primary causes of failure include improper installation, improper inspection, material defects, and cyclic loading conditions leading to fatigue. Fractography revealed presence of ratchet marks on the edge of the sample. Striation marks were not observed.

Recommendations are provided to address these issues, including improved installation practices, enhanced material selection, and regular maintenance schedules to prevent recurrence and enhance the reliability of apron feeders.

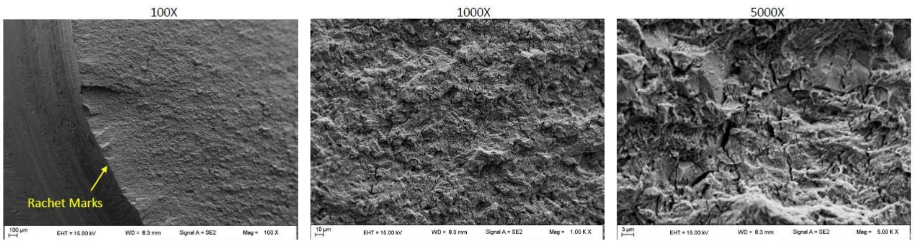


Fig. 1: Fractography of broken bolt samples

**Key words**: Apron Feeder Sprocket mounting bolts . Root Cause Failure Analysis . Material Analysis . Fractography

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Lehner,,Stanislav Seitl, Zdeněk Kala, Vlastimil Krejsa MATEC web of conferences, 2020

# Failure Analysis of Finishing Mill Work Roll Cooling Hose Pipe at Hot Strip Mill in an Integrated Steel Plant

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## Abstract

The finishing mill in a hot strip mill is where steel is given its final shape and size. To withstand the intense heat and pressure involved, work rolls require constant cooling. Hose pipes deliver water to these rolls to prevent overheating, ensuring the steel produced is of high quality without any defect and consistent dimensions. Effective cooling is crucial for maintaining roll integrity, preventing damage, and optimizing mill efficiency.

The failure analysis of Stainless Steel (SS) hose pipes used in the cooling system of finishing mill work rolls at a hot strip mill in an integrated steel plant highlights critical insights into material performance and operational challenges. Stainless steel corrugated hoses are integral to spraying water on the working rolls in the hot strip mill, ensuring the rolls remain cool and functional during operation. The specific incident of failure occurred in the F#7 stand of the finishing mill, where the top work roll cooling hose burst, necessitating an immediate shutdown for replacement. In the analysed case, the failure of the SS hose was attributed to several factors. The hose showed no prior signs of damage, but post-failure examination revealed a flattened section, damaged braiding, and a thinned area with pitting and fractures. The dust material trapped between the hose and wire braiding was found to have high sulphur content, which likely reacted with steam to create an acidic environment, leading to corrosion. The standard SS304 stainless steel used was deemed inadequate for this application, with a recommendation to switch to a more corrosion-resistant grade like SS316L. The investigation identified that fume dust trapped between the hose and the wire braiding restricted movement and added stress, exacerbating the corrosion process. The failure was classified due to material defects, improper design, and environmental factors. The hoses' material should ideally match the ISO 10380 standards, with AISI grades like SS310 or SS321 being more appropriate for high corrosion environments. To prevent future failures, it was recommended

to replace existing hoses with more corrosion-resistant materials, implement protective measures to reduce dust entrapment, and ensure regular inspections for wear and corrosion. Specific preventive measures included cleaning the hose with high-pressure water jets every

two months and developing a Quality Assurance Plan (QAP) for SS corrugated hoses.

Fig: Visual image of the failed hose

Keywords: Hose pipe, Cooling, Finishing mill, Stainless Steel, Bursting, Fumes, Dust

# Failure Modes, Mechanisms and Causes of Shafts Breakdown in Steel Plant

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## Abstract

Shafts are critical components in mechanical equipment, essential for supporting rotating devices and transmitting motion, torque, or bending moments. Their quality and performance are vital for the normal and safe operation of equipment. Shaft failures can significantly impact plant operations, leading to costly downtime and maintenance. Conducting a comprehensive failure analysis is crucial for ensuring safe operations and preventing future accidents in mechanical systems. This study reviews failure analysis cases of shafts reported over the past ten years at JSW Steel Ltd., Dolvi works.

It summarizes typical failure modes, including fracture, corrosion, wear, and deformation. Fatigue fracture is identified as the predominant failure mechanism, primarily due to the cyclic loads experienced by shafts under normal working conditions. Detailed descriptions of fatigue failure characteristics, environmental factors, wear fatigue, and the causes of fatigue failure are provided. Notches, which can be intentional (like keyways and grooves) or unintentional (such as scratches, dent or wear), create localized areas of increased stress. These stress concentrations significantly reduce the fatigue strength of the shaft by promoting crack initiation and propagation under cyclic loading conditions (Figure 1a).

Shafts in industrial machinery are frequently weld repaired rather than replaced to avoid unplanned shutdowns (Figure 1b). However, these repairs often lead to rapid or immediate shaft failure once the machinery resumes service, even if the weld are of high quality. Shaft repairs are not recommended by the original equipment manufacturer as the meticulous engineering of the initial design may not be considered during repairs. This paper critically examines the failure analysis concerns associated with weld-repaired steel shafts and provides an overview of repair methods along with several case studies of failures.

By identifying failure modes and causes, effective measures can be implemented to extend shaft service life and mitigate potential safety risks. The findings of this study offer valuable insights for plant engineers and maintenance professionals, contributing to enhanced operational efficiency and reduced equipment failures in steel plants.

**Key Words:** Shaft, Failure; Fatigue Fracture; Failure Prevention; Repair Welding

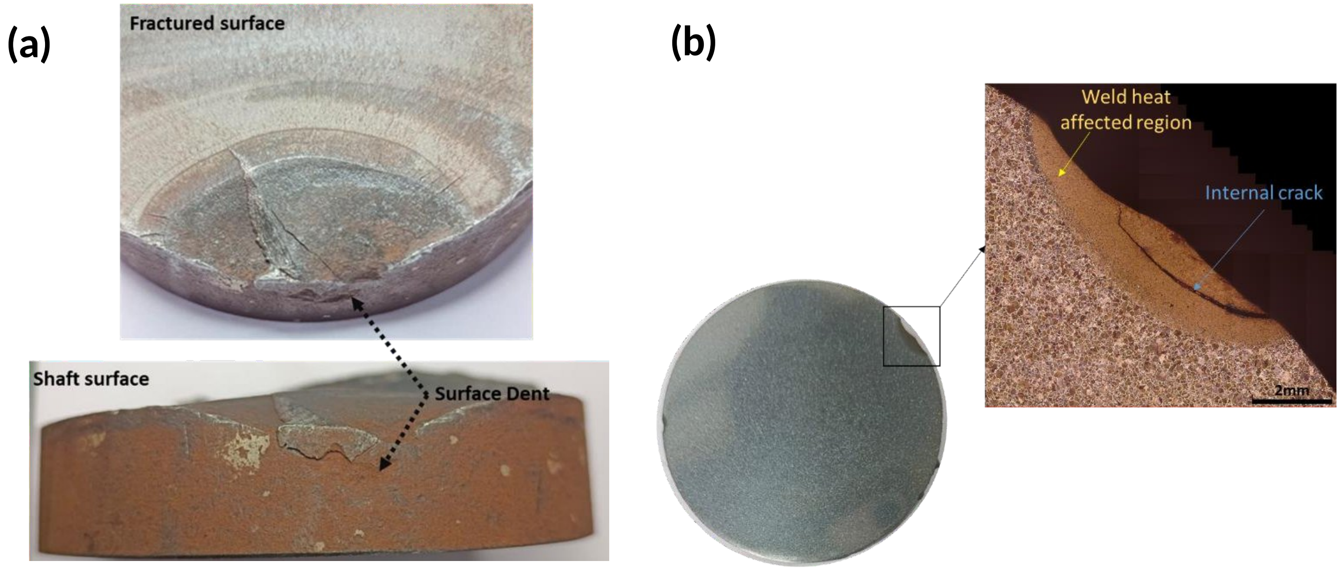


Figure 1: Typical fatigue failure in pulley shaft (a) due to notches and (b) due to repair welding.

# Metallurgical investigation into the causes of premature failure of steel tubes during production.

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## Abstract

The quality of finished steel products is often compromised by the presence of 'surface' defects such as slivers, cracks, and laps and/or 'internal' defects like porosity, inclusions, and segregation. Defects in finished steel products may arise from poor steel quality (high non-metallic inclusion content) at steel making stages or may be caused during subsequent downstream operations such as casting, reheating, hot or cold rolling. As a kind of ultra-deep-drawing steels, the interstitial free (IF) steel is widely used in the automobile and household appliances. To avoid the cracking under deep-drawing IF steel sheets must free from surface crack and faint-sliver defect. Such defects may remain unobserved in transitional stages and ultimately reveal in the finished product during final inspection. The present paper highlights premature failure of steel tubes which failed during production. Visual observation revealed blackish patch with intermittent chip-off, oriented along rolling direction. Cross sectional micro revealed sub surface crack opened from both ends up to the depth of ~466µm associated with scale at interface inside defect. Etched micro revealed defect microstructure is similar to base metal also mixed grained structure (coarse grains along with fine grains) found at defect location as compared to base metal.

Key words: Tube; Blackish Patch; Scale; Fine Grains

# Breakage of Spring Steel during Manufacturing: A Metallurgical Investigation

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## Abstract

Spring steel is a name given to a wide range of steels used in the manufacture of springs, prominently in automotive and industrial suspension applications. High carbon of HC82BCr grade steel is drawn in the range of 4.0 mm to 3.0 mm as per customer's requirement for production of spring mainly in automobile components. This spring steel grade is produced from continuous cast billet of size 150 mm x 150 mm and then hot rolled into the size of 5.5 mm diameter wire rod. Quality aspects of these spring are significant as any inherent abnormality in the material could lead to unwanted productivity losses or quality claims or sometimes serious safety issues. In this present study, spring samples broken during coiling stage were collected from plants for understanding their quality aspect and potential causes of breakage during production. Detailed microstructural investigation revealed that the root cause of breakage of the spring is related to the segregation of Phosphorous and Chromium in the billet which leads to the formation of martensite (brittle and less ductile) in wire rod during rolling process. This volume change due to formation of martensite increases the stress level at the interface of pearlite and martensite. During wire drawing, this increased stress level causes formation of internal crack in subsequent passes causing breakage during spring formation.

Key words: Spring steel; productivity; segregation; breakage; martensite.

# Stress Analysis and Fatigue Life Prediction of Leaf Springs in Heavy-Duty Vehicles

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## Abstract

Failure analysis of springs is a critical area of research in mechanical engineering, particularly in applications where springs are subjected to high stress and cyclic loading. Understanding the mechanisms and causes of spring failure is essential for improving the design, material selection, and manufacturing processes to enhance the reliability and performance of springs in various applications. Helical and leaf springs are modelled in software and various load conditions are applied to test the springs in fatigue, buckling and other failures. Fatigue life shows critical locations at the edges of the leaves and near bolt holes. S-N Curve is plotted to show the expected fatigue life of the leaf spring under different stress levels. Experimental fatigue tests show the actual life of the spring under controlled cyclic loading, which can be compared to the predicted fatigue life from the S-N curve. A Design Failure Modes and Effects Analysis (DFMEA) and process FMEA is used to identify potential failure modes in a spring design and manufacturing process to assess their impact, causes, and controls. More than 20 failure modes were identified, and corrective measures suggested to overcome them. These results provide valuable insights for engineers to refine the design, material selection, and manufacturing processes of leaf springs to ensure they meet the required performance standards and have an adequate lifespan. Use of smart materials like SMA (Shape memory alloy) and additive manufacturing methods potentially increases the lifespan of the spring. Research in this area continues to evolve, with ongoing studies focusing on understanding complex failure mechanisms under various conditions and developing new materials and designs to mitigate these failures.

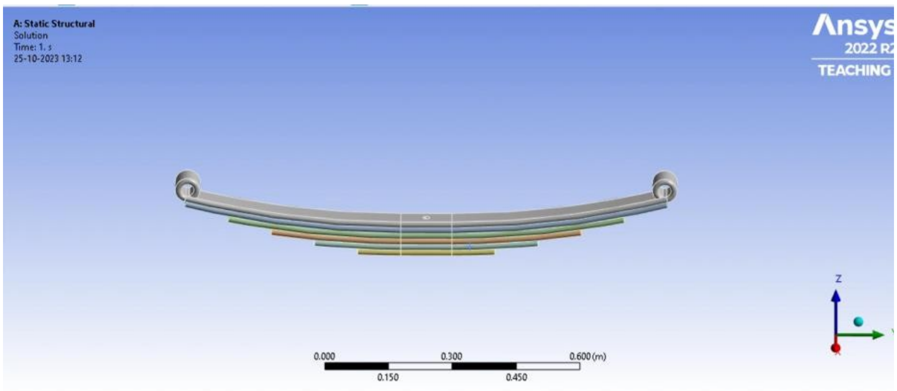


Figure 1: Leaf spring model and analysis (Author's Work)

**Key words** : Leaf Spring, Fatigue failure, S-N Curve, Smart materials, Failure Mode and Effect

# Fabrication, microstructure and mechanical properties of Kiln Steel

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## Abstract

To explore the industrial application of kiln steel in the production lines of cement manufacturing industries, two different grades, named A and B, were examined. Detailed microstructural investigations were conducted using optical microscopy, Electron Back Scattered Diffraction (EBSD), and Field Emission Scanning Electron Microscopy (FE- SEM). The phase diagrams for grades A and B were plotted using ThermoCalc software. Two methods were used to estimate the material's fracture allowable: (1) fracture toughness determination (FTD) and (2) fatigue crack growth rate (FCG), which can generate the entire regions of the da/dN curve. The impact of heat treatment on tailoring the microstructure was studied, revealing significant improvements: hardness increased by 129.18%, tensile strength by 303.72%, fracture toughness improvement enhanced the fatigue cycle by 656.55%, and the fatigue threshold improved by 47.12%. The maximum fracture toughness reached 613.50 KJ/m² after modifications, compared to a minimum of

395.23 KJ/m² in the initial samples. The present phases of ferrite, cementite, and graphite, along with the pearlite colonies in the microstructure, governed the improved properties of kiln steel. Considering all these factors, the crack propagation mechanism for kiln steel was proposed in this study.

Keywords: Kiln steel, Electron Backscatter Diffraction, Fatigue Crack growth rate (FCGR) and J(1c)

# Effect of thermomechanical processing on Elastic plastic (J1c) fracture toughness of Al- Mg-Zn alloy

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## Abstract

This study investigates the impact of thermomechanical processing route on the microstructural evolution, and mechanical properties (tensile strength, hardness and elastic plastic (J1c) fracture toughness) of the 7075-aluminum alloy. As received 7075 Al Alloy underwent for the solution heat treatment (SHT) followed by artificial aging and cold rolling (CR) process, respectively. Generally, it was observed that cold rolling of 7075 Al alloy is very challenging, but in this work 90 % cold rolling successfully achieved by optimizing the thermo-mechanical process. The novel heat treatment process for achieving the 90% cold rolling reduction as follow: firstly, SHT was performed at 470°C for 8 hours(h), there after aging at 140°C for 21 h was performed. Characterization techniques like X-ray diffraction (XRD), optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM) was employed to assess the microstructure and phase constituents. Elastic plastic (J1c) fracture toughness was studied well on SHT, peak aged and rolled sample. Additionally, Vickers hardness and tensile test were performed. Aging and Cold rolling treatment effectively enhanced tensile strength and hardness ascribed to formation of fine rod shape precipitates of η''($Mg_2Zn_3$) and formation of sub grains with localized strain accumulation, respectively. Split diffraction spots with satellite pattern in long range ordering has also observed in selected area electron diffraction (SAED) pattern of η'' attributable to stacking faults and periodic arrangement of precipitates, respectively, as a consequence of this 90% cold rolling of 7075 Al alloy was accomplished. The maximum Vickers hardness, Tensile strength and Elastic plastic (J1c) fracture toughness values were achieved after SHT (470°C for 8 h), peak aged (PA) (140°C for 21 h) and 90% cold rolling are 226 HV, 526 MPa and 344.54 kJ/m$^2$, respectively.

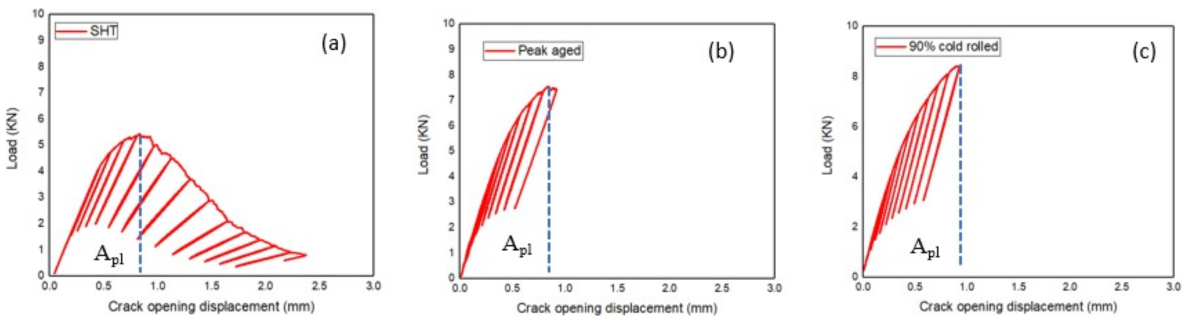


Fig. 1 Load vs displacement diagram of (a) SHT, (b) Peak aged, (c) Peak aged and 90% cold rolled samples (SHT+PA+90% CR)

Key words: Thermomechanical processing, cold rolling, Elastic plastic ($J_{1c}$) fracture toughness

# Effect of thermomechanical processing on microstructural and mechanical properties of 2519AA

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## Abstract

This abstract provides an overview of our research study on the effect of thermomechanical techniques, employing various mathematical modelling and simulation processes, on the mechanical behavior of 2519 aluminium alloy. 2519 aluminium alloy is known for its exceptional strength-to-weight ratio and high resistance to stress corrosion cracking. In this study, we investigate the impact of thermomechanical techniques on enhancing the mechanical properties and performance of 2519 alloy. Our research employs to analyze the thermomechanical behavior of the alloy under various processing conditions. Through a combination of experimental data , we investigate the effect of parameters such as deformation temperature, strain rate, and cooling rate on the microstructure and mechanical properties of the alloy. Furthermore, we explore the influence of thermomechanical processes, including rolling, heat treatment, and quenching, on the resulting microstructure and mechanical behavior of 2519 alloy. The approach allow us to predict and optimize the processing parameters to achieve desired mechanical properties, such as improved strength, ductility, and fatigue resistance. Through experimental validation, including tensile testing, hardness measurements, and micro structural characterization techniques such as optical microscopy and electron microscopy, we assess the accuracy and reliability in predicting the response of the alloy to thermomechanical treatments.

Furthermore Failure analysis of all the fractured sample is done through FESEM and analysis is done to evaluate what kind of fracture morphologies is there and the effect of secondary phase particles and microstructure is also done.

The findings from this research provide valuable insights into the relationship between processing parameters, microstructure evolution, and mechanical properties of 2519 aluminium alloy and also the kind of failure is analyzed.

By presenting our research at the IIM-ATM 2024 conference, we aim to engage with researchers, professionals, and academicians in the field of advanced materials. We anticipate that our findings will contribute to discussions on the advancement of thermomechanical techniques for enhancing the mechanical behavior and performance of 2519 aluminium alloy in various industrial applications.

**Keywords**: Thermomechanical techniques, 2519 aluminium alloy, mechanical behavior, microstructure evolution, failure analysis.

# Effect of Aging Temperatures on Plastic flow behaviour and Impact Toughness of Nickel Free High Nitrogen Austenitic Stainless Steels

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**Abstract**

In the present study, tensile properties, plastic flow behavior and impact toughness of Nickel free High Nitrogen Austenitic Stainless Steels (NFHNSS) were analyzed under solution annealed and aged at 700º C, 800º ℃ and 900º C for 14 hours using tensile tests and TEM. Plastic flow behaviour is analyzed using Holloman and Ludwigson flow equations. The samples in solution annealed and aged conditions exhibits flow transition behaviour. Ludwigson flow equation produces best fit for flow transition behaviour as eviedent from the highest value of the square of co-relation coefficient $R^2$,of the fit. NFHNSS samples have dislocation network, planar arrangement of dislocations nearer to Grain Boundaries (GB) under solution annealing and aged conditions respectively. Plastic deformation of NFHNSS occurs by a combination of planar glide and twinning. Formation of chromium nitride ($Cr_2N$) Decrease the Cr and N in austenite matrix significantly increase the stacking fault energy of the matrix by increasing aging temperature. The impact energy value of solution annealed condition is significantly higher in solution annealed condition than aged condition. Impact energy values are decreased with increasing aging temperature. Precipitation, growth and morphology of $Cr_2N$ at the GBs can predominantly reduce the impact energy values of NFHNSS. Presence of larger precipitates readily pull out from GB easily than smaller precipitates at low temperatures.

**Keywords**: High Nitrogen austenitic Stainless Steels, Chromium nitride, Plastic flow behaviour, Impact toughness, TEM.

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# Failure Analysis of Components in Power Plant-A Case Study

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**Abstract**

Engineering components fail because of a numbers of reasons like wrong selection of materials, improper designing, manufacturing defects and interaction with the environments. Failure analysis aims at investigating the genesis of failure of engineering components. It follows a systematic investigations of failed parts, starting from background information to finally, report writing and final recommendation. Failure analysis is an important step for improving the quality of product and also to minimize the root cause of failure by following proper precautions. Failure of components in power plant might cause accident to significant downtime, costly repairs, and potential safety hazards. In the present contribution, failure analysis of components collected from Budge Budge power station will be presented. The failed components were Superheater front hanger tube sample of Unit No.3 made of mild carbon steel of SA 210 Gr. C. The sample contained a "Fish Mouth" rupture. Extensive swelling and deformation were observed at the area adjacent to the rupture and longitudinal deep external wearing mark observed. Findings indicate that the tube had failed due to rapid or short-term overheating. It is pointed out that rupture caused by rapid overheating shows an obvious reduction in tube wall thickness due to yielding of tube wall adjacent to the rupture, often leading to an almost 'knife-edge' at the fracture surface.

Keywords: Systematic Investigations, Extensive Swelling, Rapid Overheating

# Comprehensive Failure Analysis of Skirt Hoses in Steel Industrial Applications

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## Abstract

In the steelmaking industry, Basic Oxygen Furnaces (BOFs) play a crucial role in converting molten iron into steel. The skirt hose in the converter is vital for directing off-gases toward the gas cleaning system. The skirt hose, or skirt, is typically part of the hood assembly that captures the LD gas emitted during the oxygen-blowing process. The efficient functioning of the skirt hose ensures that off-gases are effectively collected and treated, minimizing emissions and improving environmental performance. However, frequent failures of skirt hoses can disrupt production, leading to significant downtime and financial impacts.

This study focuses on the systematic analysis of skirt hose failures in a steelmaking shop. The investigation encompasses theoretical assessments and practical examinations conducted on-site to identify the root causes of these failures. Through the utilization of advanced analytical techniques such as metallurgical analysis, stress analysis, and failure mode and effect analysis (FMEA), the study aims to provide insights into the underlying factors contributing to skirt hose failures.

Key findings from the analysis include the identification of common failure modes such as higher or sudden repetitive tensile forces, operation beyond permissive limits, material degradation due to high-temperature exposure, mechanical wear from operational stresses, and structural weaknesses exacerbated by environmental factors. Furthermore, the study explores potential improvements in material selection, design modifications, and maintenance practices to enhance the reliability and longevity of skirt hoses in BOF operations.

Ultimately, this research contributes to the broader understanding of practical recommendations for mitigating skirt hose failures. By implementing these insights, steelmaking facilities can improve overall equipment efficiency and reduce downtime.

**Keywords:** Basic Oxygen Furnace (BOF), Skirt Hose, Failure Analysis, Steelmaking, Metallurgical Processes

# Unraveling the Impact: Analysis of RH Vacuum Failure and Its Consequence

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## Abstract

The RH (Ruhrstahl Heraeus) vacuum degassing process plays a critical role in modern steelmaking, ensuring the production of high-quality steels by removing impurities such as hydrogen, nitrogen, carbon, and oxygen. However, vacuum failures can significantly compromise the efficiency of this process, leading to suboptimal steel quality and increased operational costs. This analysis utilizes a multi-faceted approach, combining field data from industrial RH units with advanced diagnostic techniques such as pressure decay tests and infrared thermography. The study focuses on identifying the root causes of vacuum failures, understanding their impact on the degassing process, and proposing effective mitigation strategies.

Key findings indicate that vacuum failures often stem from a combination of equipment malfunctions, such as steam injection degradation and valve failures, and system integrity issues, including seal wear and unexpected leaks. These failures can result in insufficient vacuum levels, leading to incomplete degassing and higher impurity levels in the final product. The study also explores the economic repercussions of vacuum failures, including increased energy consumption, extended processing times, and potential downtime for repairs and maintenance.

By examining case studies and empirical data, the paper highlights the importance of regular maintenance and monitoring to prevent vacuum failures. It suggests implementing a predictive maintenance regime, supported by real-time monitoring systems, to detect and address potential issues before they lead to significant failures. Additionally, the research advocates for the adoption of improved materials and technologies to enhance the durability and reliability of vacuum system components.

In conclusion, the analysis provides a detailed understanding of the causes and consequences of vacuum failures in RH degassing processes. The proposed strategies aim to enhance system reliability, reduce operational costs, and ensure the consistent production of high-quality steel, thereby offering valuable insights for industry practitioners and researchers alike.

**Keywords** : Basic Oxygen Furnace (BOF), Ruhrstahl Heraeus, Failure Analysis, Vacuum

failures, Metallurgical Processes

# Failure analysis of Spring Steel Anvil plate of a Hydraulic press bending machin

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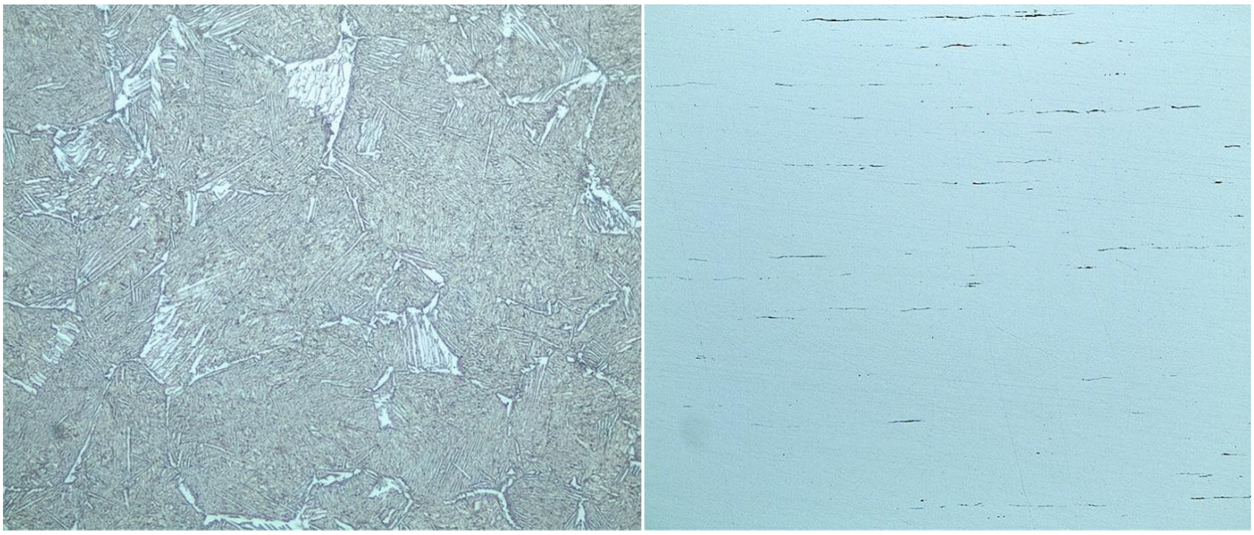
## Abstract

In industry, engineering machinery parts and components such as anvil plates are typically made from spring steels because they are well tailored with specific unique properties such as high strength, elasticity, resilience with appreciable levels of toughness and ductility in hardened and tempered conditions. This research activity involves the investigation of an unexpected and unpleasant massive failure of an anvil plate installed in a hydraulic press bending machine in service, i.e., while performing a bend test of an HSLA steel. So, in order to explore all possible responsible causes for the event failure, the spalled part of the anvil plate was collected from the event site and analysed comprehensively by adopting macroscopic analysis methods such as visual inspection, hardness testing, chemical analysis and Microscopic analysis such as optical microscopy and scanning electron microscopy (SEM) and XRD analysis of the spalled part were also carried out. Finally, the consolidated investigation results revealed that the presence of microstructural heterogeneity such as inhomogeneous distribution of soft and hard phases in the case, core regions of the plate, as well as the presence of inclusions with undesirable morphology such as sharp corners and its hard-brittle characteristics in the anvil plate were the major responsible causes of its failure in service.



(a) Magnification: 500x (b) Magnification: 100x

Figure 1: An Optical microscopic overview of failed anvil plate. (a) it shows the presence of undesirable soft phase at grain boundaries & hard phases at triple junction locations in the matrix of tempered martensitic structure. (b) it shows the presence of highly elongated long sulphide inclusions with sharp corners.

Key words: Anvil plate, Spring Steels, Inclusion, Tempered martensite

# A review on laser shock peening to attenuate chloride stress corrosion cracking

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## Abstract

Chloride Stress corrosion cracking (CSCC) arises from a conglomerate of high chloride corrosive environment, vulnerable material and sustained tensile stress, posing a significant integrity risk to valuable assets within seawater applications or downstream oil and gas processing refineries including pipelines with their fittings. Given the frequent utilization of austenitic stainless steel in the distribution systems for such applications, SCC emerges as a pressing concern for the industry.

National Association of Corrosion Engineers (NACE) provides guidance on which corrosion resistant alloys and materials should be used for preventing stress corrosion cracking. However, NACE guidelines limit the application of SS300 series material for chloride environments greater than 50 mg/L at temperatures exceeding 60°C.

This paper aims to investigate and propose novel approaches for mitigating CSCC in oil and gas refineries, notably through Laser Shock Peening (LSP). The research assesses the impact of various laser parameters—such as intensity, wavelength, frequency, and pulse duration—on SCC, and examines how resulting residual compressive stresses at different depths influence material performance in a high chloride environment.

In conclusion, the review study suggests surface engineering utilizing lasers to combat CSCC for austenitic stainless steel. By elucidating the application of laser shocks to induce compressive stress at different depths, the aim is to enhance the sustainability of austenitic stainless-steel materials in such environments.

Keywords: Stress corrosion cracking, Laser shock peening, Pipeline corrosion, Corrosion management, Residual stress

# Failure Analysis of Crop Shear Tie Rod at Hot Strip Mill

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## Abstract

Crop shear tie rod is a critical component in the unit of hot strip mill. It is a high strength metal bar that connects and stabilizes the shear moving part. Its primary function in rolling process is to cut head & tail end of the incoming hot rolled transfer bar. The tie rod is a structural element that provide stability and support to the crop shear. Due to the force exerted during the shearing process. It prevents equipment damage by absorbing vibrations and stresses from the force exerted during the shearing process. A reliable crop shear tie rod is essential for efficient and safe mill operations, contributing to overall production quality and mill uptime.

One such tie rod failed in service within three months of application. Metallurgical analysis of the failed crop shear Tie rod was carried out. Tie rod failed from the thread location and fracture surface revealed a very small fatigue zone (~5%). Rest portion failed in brittle mode.
Surface microstructure of tie rod revealed mixture of martensite and bainite phase. Core microstructure of tie rod revealed mixture of ferrite and bainite. Severe sulphide inclusion was observed in the component. Presence of inclusions impart brittleness in the component and inhomogeneous microstructure indicated improper heat treatment of the component with a reduction in hardness.
The paper details how the failure was investigated metallurgically, and the root cause was found; along with recommendations for preventing such failures.

Fig: Failed tie Rod of Crop Shear Key words: Crop Shear Tie Rod, Brittle Fracture

# Metallurgical analysis of corroded AA 7075 valve body

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## Abstract

AA7075 is a high strength aluminium alloy (Al-6Zn-3Mg-2Cu) extensively used in highly stressed structural applications owing to its excellent properties such as high tensile strength, excellent formability and satisfactory corrosion resistance through suitable heat treatments. During visual inspection of valves, multiple defects with varying size and change in the surface appearance as indicated by dot marks and black shaded lines in Fig.1 were observed on the body of both fuel and oxidizer. Detailed metallurgical analysis was carried out on the valve body to understand the root cause of damage. The suspected cause of these many marks can be attributed to valve body material issue, mechanical damage or corrosion due to anodization degradation. The paper investigates the corrosion behaviour of AA7075 due to the presence of Al-Cu-Fe inter-metallic particles containing Cu, which are known to act as initiation sites for pitting corrosion. These particles are formed during alloy solidification and not appreciably dissolved during subsequent thermo-mechanical processing. As these particles are rich in alloying elements, their electrochemical behaviour is often significantly different than the surrounding matrix phase. However, the susceptibility to pitting corrosion is a significant drawback attributed to the presence of Cu in the composition. The present study is an attempt to understand the reason for such corrosion spots and suggest remedial measures to avoid their recurrence.

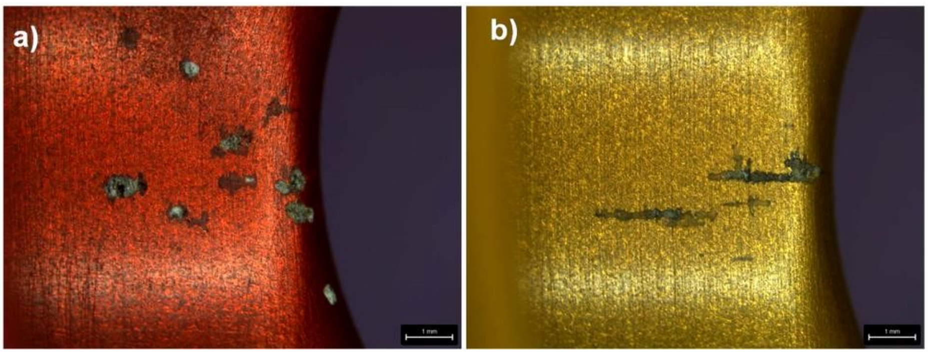


Fig. 1: Stereomicroscopic images of valve bodies at the defect area (a) Fuel (Red) (b) Oxidizer (Yellow)

**Key words**: AA 7075, pitting corrosion, intermetallic particles, metallurgical analysis

# Failure Analysis of Segment Roll of SMS Slab Caster

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## Abstract

Slab Caster in a Steel Melting Shop (SMS) has a vital role in continuous casting process to convert molten steel into solid slabs. These slabs are the primary raw material for rolling mills, where they are further processed into finished steel products like sheets, plates, and coils. The slab caster ensures the efficient and continuous production of slabs by solidifying the liquid steel as it moves through a series of molds, cooling zones, and rollers. Segment rolls are a vital component of the slab caster, responsible for supporting and guiding the solidifying steel slab as it moves through the caster. The drive roll, a type of segment roll, provides the necessary driving force to pull the strand (the solidifying steel) through the caster. This movement ensures uniform cooling and solidification of the steel, preventing defects and ensuring the quality of the final slab. During operation, segment rolls are subjected to the following loading and atmospheric conditions:

Rotational Forces: The drive roll rotates to move the strand, and this motion exerts torsional stress on the roll shaft.

Bending Forces: As the steel strand moves through the caster, it exerts a bending force on the segment rolls due to its weight and the resistance to movement.

Thermal Stresses: The high temperature of the steel and the cooling processes induce thermal stresses in the segment rolls.

Corrosive Environment: The presence of steam, heat, and possibly other corrosive elements in the caster environment can lead to material degradation over time.

These forces, particularly the combination of rotational bending and thermal stresses, can lead to fatigue in the segment rolls, making proper material selection and heat treatment are essential for their longevity and performance.

The failed segment roll of an integrated steel plant under investigation, was composed of 24CrMo5 steel and had experienced failure after 8,297 heats, leading to a three-hour shutdown of the casting machine. The failure analysis revealed that the drive roll shaft failed due to rotating bending fatigue, evidenced by beach marks on the fracture surface and rachet marks near the fracture zone. The failure initiated at the cross-section of the fillet radius, a common stress concentration points in rotating components. The metallurgical analysis indicated that the roll was supplied in a normalized condition instead of the specified quenched and tempered condition. This deviation from the required heat treatment process significantly reduced the mechanical strength and fatigue resistance of the component, leading to premature failure. In conclusion, the primary cause for the failure of drive segment roll was the improper heat treatment, which resulted in a microstructure with inadequate mechanical properties for the demanding operating conditions. To prevent such failures in the future, it is recommended that all critical components must undergo specified heat treatment

process, and regular inspections are to be conducted to detect early signs of fatigue and stress-related damage.

**Keywords**: Rotating Bending Fatigue, Segment Roll, Caster, Heat-treatment, Thermal Stresses

# Reduction in Slow Cooling material by Eliminating the Hydrogen Flakes in alloy Steels.

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## Abstract

In the automotive industry the material should be free from any type of internal crack, like hydrogen flakes. The mechanical properties will be reduced, and components will be failed, if hydrogen flakes crack present in the steel. The ability of a steel to get free from hydrogen flakes are required to comply with Standards or requirements which are critical to the end users and OEM's. The OEM's have set zero deviation regarding for hydrogen flakes.
Hydrogen Flakes contribute more to ultrasonic defects in medium carbon, molybdenum steel such as 45C8, EN353. As hydrogen tend to escape during cooling due to its smaller atomic radius and high diffusivity in the solid phase. Experiments were conducted to reduce hydrogen flakes by modification of chemistry and steel making process. The paper discusses various metallurgical changes, which facilitated the elimination of hydrogen in 45C8, EN353 grade steel.

The paper also discusses a few case studies of meeting of stringiest through innovative ideas and chemistry design.

Keywords: Hydrogen Flakes, medium carbon, molybdenum steel, Microstructure, Chemistry design

**Dynamic Modelling and Analysis of Roller-Pin Assembly of Bucket Wheel Excavator**

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## Abstract

The study focuses on analysing structural failures under dynamic loading conditions for roller and pin assembly of Bucket Wheel Excavator (BWE) used in opencast coal mines. BWEs operate in severe conditions, where variable dynamic loads significantly affect the performance and reliability of the roller and pin assemblies. To address these challenges, Finite Element Analysis (FEA) is employed to identify the critical regions and potential failure points of roller-pin assembly under diverse loading scenarios. In this investigation, the dynamic behavior of the BWE roller-pin assembly is numerically analysed under a maximum pressure load of 200 MPa and a velocity of 0.75 m/s, which are considered optimal operating conditions for BWEs based on previous research of the present research group. The dynamic load applied in the FE analysis is modelled as a sinusoidal variation to simulate the realistic dynamic loading conditions encountered by roller-pin assembly during operation of BWEs.

In this study, the stress states of the roller-pin assembly are calculated using the Finite Element (FE) method, at the onset of dynamic loading. The key outcomes of the analysis include the distribution of von Mises stress, maximum principal stress, and pressure across the roller and pin assembly. Additionally, the study provides a detailed investigation of the deformation behavior of the roller and pin elements. By evaluating the relationships between von Mises stress and plastic equivalent strain (PEEQ), as well as maximum principal stress and strain for both components, the study offers a comprehensive understanding of the stress-strain responses under different dynamic loading conditions. Finally, the simulation findings are validated via experimental investigations. The study reveals the critical factors contributing to the failure of roller and pin assemblies, offering valuable insights for enhancing their design and durability.

Key words : Fatigue, GS-42CrMo4V Steel, FEA, Bucket Wheel Excavators

**A Case Study on Metallurgical Investigation for Root Cause of Blast Furnace Tuyere Failure**

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## Abstract

Blast furnace tuyeres are subjected to extreme thermal and mechanical stresses, making them susceptible to various types of degradation. The investigation involved a systematic examination of failed tuyeres, focusing on the morphological, metallurgical, and operational factors contributing to the observed holes leading to water leakages. A comprehensive analysis was performed, including visual inspection, scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and metallographic examination. The results obtained in this investigation indicate a complex failure mechanism of blast furnace tuyeres consisting of two interacting stages: corrosion and localised melting of tuyeres. The corrosion is caused by the attack of aggressive chemical compounds present in the blast furnace which may be due to high pressure in the tuyere causing water vapor present in the furnace to condense on the cold tuyere surface. These condensed water vapour dissolve volatile chlorides and sulphides and form corrosive media on tuyeres. The cracks originated from the corrosive attack on the tuyere cause a significant decrease in the thermal conductivity of the copper and consequently a weak cooling of the affected area leading to localised melting on tuyeres, particularly upon contact with hot metal. Recommendations were made to mitigate these issues.

Key words: Blast furnace tuyeres, metallurgical failure analysis, corrosion, localised melting, copper.

# Failure of a High Chrome Work Roll in a Hot Strip Mill

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## Abstract:

Rolls play a vital role for achieving desired surface finishes and mechanical properties in steel products. Failure of rolls in steel mills cause substantial disruption in production and demands immediate replacement and thorough investigation to prevent recurrence.

A high chromium (HiCr) bottom work roll broke into two pieces in finishing stand 1 of a hot strip mill of an integrated steel plant. The roll breakage was investigated through analysis of the mill process parameters, visual inspection, chemical analysis and detailed microstructural examination of the samples collected from the core and shell of the failed roll. Overview of the fracture surface revealed that the roll failed in brittle mode under torsional loading condition. Microstructure of shell revealed chilled cast structure with distributed carbides.

Microstructure of core revealed presence of coarse chromium carbide network which is not desirable. Chemical analysis of core also indicated presence of Cr & Mo in excess which are strong carbide forming elements. This leads to poor impact toughness of the core. The roll failed because of the poor quality of the core. The paper explains the root causes of the premature roll failure as well as the precautionary measures to ensure minimal future disruptions.

**Keywords:** Work roll, High Chromium roll, Chromium Carbide

# Transforming Failure Analysis Procedures: From Conventional to Advanced Methods (Nanoindentation)

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## Abstract

Failure analysis is a crucial methodology for identifying the primary factors contributing to component failures, including materials defects, process flaws, and operational conditions. Traditionally, this involves various metallurgical and mechanical instruments such as optical emission spectroscopy, optical microscopy, stereo microscopy, hardness testing, scanning electron microscopy with energy dispersive spectroscopy, and X-ray diffraction etc. However, with the shift from conventional to advanced manufacturing methods for faster production, it is essential to update failure analysis techniques also to keep pace with these advancements. This presentation will focus on the failure analysis of various automotive components and demonstrate how advanced techniques, such as nanoindentation, can be applied for more effective analysis. The study aims to improve the durability and reliability of automotive components, contributing to safer and more efficient vehicle operation. The insights and recommendations provided are intended to help manufacturers analyze component failures more efficiently and promptly.

Key words: Failure analysis; Energy dispersive spectroscopy; X-ray diffraction; Nanoindentation; Advanced manufacturing

# Uniaxial compressive behaviour of additively manufactured H13 tool steel at slow strain rates at elevated temperature

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## Abstract

In recent years, additive manufacturing (AM) has emerged as a substitute for conventional manufacturing processes. Laser powder bed fusion (LPBF) process is an AM process to melt metal powder layer-by-layer using a laser as a fusion source. H13 tool steel has been recognized as a hot work tool steel for manufacturing hot forging dies and extrusion dies owing to its high hardness and fracture toughness. The microstructure of H13 hot work tool steel manufactured by LPBF has been evaluated in three conditions – as-printed (AP), direct tempered (DT), and quenched (Q) states. The as-printed specimen's microstructure predominantly exhibited cellular/ dendritic grains (average grain size ~700 nm). Quenching resulted in fully martensitic, and prior austenite grain boundaries (average grain size ~4 µm) were also evident. At the same time, tempered specimens showed the partial dissolution of cellular microstructure and precipitation of fine carbides. Hot compression tests were conducted in three conditions, viz. AP, DT and Q, with the loading direction parallel to build direction (z) at a slow strain rate viz.$10^{-3}$ /s at 700°C. The flow stress curve is composed of four stages: stage I (work hardening stage), stage II (transition stage), stage III (softening stage) and stage IV (steady stage). The work-hardening stage is dominated in AP and DT specimens compared to quenched specimens due to the retained austenite phase. The present study provides a basis for understanding the LPBF fabricated H13 microstructure and their deformation behaviour under high temperature and slow strain rate.

**Keywords:** H13 tool steel, Additive manufacturing, Laser powder bed fusion, Slow strain rate, Compression Test.

# Failure Analysis of Skip Hoist Drive Gearbox

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## Abstract:

Gearboxes are critical components in any production environment. The gearbox and shaft work together as a system to ensure smooth and efficient operation of plant machinery. Sudden failure of a gearbox in a production unit can have significant implications, impacting production, safety, and financial performance.

This research paper talks about failure of a skip hoist drive gearbox in a Lime Calcination Plant (LCP) kiln in an integrated steel plant. The failure occurred when a skip car full of limestone suddenly started moving downward and hit the buffer at the bottom. Upon inspection, it was found that the intermediate gear had failed.

Through visual observation, microscopic examination, and scanning electron microscopy analysis, the failure was attributed to a pre-existing crack in the gear tooth. The crack propagated under fatigue loading, ultimately resulting in brittle fracture. The chemical composition of the gear tooth and input shaft matched with EN24 grade, and the components were found to be through hardened.

The study concludes that the gear teeth failed due to fatigue caused by the pre-existing crack and the crack generated in fatigue. The findings highlight the importance of proper inspection and maintenance to prevent similar failures in the future.

**Keywords:** Gearbox, Fatigue, Crack

# Failure Analysis onLeak in 'RH-Cylinder'during Qualification testing of Main Rotor Actuator (MRA) assembly meant for use in military helicopter

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## Abstract

An oil leak was detected in RH-Cylinder of Main Rotor Actuator (MRA) assembly during its qualification test. The leak was observed in the RH-Cylinder at about 5.82 lakh Pressure Impulse cycles against a requirement of 10 lakhs cycles. RH-Cylinder experiences pressures of 0-315-0 bar during each cycle [which lasts 1 second] of the Pressure impulse testing.
RH-Cylinder was made of 15-5 PH steel of specification AMS 5659 [Condition:H1025] with ID surface hard-chrome plated.Laboratory analysis revealed that material of construction (MoC) of the RH-Cylinder met the specified requirements with respect to chemistry, hardness, microstructure and chrome-plating requirements.
RH Cylinder was subjected to Fluorescent Penetrant Inspection (FPI) to identify the exact location and extent of crack. FPI revealed presence of an indication of about 3 mm on the ID surface. No conclusive evidence could be drawn on the extent of crack on OD surface due to Laser marking identification [Fig.1a]. Based on the FPI indications on ID surface, the crack was opened up for fractographic studies.
Fractographic studies using Scanning Electron Microscope (SEM) revealed that RH-Cylinder had failed due to a Fatigue crack originating from OD surface (from identification mark 'E' as indicated in Figure 1b). The laser marking identification acted as a Stress riser resulting in this failure. The same was confirmed through Optical microscope when a depth of about 110 µm observed at other markings). However, the reason for leak/crack at mark 'E' onlywas further was analyzed and discussed in detail in this paper to arrive at the root cause of failure for crack initiation at the identification mark 'E'.

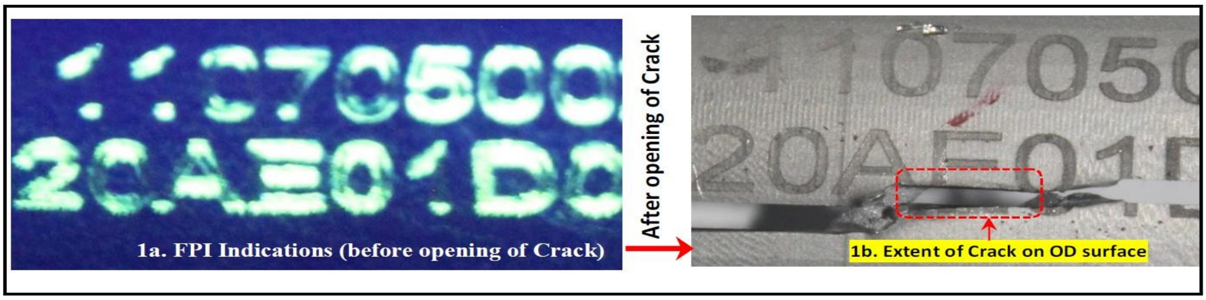


Fig. 1a & 1b: Photograph showing the extent of Crack on in line with Laser marking 'E'. key words : Pressure Impulse testing, Hard-chrome plating, FPI indications, Scanning Electron Microscope, Fatigue crack.

# Microstructural Engineering of Thin Steel Strips and Effects of Heat Treatment on Local Deformation: An Experimental and Analytical Approach

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## Abstract

The mechanical performance of high-strength steel strips is critically influenced by their microstructural constituents, which govern deformation behavior, including local and diffuse necking during tensile loading. This paper aims to investigate the effect of microstructure on necking phenomena in a cold-rolled plain C-Mn steel containing 0.5 wt.% carbon. Steel strips of 1.2 mm thickness were processed through various heat treatments to develop distinct combinations of microstructural phases. Detailed microstructural characterization, including phase fraction, grain size, and morphology, was performed to quantify the impact of the engineered microstructures. Mechanical properties such as hardness and tensile strength were measured. The correlation between microstructural constituents and the observed mechanical properties was established, leading to the identification of an optimized heat-treatment process that yields the best combination of strength and ductility. Additionally, finite element modeling (FEM) incorporating a damaged module was employed to gain insights into the role of local and diffuse necking in the deformation process contributing to the development of steel strips with improved performance for applications requiring a balance of strength and ductility.

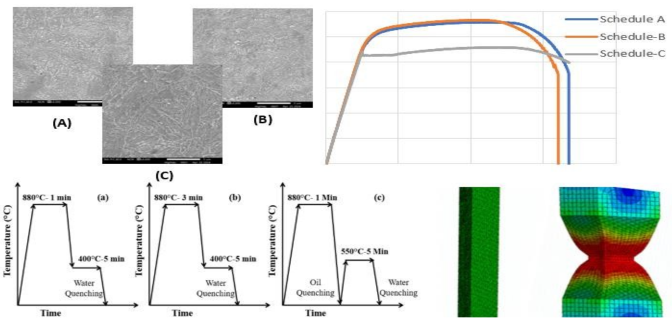


Figure 1Graphical Abstract

Keywords: Steel, Heat Treatment, Microstructure, Tensile Behaviour, Necking, Finite Element Analysis

Referencing:

Li, J., Zhang, W., & Wang, H. (2017). Influence of microstructural evolution on local and diffuse necking in steel. Acta Materialia, 126, 129-140. https://doi.org/10.1016/j.actamat.2016.12.047

Wang, H., Yang, Z., & Zhao, X. (2019). Finite element analysis of necking behavior in steel: The role of microstructure and heat treatment. Journal of Materials Science & Technology, 35(6), 1107-1115. https://doi.org/10.1016/j.jmst.2018.12.005

# Effects of annealing on microstructural and mechanical properties of (CoCrFeNi)100-xNbx eutectic high-entropy alloy

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## Abstract

Eutectic high-entropy alloys (EHEAs) are a sub-class of high-entropy alloys (HEAs), exhibiting fine lamellar microstructure of two different phases, providing an optimum combination of strength and ductility. Due to their superior physical and mechanical properties, EHEAs show great potential for application as advanced engineering materials.

In this work, three different EHEAs of nominal composition $(CoCrFeNi)_{100-x}Nb_x$ (x = 3, 11.11, and 25 at. %) were prepared by arc melting, followed by annealing at 700 $^0$C, 900 $^0$C, 1100 $^0$C temperatures, cold rolling and stress relieving annealing at 500 $^0$C. The effect of different heat treatment processes on the microstructural and mechanical properties of the EHEAs has been investigated thoroughly. The as-cast, annealed and cold-rolled EHEAs were characterized using XRD, SEM, EDS and their mechanical properties were evaluated using Ultrasonic phase spectroscopy (UPS), Vickers hardness test, compression test. The $(CoCrFeNi)_{97}Nb_3$ shows FCC microstructure with lower microhardness value of 235 HV, whereas the $(CoCrFeNi)_{75}Nb_{25}$ shows HCP-Laves microstructure with very high microhardness of 885 HV and the $(CoCrFeNi)_{88.89}Nb_{11.11}$ shows nano-lamellar eutectic microstructure consisting FCC + Laves phases with high microhardness of 572 HV in their as-cast condition. The as-cast EHEAs exhibit high values of young's modulus (E) from 204.33 GPa to 236.43 GPa, and shear modulus (G) from 78.38 GPa to 92.1 GPa. The nano-lamellar eutectic structure acts as an in-situ composite consisting soft FCC and hard Laves phase. After annealing at 700 $^0$C and 900 $^0$C temperature for 24 h, the EHEAs show good microstructural stability, although some amount of grain growth and lamellae coarsening occurs. The microhardness value decreases 5 – 15 % for the FCC and eutectic HEAs, but increases 5 – 7 % for the Laves HEA after the annealing. Whereas, the EHEAs annealed at 1100 $^0$C for 24 h have shown lamellar breakage, segregation in microstructure and reduction in mechanical properties. However, the XRD patterns or EDS results of the annealed EHEAs do not indicate any new phase formation after annealing. The uniaxial compression test results show that the FCC HEA exhibits lower compressive YS of 311 – 398 MPa with no fracture up-to 50 % deformation, whereas the eutectic HEA exhibits very high compressive YS of 1755 – 1950 MPa with 5 – 13 % deformation before and after annealing. Additionally, the microhardness value increased for the $(CoCrFeNi)_{88.89}Nb_{11.11}$ EHEA up-to 12 – 14 % after 5% and 10% cold-rolling and subsequent annealing at 500 $^0$C for 1 h, 2 h, and 5 h. The enhanced mechanical properties of the EHEAs have been correlated properly with the advanced effect of the eutectic lamellar microstructure.

Key words : High entropy alloy, eutectic, annealing, microstructure, mechanical properties.

# Design and synthesis of six-component high entropy oxides (HEO)

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## Abstract

"High entropy" ceramics (HECs) is a new class of materials based on the presence of 5 or more system components in nearly equal molar proportions such that the composition is not dominated by any one component. A single solid solution phase is often obtained. In recent years, HECs have gained great research interest owing to their improved physical and functional properties over conventional materials. Multicomponent equimolar oxide "high entropy" ceramics are developed using multiple cations in equiatomic amounts which form a single-phase solid solution. These are some of the most advanced ceramic materials with potentially attractive properties.

In the current research, a multicomponent equimolar oxide (MEO) of 6 metals (Ti, Mn, Fe, Co, Ni, Zn) was designed with the aim of obtaining a spinel solid solution. The solution combustion synthesis (SCS) technique was used for synthesising powders of this composition, which crystallised into a single-phase spinel structure. Structural characterization was performed by XRD and SEM. FTIR with far-IR wavelength was used for obtaining information about M-O bonds, and UV visible spectroscopy was used for calculating the optical bandgap. Sintering behaviour of this novel material was studied with the aim of developing targets for thin film deposition by physical vapour deposition techniques.

**Key words** : Multicomponent Equimolar Oxides, Spinel structure, XRD, FTIR.

# Effect of Ta content on microstructure, elastic properties and mechanical properties of $Ti_xTa_{2-x}NbZrMo$ refractory high entropy alloys

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## Abstract

TiZrNbTaMo, a prominent refractory high entropy alloy (RHEA), shows potential for articulating surfaces in total joint arthroplasty (TJA) owing to its excellent biocompatibility, mechanical and anticorrosive properties over traditional ceramics and CoCrMo alloys. For articulating surfaces, high hardness and stiffness are crucial to maintain excellent wear resistance. Therefore, in this study, we replaced Ti with Ta in the equiatomic TiTaNbZrMo RHEA to improve the hardness and Young's modulus. The impact of the replacement of Ti by Ta on the microstructure, elastic properties, and mechanical properties was examined through a combination of theoretical and experimental approaches. Moreover, their strengthening mechanism and deformation behavior were investigated and correlated with the electronic structure. CALPHAD modeling and experimental results indicate that the present alloys consist of two distinct BCC phases (BCC1 and BCC2) and the volume fraction of the BCC1 phase increases when Ti is replaced by Ta. Density functional theory (DFT) studies predicted that the stability of a BCC phase increases with Ta content. Additionally, with the substitution of Ta for Ti, the microstructure changes from fine to coarse dendritic structure and the segregation of Ta and Zr within the BCC1 and BCC2 phases leads to an increase in the lattice parameter. DFT calculations predicted that the elastic modulus, hardness, and strength of the RHEAs enhanced with Ta concentration which is also supported by experimental results. Further, the strengthening and deformation behavior of present RHEAs were studied by nanoindentation of molecular dynamics (MD) simulations and experiments. Results shows that during nanoindentation, when Ti is replaced by Ta the lattice distortion increases, which lowers the migration of atoms and increases the kink densities, which further hinders the dislocation nucleation and mobility. Moreover, during the retraction stage with the substitution of Ta for Ti, RHEAs underwent little relaxation in the dislocation network, smaller plastic zone, and higher density of sessile dislocations, these features explained the hardness increases with Ta content. Further, the density of states (DOS) and Crystal Orbital Hamiltonian Population (COHP) analyses revealed that the enchantment of properties with Ta concentration is due to the formation of strong directional bonds and a higher percentage of occupied bonding states. The preliminary advantage of the Ta-rich alloy over the equiatomic RHEA in mechanical properties suggests that it could be a promising candidate for articulating surfaces. Moreover, theoretical results provide new insights to improve the mechanical properties of RHEAs for articulating surfaces.

**Keywords:** TiTaNbZrMo; Density functional theory: Molecular dynamics; Elastic & mechanical properties; Dislocations

# Effect of Ti addition on strengthening and deformation mechanism of Ni-rich high entropy alloy synthesized via spark plasma sintering: An experimental and atomistic approach

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## Abstract

Due to the immense alloy designing compositional space, high entropy alloys (HEAs) exhibit unique single phase microstructure with outstanding mechanical properties such as superior strength and ductility synergy, excellent toughness and higher hardness. For the design of high performance HEAs, understanding the strengthening mechanisms and deformation behavior is crucial, which remain less explored till date. In the present study, effect of Ti microalloying on phase evolution, microstructural development, mechanical behaviors and deformation mechanism of novel Ni46-xCo20-xAl12Cr8Fe12Mo2Ti2x (x = 0, 1, 2 and 3) high entropy alloys (HEAs) synthesized via mechanical alloying and spark plasma sintering (SPS) were systematically investigated. The equilibrium phase formation by varying Ti content was predicted using Thermo-Calc software (TCHEA-4.2 database), indicates that the proposed HEAs exhibit single-phase solid solution at the sintering temperature of 1150 °C without presence of any brittle intermetallic phases, shown in Fig. 1(a). Phase analysis of the sintered HEAs envisaged the formation of face centred cubic (FCC) structured solid solution with minor amount of brittle Cr-rich and Mo-rich sigma (σ) phases along with essential L12 phase in the FCC matrix. Phase fraction of the σ phases deceases continuously with raise in Ti amount. Increasing in Ti content promotes continuous increase in number average twin boundary per grain i.e., ~2 per grain for 6 at. % Ti HEA (Ti- 06) compared to other HEAs, ascribed to decrease in generalized stacking fault energy (GSFE), as shown in Fig. 1(b), estimated by performing molecular dynamics (MD) simulations. The calculated barrier energies and twinnabilities revealed that the addition of Ti increased the tendency of dislocation glide and deformation twinning. Ti-06 HEA exhibits excellent strength-ductility trade-off, where the yield strength and compressive strength reached up to 1458 ± 8 MPa and 2011 ± 12 MPa, respectively, with an appreciable fracture strain of 26 ± 0.3 %, shown in Fig. 1(c). Further, MD simulation was employed to model the deformation mechanism of current HEAs under compressive loading. The results show formation of continuous stacking fault networks including intrinsic stacking faults, extrinsic stacking faults, deformation twins and dislocations along which plastic deformation carried-out in Ti-06 HEA. Due to activation of multiple deformation twins and stacking faults and their complex interaction contribute to the appreciable plasticity, and increased sessile stair-rod dislocation results in enhanced strength in Ti-06 HEA. This pioneering work provides further insights into the significance of SFE effect on the deformation behavior and also sheds light on designing of high-performance HEAs.

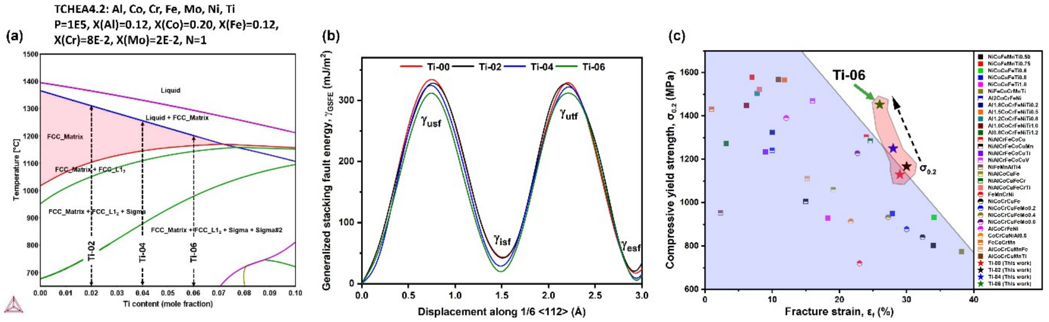


Fig. 1: (a) The pseudo binary phase diagram of the (NiCoAlCrFeMo)-Ti alloy system, (b) generalized-stacking fault energy of FCC {111} <112> slip of $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) HEAs and (c) comparison of the compressive properties of the present alloys with other HEAs

**Keywords**: High entropy alloy, Spark plasma sintering, Generalized stacking fault energy, Solid solution strengthening, Twin boundary, Molecular dynamic simulation

# Successful and Safe Blow down of BF#1 of Vizag Steel, RINL

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**Abstract**

Blowing down of BF#1 was carried out to bring down the burden level up to 1 meter above tuyeres due to shortage of raw materials. Blowing down procedure and limits of flammability of various explosive gases were thoroughly discussed well in advance. Nitrogen purging facility was incorporated through pressure probe points at different level of the furnace. Top gas temperatures were controlled by 8 top water spray points while burden level was going down. Critical composition & combination of blast furnace top gas components were monitored online and cross-checked by taking gas sample manually at uptake in every 30 minutes. Hydrogen concentration in top gas was diluted by nitrogen purging (30000-45000 nm3/hr) and kept in the explosive limit throughout the blowing down period. Blowing down rate was controlled accordingly to keep the top gas temperature ($300^0$ - $400^0$C) & $H_2$ (< 8%) within the limit. It took 20 hrs to complete the blowing down process.

Present paper illustrates the practical experiences of blow down of BF#1 at Vizag Steel, RINL in the month of May'2024.

Key words: Blast furnace, blow-down, stock level, top gas analysis & temperatures, nitrogen purging

# Improved Calcium Treatment in Steelmaking for Clean Steel Refining

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## Abstract

Treatment of liquid steel with Calcium in ladle refining process has become an important means to transform the shape, size and distribution of oxide & sulphide inclusion in steel to less harmful inclusions.

Developed almost four decades ago, continuously improved , Calcium treatment directly attributed the benefits include fluidity, smoother continuous casting by reducing nozzle blockage and improved cleanliness.

Deoxidation, desulphurisation and inclusion modification are some of the essential features in secondary steel refining through injection of calcium alloy in the form of a cored wire.

Amongst all the processes in secondary metallurgy, calcium treatment is certainly the most difficult due to its low density, low melting and boiling temperature as well as higher vapour pressure. A failure in calcium treatment may have catastrophic consequences. These problems have led to the development of special addition technique like cored wire injection.

Minex Metallurgical Company Limited, started journey almost four decades back pioneer in "Cored Wire Injection System" as well as "Cored Wire Manufacturing Technology".Minex launched first time Green CaSi injection cored wire solution for the steel & foundry industry. Minex also introduced Accurate Density Control (ADC) with PLC based weighing system to control as well as measure the density which ultimately improve the quality of wire in terms of stable density.

The focus of efficiency of Calcium treatment process is being shifted from calcium yield to percentage of globular inclusions as well as low inclusions density.

Developed different types of cored wire in addition to traditional CaSi cored wire to become example of calcium treatment. Introduction of newly developed high performance pure calcium (Camore than 98%) cored wire have enhanced the calcium recovery than that of conventional calcium based cored wire.

Indeed, according to the steelmaking process parameters (steel grades, treatment temperature, ladle size, calcium content targeted in tundish and injection conditions), their technical specifications may be adopted in order to optimise the calcium treatment as high as possible.

For the enhancement of the technical efficiency of calcium treatment, characterization of CaSi with respect to its quality is very important factor. In order to succeed right & efficient calcium treatment, continuous improvements are being pursued on both aspects: calcium based wire as well as injection conditions of the wire.

Theoretical aspectsof calcium treatments as well as salient features of plant scale trials have been presented in this paper.

**Keywords**: Calcium Treatment, Ladle Refining, Clean Steel, Inclusion Modifications, Green

# Cost Optimization of Ferroalloys in Steelmaking for Structural Grades

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**Abstract**

Ferroalloys play a crucial role in achieving desired material properties such as strength, toughness, and corrosion resistance in steelmaking. However, the cost associated with ferroalloy additions constitutes a significant portion of the overall production expenses for steel manufacturers. Various types of ferroalloys, including High Carbon Ferromanganese (HC FeMn), Medium Carbon Ferromanganese (MC FeMn), Low Carbon Ferromanganese (LC FeMn) and Ferrosilicon (FeSi) are integral to the production of structural grades in steelmaking and play pivotal role in designing grade. Present study explores various strategies and methodologies employed in the industry to optimize ferroalloy costs in structural grades while maintaining or enhancing the quality of steel products. A key component of this optimization strategy involves evaluating and refining existing ferroalloy models used in steelmaking, data is analysed for six months. Statistical analysis is done to identify the areas of improvement to optimize ferroalloy costs, Linear programming is utilized to determine the optimal cost based on initial bath chemistry. Cost reductions can be achieved by increasing the use of low-cost ferroalloys or reducing the consumption of existing ferroalloys. Strategic adjustments in bath chemistry play a crucial role in achieving cost-effectiveness based on the control limits of each grade. By replacing high-cost materials with suitable alternatives, it is intended to target steel chemistries at reduced production costs. This approach includes fine-tuning process variables and optimizing alloy additions to achieve final steel chemistry within specified ranges, thereby minimizing material wastage without compromising steel quality.

**Key words** : Ferroalloys, Cost, Structural Grade, Steel making

# Gas channeling prediction model in Blast Furnace in Bhilai Steel plant

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**Abstract**

Gas channeling in a blast furnace is indeed a critical abnormality that can lead to various operational challenges and potential damage to the furnace equipment. Gas channeling results in formation of large volume of gas pockets inside the furnace, disrupting the normal flow patterns and affecting the efficiency of the iron-making process. It often involves gases passing through a specific area of the furnace at an accelerated rate, creating imbalances in temperature distribution and flow dynamics. In response to the increased gas pressure, the bleeder valves installed in the furnace may open to release excess gas. The gases exiting the furnace through the bleeder valves are typically at very high temperatures, posing a risk to the top equipment of the furnace and potentially causing damage or malfunction. While this action helps alleviate pressure build-up, it also increases the heat load on the furnace walls.

The sudden increase in heat load and temperature imbalances caused by gas channeling can lead to severe thermal shock, particularly in the lower part of the furnace. Thermal shock can weaken the furnace structure and compromise its integrity.

In Bhilai Steel Plant’s Blast Furnace 8, there are 24 pressure tapping points at different stack levels of the furnace to measure the internal pressure. Around 150 temperature measurement points are installed to monitor the temperature of the stack. These pressure tapping points and temperature measurement points gather real-time data on pressure and temperature variations within the furnace. We have developed a predictive model that leverages this data to detect signs of gas channeling. The model analyzes the incoming data in real time, looking for patterns and anomalies that could indicate the onset of gas channeling. When the model detects early signs of gas channeling, it triggers an alarm to alert the operator. This allows them to take immediate action before the situation escalates. By providing timely alerts, the model helps operators make informed decisions promptly, preventing potential damage to the furnace and ensuring continuous operation. With early detection and intervention, the model helps optimize furnace operations, minimizing downtime and maximizing efficiency. Overall, the gas channeling prediction model enhances operational safety and efficiency by providing proactive monitoring and alerting capabilities. It empowers operators to respond promptly to potential issues, ultimately improving the overall performance of the furnace system.

# Enabling Sustainable Hot Metal Desulphurisation

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**Abstract**

Integrated Steel Plants desulphurise hot metal through injection process or mechanical stirring to produce high-end quality steel. In the injection process, a submerged refractory coated lance is used to inject the reagents (normally lime and magnesium) to the bottom of the hot metal bath. A carrier gas, nitrogen transports the reagents through the injection line and creates enough turbulence in the ladle for proper mixing. When the reagents react with sulphur, the products (MgS and CaS) ascend to the slag layer, where it is removed with a skimmer.

During mixing of these reagents, some amount of metal gets entrapped into the slag which is subsequently lost during deslagging operation. This loss of metal with slag reduces the yield of hot metal in steel plants. This yield loss varies from plant to plant and also depends on the practice being followed. The team has identified an opportunity to reduce this yield loss at one of the major steel plants.

To reduce this metal loss, it is obvious that the entrapment of metal droplets in slag has to be reduced. This may be reduced by changing the viscosity and foaminess of the slag or by changing intensity of reaction between metal and slag. One of the options team has studied and taken up a target to reduce the viscosity of slag without affecting the refractory of injection lance and treatment ladle.

To achieve this, the team has developed a new lime based desulphurising reagent with optimum quantity of viscosity modifier. The effect of this innovative reagent was evaluated and successfully reduced 10% metal loss in slag and thus resulting in lowering the yield loss.

Keywords: Desulphurisation, Hot metal, iron loss, Injection process

# Opticlean Auto Rotary strainer for HP Gas compressor.

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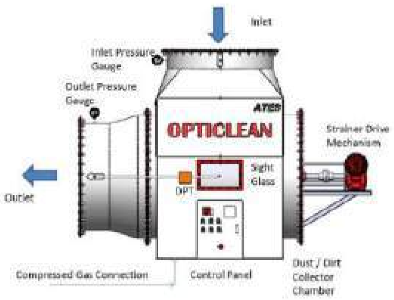
**Abstract**

We had stationary strainer for 60Knm3/hr HP gas centrifugal compressor. There were so many challenges we faced with this strainer such as 1).Filtering Element or Strainer have to be removed after dismantling of entire Booster Inlet Pipe line (DN1800). 2). Filtering Element need to clean offline and have to kept ready for each strainer replacement job & Shutdown Required to replace the Strainer around 8 to 10Hours. 3).Continuous deposition gas particles on Filtering element clogging rate is high. 4).Equipment need to take shutdown 5). High maintenance Cost & Strainer Filter cleaning takes 3Hours.

To eliminate the above challenges, we have conducted the brainstorming session and finally conceptualized the system of Auto rotary strainer with the support of M/S ATES. We have installed the Opticlean Auto Rotary strainer and eliminated the above challenges faced in the conventional stationary strainer and following are the benefits.




1).Filtering element can be dissembled and assembled easily without removing strainer assembly from its position. 2). Online cleaning of filtering element and continuous operation. Intermittent impingement of supersonic compressed steam ensures balance tough particles to unclog from screen holes. 3). Low maintenance time & cost. 4). Auto Rotary system not required to stop the Equipment. 5).It works online without interrupting Gas operation system.

Key words : Auto Opticlean Rotary strainer for HP Gas compressor.

# Improvement in Techno-Economics and Process Safety by Implementing Thermal Profile based PCI Flow-Rate Injection Model in Blast Furnaces

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## Abstract

Coking coal is the most precious and scarce raw material required for producing hot metal in a blast furnace. Coking coal is heated in absence of air in Coke Ovens to make coke which is subsequently used in Blast Furnace as reducing agent and source of heat. The price of coking coal keeps on fluctuating, but usually it is Rs.35000-40000/ton. Due to high consumption of coke in Blast Furnace process, even a small saving in coke rate by replacing coke with auxiliary fuel i.e. pulverised coal, would result in substantial savings.

In Blast Furnace 7 of Bhilai Steel Plant, there are 24 tuyeres and 24 PCI (pulverised coal injection) lines connected to each tuyere. For safe PCI process there is a Differential Pressure Transmitter (DPT) across each tuyere and hot blast, and a flow switch in each of 24 coal injection line. The DPT is monitored by operator to see if there is any choking in front of tuyere and flow switch indicates if there is any choking in injection line or no coal flow in these injection lines. DPT is programmed with alarms (high/low), to alert operator for any abnormality in tuyere phenomena. For any reason, if DPT fails and actually there is a tuyere blockage then the DPT interlock fails but coal dust injection will continue and the coal dust will start accumulating in blow pipe and nearby area. This is a highly unsafe condition and may lead to an explosion if tuyere is blocked and coal dust keeps accumulating. In the recent past in BF#4 and BF#7 this incidence has occurred and resulted in untimely stoppage of furnace

To avoid this unsafe condition in tuyere blow pipe we have introduced a Delta temperature interlock in all 24 injection line of PCI. That indicates if Delta temperature of tuyere decreases to a particular limit which means tuyere is choked, alarm will pop up and interlock will be activated and injection shall stop. Interlock was implemented in HMI pages to facilitate the operator. This job ensured stoppage of coal injection in tuyere if cooling water delta body temperature increases beyond a particular set point.

This implementation avoids the jamming of coal dust in blow pipe and nearby blow pipe area. There is always a possibility of explosion in blow pipe if pulverised coal is accumulated in the blow pipe which may result in unplanned shutdown of furnace and even lead to chilling of furnace. With this modification, possibility of any such incident is negligible. With this implementation it is now very safe to run the injection system even at higher PCI rate. We have noticed significant improvement in PCI rate which contributed greatly to the techno economics of the furnace.

# Optimization of Micro alloying elements in High strength steel

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**Abstract**

The effect of Micro alloying elements (Niobium, Titanium, Vanadium) and optimization of Micro alloying element in Hot rolled steel were studied. The impact of Micro alloying elements studied by Microstructure and Mechanical properties by using Scanning Electron Microscope, Tensile strength, Yield strength, Elongation and Fatigue strength. The experiments considered BSK46 material (HSLA) where niobium content 0.09%, Yield strength >460MPa and Elongation 21% Minimum. This material using for cross members and bracket application in automotive industry. The Niobium element is expensive than other Micro alloys. The Niobium would provide grain refinement and precipitation hardening. Reducing the Niobium % to 0.03 and increased Titanium % to 0.08%, to get required mechanical and fatigue properties. Material properties comparison has been made with existing material and optimized material. Due to optimization of Micro alloying elements, no significant change in Mechanical properties.

key words: HSLA, Micro alloying Elements, SEM

# AN INNOVATIVE APPROACH FOR REDUCTION OF CARBON IN FLY ASH AT DRI UNIT

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**Abstract**

JSWBPSL produces 1.8 MT of direct reduced iron (DRI) annually. The reduction process, which uses coal as its energy source, is based on both exothermic and endothermic reactions that produce a significant amount of heat. Meanwhile, natural gas is used in more than 90% of the world's direct-reduced iron facilities. The electrostatic precipitator (ESP) fly ash generated 7-9% unburnt carbon. When the ash contains a high percentage of unburned carbon, the high carbon concentration can cause increased sparking and reduced secondary voltage levels in the ESP, as well as less flue gas in the afterburning chamber (ABC), resulting in less steam generation in the waste heat recovery boiler (WHRB) and high unburnt carbon in the ESP ash. To address this issue, an innovative approach was taken to install a centrifugal fan or blower to control temperature as per the different conditions of the kiln, increasing air flow into the afterburning chamber by another 10000–12,000 m3/hour. wherein the un-burnt carbon and CO are burnt to complete the combustion resulting in formation of $CO_2$ and heat, by supplying extra air. The sensible heat thus generated further increases the waste gas temperature. However, to restrict temperature in the desired window, the amount of additional supply of air directed to the ABC needs to be controlled.

The innovative approach reduces unburnt carbon in ESP fly ash from 7-9% to 4-5%, while steam generation increases from 38.55 to 41.14 tons per hour.

Keywords: coal, esp, abc, whrb, Co, $Co_2$, steam generation.

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# TAILING OPTIMIZATION THROUGH NOVAL APPROACH IN BENEFICIATION PLANT

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**Abstract**

Iron ore tailings (IOTs) are a type of solid waste generated during the beneficiation process of iron ore concentrate. IOTs are one of the most common forms of mining solid waste in the world due to their high output and low usage ratio. It is essential to make use of the waste tailing pond slimes because of the growing demand for high-grade ores for metallurgical operations and the strict environmental regulations on mining activity. Recovery of iron values from these tailing ponds not only enhances the life of the existing operational mines but also discovers a way to achieve a sustainable process. Iron tailings provide challenges for effective iron recovery due to the complicated mineral compositions and discharge modes. In the present studies, the tailings are optimized using several strategic & innovative techniques, as well as the installation of a high-intensity magnetic separator (LONGI) in the beneficiation plant.

The results of the present study show that this novel method has optimized the tailing from 18% to 6% and with incorporation of Longi in the circuit tailing Fe reduced from 53% to 48.5%.

Keywords:- Iron ore tailings, Beneficiation process, Iron recovery, Longi.

# Operational Control Philosophy for Minimizing Hot Metal Silicon in Blast Furnace

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**Abstract**

Blast Furnace operation with low silicon hot metal is desirable from both technical and economic point of view. Operator tries not only to keep average hot metal silicon <0.50% range, but also for minimizing the variation in silicon on cast-to-cast basis. Study of cast data suggests that it is difficult to control silicon within preferred range (0.50-0.70%) and occasionally reach level to even higher that 1 wt% level. In terms of techno-economic sensitivity for 0.1% increase in hot metal silicon level may lead to equivalent fuel penalty of approximately 1% i.e. ~4-5 kg per tonne of hot metal.

Bokaro Steel Plant has four operating blast furnaces & has fixed the target of achieving hot metal silicon in the range of 0.50-0.70% in more than 90% of casts. Analysis of casting data of furnaces suggests the present level around 70% with average hot metal silicon of 0.73%. In order to achieve this target, a number of process optimization measures and operational control philosophy has been undertaken. A few thermal control action parameters have been identified for production of low silicon hot metal.

Laboratory tests are aimed on finding the behaviour of hot metal and slag in the lower part of a blast furnace and its application in controlling hot metal and slag quality. Laboratory investigations are to correlate temperature, viscosity and MgO content of slag on the dynamics of silicon transition to the hot metal at liquid phase at the time when slag lies on metal. Observation of industrial data in combination with laboratory tests allows to approximately determining the contribution of silicon from the gaseous SiO to Si containing in hot metal.

Based on findings of statistical analysis and laboratory investigations, this paper discusses about developed guidelines and proposals for the blast furnace operation to minimize hot metal silicon. It also encompasses the behaviour of silicon under high CDI rate due to increased peripheral gas flow and heat loss. Increase in ore layer thickness at high CDI operation reduction retardation in upper part of blast furnace is observed leading to increasing heat fluctuation. The low coke rate and high productivity operation limits its flexibility and in such situation fuel rate adjustment by grasping the heat level of the lower part of the furnace becomes critical in controlling silicon level.

key words: Blast Furnace, Hot Metal, Silicon, Thermal Control, Sensitivity

# Effect of internal gas injection in various ladle shrouds on tundish hydrodynamic performance and tundish open eye: A three-phase numerical and experimental study

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**Abstract**

Flow of molten steel through a shroud, with or without inert gas injection, can influence the flow in tundish and thus has a considerable influence on the metallurgical performance of steelmaking tundish system. Gas shrouding of the stream during ladle to tundish transfer is an essential step to prevent air aspiration and improve the melt cleanliness. In continuous casting, large throughput rates may promote refractory wear, slag entrainment, and large tundish eye which are known to seriously impair steel cleanliness. It is well known that for inclusion floatation and removal in tundish, plug flow is desired which can be ensured by a slowly moving, rather than a highly turbulent melt. It can be achieved through internal gas injection in the shroud and modification of shroud geometry.

In the present work, a 0.35 reduced scale single strand slab casting tundish incorporated with snorkel and fitted with flow modifiers viz. pouring box, a weir and two dams has been considered. Further, four different ladle shrouds namely, conventional ladle shroud (CLS), bell-shaped ladle shroud (BLS), reverse tapered ladle shroud (RTLS) and direct tapered ladle shroud (DTLS) have been considered with gas shrouding for gas loading ratio of 10%, 20%, and 30% to investigate the consequent effect on tundish hydrodynamic performance and tundish open eye. A numerical and experimental study has been carried out for three phase system of water-air-petroleum ether. The numerical study has been performed using the commercial CFD software ANSYS Fluent 21R1. To numerically model the various phases, volume-of-fluid method has been used and integrated with the species transport method to obtain the residence time distribution curve for further evaluation of tundish hydrodynamic parameters viz. mean residence time, plug flow, mixed flow and dead region. In addition, water modelling experiments have been performed to validate the numerical results and present elaborative and robust results.

Under similar operating conditions, from associated residence time distribution curve, it is expected from BLS and RTLS to have higher mean residence time along with higher dispersed plug flow volume. Further, BLS and RTLS are expected to form relatively smaller tundish eye due to lower turbulence at respective gas loading ratio. Thus, suggesting that delivery of metal through gas shrouded BLS or RTLS in a tundish fitted with pouring box and flow modifiers can be beneficial and facilitate inclusion removal from tundish and thus improving melt cleanliness.

**Keywords:** Hydrodynamic behavior of tundish; Residence time distribution; Tundish open eye; Bell-shaped shroud; Slag eye.

# Slag Free Eccentric Bottom Tapping in Electric Arc Furnace by Physical Modelling Studies

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**Abstract**

Electric Arc Furnaces (EAF) are one of the transformative trajectories in industrial practice, where steel scrap and DRI are taken as inputs and produce quality steel. The EAF has higher energy efficiency and lower environmental impact which is the aim of ongoing research and development. However, slag carryover during tapping is one of the main challenges which EAFs are facing in producing the ultra-high-quality steel. Very few studies investigated about the eccentric bottom tapping in EAF and hardly any research about slag carryover in EAF tapping is studied. The present study focuses on the slag carryover which is mainly due to vortex and drain sink formation. The complex shape of EAF along with various parameters which affect the vortex and drain sink formation are studied to predict the inception period of vortex and drain sink while tapping. A physical model which is geometrically scaled down of an industrial EAF is constructed with Perspex material. The tapping experiments were conducted in the physical model with water because of its similar kinematic viscosity to molten iron at its melting point. The drain curve analysis of water with varying nozzle diameter, initial liquid heights and dwell time between filling and tapping are studied. The critical heights for vortex and drain sink formation are predicted by using dimensional analysis, which is followed by the mathematical formulation, that gives the time of vortex and drain sink formation. The observation suggests that the heights of vortex and drain sink formation are clearly influenced by the nozzle diameter and dwell time between filling and tapping processes. The proposed mathematical equation can give the appropriate time of vortex formation which can be employed in the industrial scale to prevent slag carryover during tapping.

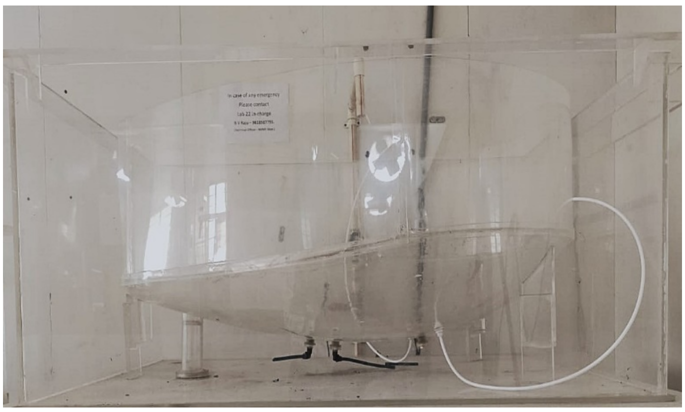

Figure 1. Pictorial representation of EAF physical model.

Key words: Eccentric bottom tapping, slag carry over, dimensional analysis, vortex, drain sink.

# Effect of Ladle Furnace Slag on the Type and Morphology of Inclusions in Low Carbon Aluminium Killed Steels

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**Abstract**

Low Carbon Aluminium Killed Steel is used for automobiles, and white goods application. ~~etc~~. This application involves critical deep draws during processing and excellent surface finish. Hence, steel quality plays an important role in steel performance. The quantity, size, morphology, and distribution of inclusions need to be well controlled. An extensive study was made on corelating the ladle furnace slag and its behaviour during processing to the final steel quality with respect to cleanliness. The slag and inclusion morphology were studied using XRF & Scanning Electron Microscopy with EDS. The FeO and MnO content of slag affected the morphology of inclusions. While the inclusions were purely $Al_2O_3$ type at the start of the processing, the MgO content of inclusions started increasing with decrease in Slag FeO+MnO. The $Al_2O_3$-CaO-$SiO_2$ ternary phase diagram for the slag system suggested that the liquidous may down as demonstrated with the slag path. The $Al_2O_3$.MgO inclusions are very hard inclusions and may affect the final forming characteristics of the cold rolled sheets. An optimum slag conditioning is critical step in achieving the desired internal quality of the steel for critical draw applications.

key words : Ladle furnace refining, Low Carbon Aluminium Killed Steel, Inclusions, Formability, $Al_2O_3$, MgO, FeO.

# REPLACEMENT OF HIGH PURITY HELIUM GAS WITH HIGH PURITY ARGON GAS IN THE ONH ANALYZER

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**Abstract**

JSWBPSL SMS Lab uses helium as a carrier gas for elemental determination. Oxygen, Nitrogen, and Hydrogen (ONH) analyzer equipment made by LECO, Model ONH 836, as per the standard ASTM E 1019:2018 for the concentration of oxygen and nitrogen and ASTM E1447:2022 for hydrogen in metals and other inorganic materials, is determined using the inert gas fusion method. The solid sample is fused at high temperatures in a graphite crucible with a carrier gas flow, and the evolved gases pass through the detectors. Argon gas is the third most abundant gas in the atmosphere, which is more than twice as much as water vapor. Argon has a much closer thermal conductivity to nitrogen than helium, by a factor of 4.14. The difference in thermal conductivity between argon and nitrogen made it too difficult to obtain accurate results. Innovative approaches were taken, such as using high-purity argon gas as a carrier gas in an ONH analyzer, to satisfy current quality results with consistency and produce more cost-effective processing. Several grades of steel samples were evaluated using carrier gas argon in a LECO machine, and there was no variation in the test findings. The novel strategy involves replacing carrier helium gas with argon gas as the carrier gas in an ONH analyzer. When an inert gas uses argon, it becomes a highly desirable and cost-effective solution.

Keywords: inert gas, helium gas, argon gas, ONH, LECO

# Effect of reducing agent on reducibility of iron ore pellets

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## Abstract

Four batch of pellets which were from two sources and ready for charging in the blast furnace were used for study. The pellets were of different reducing time periods. The purpose of this work is to investigate the effect of reducing agent on reducibility and reduction time of iron ore pellets. The impact of voids and particle size has been analyzed. Different batch of pellets have different mechanism of reduction. Phase transformation and microstructure formation has major effect on reducibility. Comparative study with different reducing agent was conducted to analysis the effect on reducibility. To assess reducibility, reduction tests were performed in a controlled laboratory condition, reductant used were blast furnace stimulant gas, hydrogen and carbon mono oxide.The study shows that voids and pores have a major role in the reducibility of pellets. The results of reduction process with hydrogen and Carbon mono oxide showed contrasting relation. The reduction mechanism showed legibly change in rate of reduction. Microstructure of unreduced and reduced pellets were studied. Change of phase present where characterized and mechanism was observed. The outer rim of the reduced pellets were having more metallic phase as compared to the core of the pellets. Understanding the link between particle size, reducing agent, and reducibility is critical for optimizing the iron ore pellet production process and improving overall blast furnace efficiency.

Key words: Reducibility; Blast Furnace; Microstructure; Green Steel.

# Journey towards Zero Rating of CHQ Grades

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**Abstract**

Cold heading quality (CHQ) wires are commonly used to make critical fasteners such as Nuts, Bolts, Rivets, Screws, etc. Our CHQ wire has a high standard of quality and technology in the field. Grades such as 10B21, 15B25, 10B35, SAE 4140, SAE 4135, etc are common CHQ Grades made at our facility in size range of 5.5-25.4 mm.

The occurrence of Upset Failure in cold-headed products presents a major obstacle in the fast-expanding cold heading (CH) industry. Many efforts have been tried before but all in vain.
Process control begins with strict requirements on chemistry, and continues with tight restrictions on process temperature, production rates and inspection regulations.
So, some factors were closely looked such as Casting process, Billet Dressing activities and Inspection System. Use of Anti-Clogging SEN was done to prevent Clogging Issues. 100% Full grinding of billets before Rolling for eliminating Seamlines for depth less than 100 microns. For elimination of Seamlines for depth less than 30 microns, releasing of coils only after 200% Cold Upset Test (from both ends of each coil) and 200% micro analysis to ensure defect depth within 30 microns where Cold Upset Test cannot be carried out in As-Rolled Condition.
This proactive approach has zeroed down Cold Upset Test Failure Issue in these grades. This is how we achieved Zero Rating in CHQ grades. Revision of Standards was done and has been incorporated in SOP and Work Instructions.

Fig. 1: Evidence of OK(Zero Rating) & NOT OK(01 & 02 Rating) Sample.


key words: Cold Headed Quality, Upset Test, Zero Rating

# Enhancing productivity by addressing quality deviations in direct heats at SMS

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**Abstract**

In order to increase the productivity of SMS at JSW Steel, Vijayanagar Works, a few heats are routed directly from the BOF Converter to the Caster (direct heats) with an average of 6 heats/day. Casting continuous direct heats in a tundish causes caster abnormalities, which significantly impact quality and often leads to unplanned sequence break. Clogging related abnormalities such as flushing, pumping, stopper rise, SEN lancing, mould level fluctuation (MLF) are experienced to be major concern. Hence it is essential to control the abnormalities during the sequence with direct heats for maintaining product quality and operational efficiency. Present study aims at detailed analysis w.r.t. the process parameters from primary steelmaking to casting, heat making practice and equipment healthiness at SMS#2 shop. Preliminary analysis showed that slag killing was not practiced for direct heats, resulting in FeO+MnO levels ≥ 7%, which contributed to the clogging issues. The absence of a dedicated Ar flow measurement facility at the tapping station and operator-dependent Argon purging led to a higher Al drop from the Argon Rinsing Station (ARS) to the tundish, averaging 0.02%. Early slag killing practice was introduced by adding Al shots after tapping. A purging matrix with a flow control valve for controlled Argon purging from tapping to ARS was implemented, and the process was standardized to reduce operator dependence. The interventions reduced the FeO+MnO content in the slag to less than 2.3% and the average Al drop to approximately 0.01%. Instances of clogging decreased from 41% in December 2023 to 23% in April 2024, with an increase in the percentage of sequences without abnormalities to 33% from 10%. The yield loss associated with scarfing abnormal slabs in direct heat was reduced by 43%.The targeted interventions, including early slag killing and improved Argon purging practices, were effective in addressing caster abnormalities in direct heats and enhancing overall production yield.

**Keywords** : Direct Heats, Caster Abnormalities, Slag Killing, Purging Flow Rate

# Surface Quality Enhancement in IF steel grade slabs

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**Abstract**

Ultra-low carbon interstitial-free (IF) steel is widely used in automobile plate/coil production due to its excellent deep drawability and uniform mechanical properties. However, surface defects such as pinholes, blowholes and micro-cracks often occur in these cast slabs, particularly in sequence first, last, fly and TCD slabs. Body skin scarfing (surface) is a highly efficient process that removes surface and subsurface defects from cast slabs. In current practice, there are various methods to remove these defects, such as manual surface scarfing and grinding. However, the most cost-efficient and effective method to meet today's requirements is mechanized scarfing. JSW Vijayanagar has a mechanized auto-scarfing machine. Initially trials have been conducted with 3mm full body skin scarfing on IF grades (Auto grades) with 220 mm thickness, resulting in a yield loss of 2.3% and reduction of SMS related sliver defect rate to less than 50% in CRCA grades. Later trials were also conducted with 260 mm slab thickness with 3mm full body skin scarfing, which resulted in a lesser yield loss, and the SMS-related sliver defect rate further decreased to 80%.

**Key words** : Steelmaking, Continuous Casting Auto scarfing Skin scarfing, Sliver

# Introduction of Mono SEN Preheating Practice for Billet Caster

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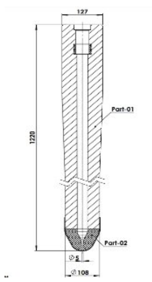
**Abstract**

Before start of the Continuous Casting, the Tundish and SEN (Sub Entry Nozzle) needs to be preheated to avoid the cracks due to thermal shock and freezing (skulling) of the steel during initial mold filling. JSW steel Vijayanagar works SMS-2 unit has the 8 strand billet caster where SEN preheating using the COG gas. This SEN pre-heaters consumes around 7861 $Nm^3$/month of this gas. Present pre-heating method involves manual intervention where operators need to go under the tundish to ignite burners and align them with the SEN port, which poses risks to human safety and affects work environment conditions. The invention proposes a system where the Submerged Entry Nozzle (SEN) is preheated utilizing the heat source intended for Tundish pre-heating. The COG gas flame from inside the tundish is leveraged to achieve sufficient preheating of the SEN. The COG gas flame from inside of tundish is capable to preheat the SEN sufficiently. This method would favour enhancement of SEN preheating by venturi effect to the desired temperature range between 800 to 1200°C, this avoided initial thermal shock and the tendency of SEN cracking while liquid metal is teemed into the mould. This method eliminates the need for additional expensive fuels like COG/LPG, reducing operational costs. It minimizes risks such as fire hazards, gas leakage, ensuring a safer working environment. This invention also focuses on reduction of $CO_2$ emission, enhancing operational efficiency, safety, and cost-effectiveness in the steel casting process by optimizing the use of existing heat sources for preheating.



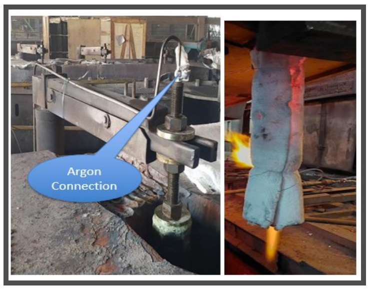




**Fig. 1: Before SEN heating** **Fig.2: Modification in MBS** **Fig. 3: After SEN Heating**

**Key words:** Steelmaking, Continuous Casting, Mono SEN Heating, Venturi Effect.

# Reduction in Process Abnormalities due to mould level fluctuations by adopting new SEN port design in Slab Caster

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## Abstract

Continuous casting is a widely adopted method in the steel industry for producing semi-finished steel products like slabs, billets, and blooms with high efficiency and quality. However, two significant challenges persist in this process: mold level fluctuation and submerged entry nozzle (SEN) clogging. mold level fluctuation refers to the variation in the height of the molten steel meniscus within the casting mold, which can adversely affect product quality and casting stability. On the other hand, SEN clogging occurs when impurities or solidified steel particles obstruct the flow of molten steel through the submerged entry nozzle, leading to interruptions in casting and defects in the final product. Industrial observations indicate that steel grades featuring low carbon content allow a maximum permissible mould level fluctuation (MLF) of up to 10 mm. presently, approx. 10 % of slab of IF & low carbon grade has MLF greater than 11 mm so, it leads to slab rejection and yield loss. MLF needs to be decreased for IF& low carbon grades. Port size of SEN is the one of the important parameters on which MLF and SEN clogging depends. CFD studies have been done to optimize the port size of the SEN. Three types of SEN design have been studied to reduce clogging and MLF, a) SEN with existing port, b) SEN with 15° port angle and c) SEN with edge port. CFD study's results show that edge port SEN has lowest clogging potential and meniscus velocity. Plant Trials has been taken with suggested edgeport SEN. Result shows that average % of slab with MLF is decreased from 7.2 % to 5 % and average sequence length increased from 4.39 heats to 4.63 heats per sequence.

**Key words** : Steelmaking, Continuous casting, CFD, SEN, Port size

# Optimization of Flux blend with Recycled slag briquettes for effective De-Sulphurisation (De-S) in Steel Making

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**Abstract**

Steelmaking is generally categorized into three stage processes. Primary steel making, secondary steel making, and continuing the casting process. Secondary steelmaking is considered a decisive quality control step between the primary steelmaking and the continuous casting of the liquid steel. With an increase in stringent quality requirements for steel, the development of refining techniques in secondary steel making while maintaining cost competitiveness in the global market is of great importance. Synthetic slag application practice is one such development that is considered cost effective when compared to the traditional usage of increasingly expensive materials. However, owing to its exorbitant cost, there was an increase in demand for supplement material to perform similar requirements for steel refining.

Also, stringent environmental regulations make waste disposal difficult today. The secondary slag after casting was earlier dumped as a waste for landfilling. Selective slag from dumped areas found similar chemical characteristics to synthetic slag. Hence, LF Slag Briquetting was developed as an alternative to synthetic slag. In the secondary process, slag control for refining through optimization of the flux blend using in-house developed LF Slag briquettes is a key feature for its success. The complete replacement of purchased synthetic slag with LF slag briquettes found it extremely challenging in flux blend selection and chemistry for effective de-sulfurization (De-S) in the steel-making process. The proportion of flux blend determines the effectiveness of its dissolution, and early-stage white slag formation is a measure of the cleanliness of steel produced.

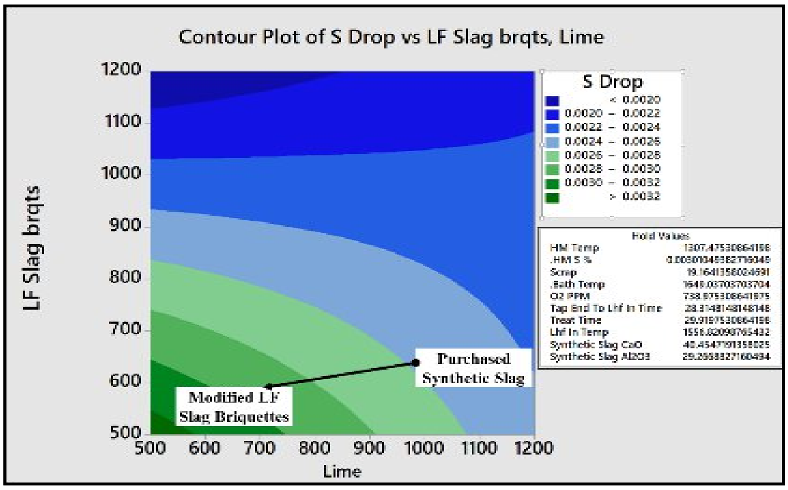


Fig. 1: Flux blend model

This present paper outlines the development of flux blende for the cost effective operational improvements in steel refining. The paper also helps steel plant operators to select a suitable option for achieving desired De-Sulphurisation (De-S) using Slag briquettes recycled from LF slags as a flux component in steelmaking.

**Keywords** : Secondary Steel Making, LF Slag briquettes, Desulphurisation

# Online monitoring and control of rolling oil for stable operation of PLTCM at CRM –II

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**Abstract**

Rolling oil used to reduce the friction & spraying the mixture of oil and water act as coolant to dissipate the heat generated during rolling process. Consumption of rolling oil in Pickling Line Tandem Cold Mill (PLTCM) was increased due to lack of continuous monitoring & uncontrolled flow of rolling oil. To achieve the market demands (Auto sectors) for flat product needs constant & unperturbed production at Cold Rolling mill-II.

One of the major challenges TCM (Tandem Cold Mill) faced was abnormal vibration sound generation while running at high speed due to inconsistent flow of lubricant between Rolls (Work-roll) and work piece, uneven oil film thickness on the rolls which leads to increasing friction, resulting in higher forces exerted on the system. Probable root cause of this particular issue was unable to predict the specific characteristics (Grade, width, thickness) of the coils being rolled to supply enough emulsion, absence of real time emulsion concentration monitoring system, lack of oil levels measuring devices, which directly disturbs our Production.

Installation of Online Concentration measuring system permits real time monitoring of the emulsion concentration, Guided Wave Technology (GWT) by ultrasonic signals provides guidance for modifying the oil percentage to ensure it aligns with the desired concentration levels, Oil measurements device on the tanks allows comprehensive monitoring of oil levels and concentrations across the system, enabling proactive management and control of the rolling process parameters.

Logic to standardize the oil percentage in the emulsion based on Grade, Width, and Thickness. A predefined lookup table generated based on Force Factor, Design Factor and Grade Factor with help of these factors a precise control of oil and demineralized water (DM water) added to achieve dynamic & desired oil percentage in the emulsion to get optimize product quality, performance, and production efficiency based on Grade, Width, and Thickness of the Product.

**KEY WORDS**: Online Concentration Monitoring & Controlling, Guided wave technology, Oil Control based on Force Factor, Design Factor, Grade Factor for optimum lubricity at bite.

# COREX Operation with PCI coal in the blend

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The COREX process is a technologically and commercially proven alternative route for ironmaking, which also functions as a gas production unit. This process generates approximately 1630 $Nm^3$/THM of gas with a 45% carbon monoxide content. Traditionally, the COREX process utilizes imported high volatile matter (VM) sub-bituminous coals. However, in line with JSW Steel's change management philosophy, Pulverized Coal Injection (PCI) coal with 70% fixed carbon (FC) and 19% VM has been introduced into the COREX process. The final blend of coal used in the COREX process now comprises 64.5% FC, 10.5% ash, and 25% VM on a dry basis. The PCI coals, characterized by low inherent moisture content, have reduced the overall moisture content of the blend to approximately 4%, which is 1.5% lower than previous blends. This reduction in moisture content, coupled with an increased FC percentage in the char bed, has led to a higher CO percentage and improved metallization rates.

As a result of these optimizations, the COREX process has achieved its lowest ever fuel rate of less than 840 kg/THM (dry), marking a significant reduction of 115 kg/THM. The reduction in blend VM has also decreased specific gas generation. To maintain and optimize gas generation, extensive trials were conducted to determine the optimal PCI coal percentage and its proximate analysis.

One challenge encountered was the higher fines content (∑-8mm) in the PCI coal. This issue was mitigated by increasing the screen mat aperture size, allowing excess fines to be utilized in the blast furnaces. The optimized PCI coal blend has significantly improved the overall performance of the COREX process. The introduction and optimization of PCI coal in the COREX process at JSW Steel Vijayanagar has led to enhanced performance, reduced fuel rates, and improved sustainability. These advancements underscore the potential of the COREX process as a viable and efficient alternative for ironmaking.

**Key words : COREX PCI Coals, Blending, Fuel rate Production, Quality**

# Strategies for Improved COREX Reduction Shaft Performance

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**Abstract**

COREX is a commercially available alternative iron-making process, with fuel rate being a critical factor influenced by the metallization of Direct Reduced Iron (DRI) in the reduction shaft. The metallization process is governed by factors such as specific bustle gas volume, bustle gas composition, temperature, and gas distribution within the shaft. Among these, the specific bustle gas volume is largely dependent on the available free bustle space, which can be significantly obstructed by the deposition of dust and low-melting or condensing constituents in the gas.

Rigorous analysis identified three primary contributors to increased resistance to gas flow: organic sulphur content in coal, alkali and zinc loads, and the cleaning practices for deposited low-melting constituents. These issues were evidenced by frequent blockages in engineering ducts between the Main Gas (MG) line and the shaft.

Given that COREX relies on coal for approximately 75% of its fuel, strategies were implemented to mitigate these challenges. These included reducing the usage of coal with high organic sulphur content in the blend, decreasing the zinc load in the COREX process from approximately 0.17 kg/thm to 0.10 kg/thm, and introducing mechanized cleaning of the reduction shaft bustle. The mechanized cleaning process not only decreased the confined space entry time for human workers, leading to more efficient cleaning, but also improved the below-bustle differential pressure from 0.003 bar to -0.001 bar (indicating suction, a positive outcome for shaft cleaning).

Additional process improvements, such as the installation of a pellet screening facility at the stock house and other engineering modifications, contributed to enhanced shaft availability and reduced shaft downtime by 20%. These combined efforts have resulted in significant improvements in shaft performance, availability, and the overall cost-efficiency of hot metal production.

**Key words:** COREX Process, Direct Reduced Iron (DRI), Metallization, Bustle Gas Volume, Pellet Screening, Mechanised cleaning.

# Impact of utilization of CDQ dust in blend of coke making process

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## Abstract

CDQ dust is generated during cooling of hot coke in CDQ chamber under inert atmosphere. The dust is a byproduct of dry quenching process which contains some amount of fixed carbon alongwith ash and VM . Dust is normally used either in blast furnaces or sinter plants.

A trial was conducted to utilize it in coke making and see its impact on coke quality as well as oven health. A series of pilot oven trials were conducted, and it was observed to have no major adverse impact on coke quality in terms of its hot strength. As the volatiles in dust are marginal to a extent of <2%, it has benefited in improved gross coke yield. At the same time, as these are already carbonized material and acts as an inert in the blend, it has improved the coke mean size which helped in better BF+Nut coke yield .

Later, plant trial was conducted, and it was established to have better utilization in coke making process. It helped in blend cost reduction as well as improvement in coke yield. There was an increase in coke mean size by around 1 mm while coke yield improved by around 0.5%.

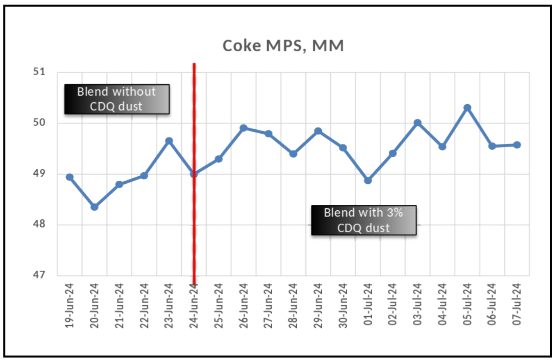


Fig. 1: Impact of CDQ dust on coke mean size.

key words : Mean size , CDQ Dust, Coke yield, coke quality

# Increase in KR impeller life

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## Abstract

Two of the most popular type's hot metal desulphurisation processes are injection and mechanical stirring process. In injection process, fluidised lime (CaO) or calcium carbide ($CaC_2$) is injected into hot metal (HM) ladle along with magnesium (Mg). These reagents are injected with the help of pressurized nitrogen gas through a submerged refractory coated lance having single bottom opening or two side openings.

In mechanical stirring process (e.g. Kanbara Reactor), lime and spar are usually poured in ladle on top of HM ladle which is then stirred by a massive refractory lined impeller. Turbulence in this case is created by rotor blades of the impeller. Rotational speed of the impeller at 85-95 rpm. Optimization of treatment time of KR, which provided a results in increases productivity of KR, overall DS success rate and with availability of treated hot metal. With respect the availability of KR refractory impeller plays a major role. If any unplanned down of KR due to refractory issue will directly lead to the waiting of treated hot metal for the converter.

In the present paper provides the outline development to come over this issue by online slag coating which is being carried out from the treated slag to avoid any surprise down due to crack formation in there factory part. This practise has provided a good result in the increase in impeller life and also helped in planned down of impeller to avoid unplanned break down and treated metal available for converter.

**Keywords** : Kanbara reactor, Impeller,

# Digitizing the Blast Furnace Operation

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**Abstract**

Digitalization is the fourth industrial revolution, and the world is going towards the age of digitalization. In Tata Steel digitalization is one of the major enablers in process optimization. Digitalization has enabled better process visualization, better decision making and better controls on the process. We have developed various models in house for better process optimization. These digital models have helped to reduce the coke rate by 30 kg/thm in blast furnaces. Models like silicon prediction model helped to reduce the hot metal silicon by 0.1%. This model predicts the hot metal silicon 2 hours prior, which helped to take proactive decisions and better control over process. Another model named as Wu star which is a thermal level predictor in the blast furnace. With the help of this the operator is now empowered with real time and quantified indication of the thermal level of the furnace. As we know that blast furnace is a black box. Thermal hawk which is a Tata Steel patented technology has helped in better visualization of the furnace top burden and optimizing the process. Proper and timely tapping of liquid metal and slag is a very important factor for smooth furnace operation, keeping this in mind we have developed a liquid level model which indicates the hearth occupancy in real time. In this paper we will be getting into the details of the various models mentioned above which we have deployed.

key words: Digital models, Blast Furnace, Digitalization, Process optimization

# Hydrogenous Oil: A new auxiliary fuel in Blast Furnace

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**Abstract**

Auxiliary fuel injection is the enabler for high productivity of blast furnace. In Tata Steel Jamshedpur except the smaller furnaces all the other furnaces have coal injection as auxiliary fuel. The smaller furnaces have coal tar as auxiliary fuel which is a patented system of TATA Steel. All the big furnaces running with coal is operating at a coke rate of less than 350 and has a productivity of more than 2.5 but the smaller furnaces running with coal tar has productivity of less than 2 with high coke rates of more than 500. In this paper we will be getting into the details of increasing the productivity of smaller furnaces greater than 2. To achieve the target of productivity greater than 2 we have started injection of a more purified derivative of coal tar. This derivative called as "Low Sulphur furnace oil" has low viscosity, low ash, higher calorific value. The chemical and physical properties of this furnace oil is a key enabler of increasing the injection rate and subsequently bringing down the coke rates of smaller Blast Furnace from a band of 500+ kg/thm to less than 400 kg/thm. Due to its high calorific value its replacement ratio is higher than pulverised coal. This oil has a replacement ratio of 1.2. With increased injection rates, hardware modification is done, and process was adjusted to optimize the furnace operation. With this new auxiliary fuel, the productivity of the smaller furnaces increased to 2.2.

key words: Low sulphur furnace oil, auxiliary fuel, productivity.

# Effects of sulphur content and Hydrogen Flakes in Forging quality Steels.

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## Abstract

In the automotive industry the material should be free from any type of internal crack, like hydrogen flakes. The mechanical properties will be reduced, and components will be failed, if hydrogen flakes crack present in the steel, as this automotive industry component is a critical requirement. The ability of a steel to get free from hydrogen flakes are required to comply with Standards or requirements which are critical to the end users and OEM's. The OEM's have set zero deviation regarding for hydrogen flakes.

The hydrogen flakes crack free forging quality steel achieved by chemistry design, control and by maintaining a steel making practice with minimised segregation. The paper discussed the effects of sulphur content and hydrogen flakes for the alloy steels and the significance of element to the contribution to the Hydrogen Flakes.

The paper also discusses a few case studies of meeting of stringiest through innovative chemistry design.

Keywords: Hydrogen Flakes, Microstructure, Segregation, Chemistry design

# Process improvisation at EOF to handle High Manganese and High Phosphorous hot metal to produce SBQ grade steel

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## Abstract

Energy Optimizing Furnace(EOF) is primary process for steel making where hot metal Manganese and Phosphorous plays major role. Phosphorous level prediction during the process is difficult with high Manganese hot metal. The challenges of using hot metal with Manganese level of >1.2% and Phosphorous level of >0.18% are 1. Impact productivity 2. Achieving Phosphorous levels of <0.010% at tapping to meet SBQ grade requirements and 3. Impact on refractory life. To counter this, 1. blow time was optimized, 2. Modification of tapping steel composition with reduced refractory impact. 3. Development of Phosphorous prediction model for high manganese hot metal.

The quantity of slag generated is more during the processing of hot metal with high manganese and phosphorous. The slag removal and flux addition pattern were revised based on the input hot metal quality. Statistical tools were used for prediction of Phosphorous level at tapping. By employing the modified process significant removal of phosphorous from hot metal was achieved meeting the requirement of special bar quality steel.

Key words : EOF-Energy Optimizing Furnace, SBQ-Special Bar Quality, Phosphorous, Manganese, Blow time, Primary steel making

# A study to compare ferroalloy hydrogen estimation by Hot Air Extraction Method and Inert Gas Fusion Method.

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**Abstract**

Ferroalloys are alloys of two or more metals, of which one is iron. These alloys are predominately made with iron and other crucial alloying elements like manganese, silicon, aluminium, chromium, or titanium. Ferroalloys are added in steel to improve properties like tensile strength, ductility, fatigue strength and corrosion resistance. Beside useful leading elements ferroalloy also contain gas impurities like nitrogen, oxygen, hydrogen. Hence ferroalloys when added during steel making acts as an important source of hydrogen impurities in steel. So accurate estimation of hydrogen content is required for stringent quality control of ferro alloys and steel. Ferroalloys can contain hydrogen in the form of hydroxide and moisture. On the determination of hydrogen in ferroalloys, values obtained are much influenced by analytical methods and conditions of sample preparation. The authors have examined about the powdered sample and granular sample by using two different analytical method, to establish a suitable method on the determination of typical hydrogen content. Hydrogen determination in Ferroalloys can be obtained using an inert gas fusion instrument (TCH/ONH instruments) or by Hot air extraction method (by DH-603 instruments). Carbon from the graphite crucible used in an inert gas fusion instrument reduces the hydroxide and moisture forms to allow for total hydrogen determination but in hot extraction method, DH603 will not reduce these forms of hydrogen completely. The present paper highlights the comparison of accuracy and precision of hydrogen content in several ferro alloys obtained via inert gas fusion method and hot air extraction method. From the analysis, it has been observed that inert gas fusion method is most suitable for different types of ferroalloys over hot air extraction method.

Key words: Ferroalloy; Hydrogen, Hot air extraction; Inert Gas Fusion

# Optimizing Cost-Efficient Molybdenum Recovery in Steel Production Using Moly Oxide

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**Abstract**

This study explores the use of molybdenum (Mo) in steel production, which is typically added in the form of ferro-molybdenum (FeMo). The efficiency and recovery rates of FeMo can vary depending on the material supplier, often leading to increased FeMo consumption to meet the desired molybdenum content in the steel. The conventional method of FeMo addition incurs higher production costs. As an alternative, using molybdenum oxide offers the potential to enhance the recovery rates of molybdenum during steel production, thereby improving overall efficiency in ferroalloy additions.

The primary objective of this work is to utilize molybdenum oxide in the steelmaking process to achieve higher recovery rates of molybdenum. A series of trials were conducted by varying the addition of molybdenum oxide during the tapping stage. These trials also involved different combinations of aluminum and lime to evaluate their impact on the recovery efficiency of molybdenum from molybdenum oxide. Typically, the average recovery rate for FeMo ranges from 88% to 90%. However, by adjusting the quantity and sequence of lime, aluminum, and molybdenum oxide additions, the recovery rate improved to 92% to 93%. The results indicate that varying the sequence and quantity of these elements can enhance molybdenum recovery efficiency, providing a cost-effective alternative to FeMo without compromising steel quality. This approach not only offers economic advantages but also promotes sustainability in steel production by optimizing resource utilization.

Keywords: Ferro-Molybdenum, Moly Oxide, Recovery, Aluminium, Lime

# Mitigating higher Sulphur content in ladle refining furnace for tire cord steels

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**Abstract**

Sulphur is typically considered a harmful impurity in steel due to its negative impact on critical properties like ductility, impact toughness (especially at low temperatures), corrosion resistance, and weldability. While manganese sulfide can enhance the deformation ability of inclusions, which is beneficial for tire cord steel, excessive sulphur, and manganese sulphide can lead to the development of banded structures, ultimately compromising the quality of the final products. In a steel mill, at the start of the secondary metallurgy process, it is essential to formulate a ladle slag with an optimal chemical composition to effectively assimilate sulfur-based inclusions from desulfurization reactions.

This paper discusses in detail about desulphurisation performance of tire cord steel with low basicity slag during secondary steel making at JSW Salem. A thorough analysis was carried out on parameters such as MgO content in slag, basicity, and sulphur partition ratios of steel and slag.

A unique calcium-based compound was developed with the supplier for improved desulphurisation practices at the ladle refining furnace. Industrial trials were performed optimizing the quantities of calcium-based compounds, deoxidizers, and refining slag constituents considering mass and heat balance requirements. The results from these process adjustments were deemed satisfactory and are discussed in detail.

Keywords: Deoxidizer, desulpuhrisation, low basicity, sulphur partition ratio

# Control of longitudinal surface crack in continuously cast case-hardening quality steel

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## Abstract

Low-carbon steel with lower alloy content and case hardening heat treatment is one of the best-suited and reliable materials for gears, and shaft applications as it can provide good tensile and wear resistance. This family of steels is made of a wide variety of compositions based on the criticality of the applications. However, the common need of all the low carbon steels is to have a superior surface quality without any surface cracks, scratches, or dent marks. Thus, manufacturing low-carbon case hardening steels in a steel mill necessitates good surface quality during continuous casting of blooms/billets followed by stricter process control measures during reheating and rolling of the same.

This study discusses one such low-carbon steel for gear applications which tends to have longitudinal surface cracks along the length of blooms. These cracks further manifest as sub-surface defects, slivers and cracks after rolling. Metallurgical characterization of fractured blooms was carried out to study the effect of pro-eutectoid ferrite and other chemical elements on the crack forming tendency. A thorough analysis was conducted on casting parameters affecting shell formation, crack development, and thermal stress during the casting process. The study also examined impact of the properties of mould flux like viscosity and crystallization behaviour on non-uniform cooling and development of thermal stress. Industrial trials were performed, by varying the mould water cooling rate, casting speed, and mould flux. The results from these process development were deemed satisfactory and are discussed in detail.

**Keywords:** Surface longitudinal crack, Mould cooling water, Mould powder, Thermal stresses

# Quality improvement of Windmill application grade at JSW Salem

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**Abstract**

In steel manufacturing for windmill applications, maintaining strict process control from scrap selection to the rolling of cast blooms is crucial. Traditionally, these steel grades were processed using the ingot route and then forged for windmill applications. However, as the industry transitions to the continuous casting route, it has been observed that the steel quality from this process is comparably satisfactory. Customers began requesting steel grades produced via continuous casting with the same quality standards as those from the ingot route. Recently, a customer reported failures in one of our windmill application grades, highlighting the stringent quality requirements from their end users.

To address the issue, Extreme Value Analysis (EVA) was conducted on the grade to assess the inclusion rating in the steel, with a requirement that the inclusion size in the forged product should be less than 200 microns. However, the current measured inclusion size exceeded this threshold. Consequently, a team was formed to address the issue using the Six Sigma methodology. Through brainstorming sessions and statistical analysis, three significant factors were identified: sulphur % content, rinsing duration, and end discards. An optimal combination of these factors was determined through design of experiments, accompanied by risk analysis. After implementing these actions, the measured inclusion size at the customer's end was reduced to below 150 microns.

Keywords: Continuous cast, EVA- Extreme Value Analysis, Inclusion size

# Control of titanium in manufacturing of bearing steel

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**Abstract**

Titanium as an impurity in certain specialized steel grades like bearing steel can lead to reduced grain size, lower yield strength, and overall diminished quality of the steel's properties. Specifically, in bearing steels, the presence of Titanium can lead to the formation of Titanium Nitride (TiN) inclusions, which significantly diminishes the steel's fatigue life.

An analysis of bearing steel production data at JSW Salem reveals that the titanium content in the steel is influenced by several factors. The primary factors include the levels of soluble aluminium and the presence of titanium oxides in the slag. The study reveals that higher soluble aluminium content is linked to increased titanium levels, mainly due to non-equilibrium reactions occurring between the slag and the steel. This technical work discusses ensuring titanium content is stably less than 30 x $10^{-6}$ in bearing steels at JSW Salem. A detailed mass balance analysis was carried out on various possible sources of titanium including carryover slag, ferroalloy additions, and slag constituents, etc. Accordingly, process steps were decided considering the mass balance and thermodynamical analysis of process steps. Also, a new synthetic slag containing low titanium content was developed in collaboration with a supplier and utilized in secondary steel making. The results from these process adjustments were deemed satisfactory and are discussed in detail.

**Keywords:** Inclusion, Top slag composition, Synthetic slag, Carryover slag

# Reduction of Ferro alloy Cost in Titanium Restriction Grades

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**Abstract**

In steelmaking, Ferro alloys are crucial for achieving the desired chemical composition and properties of steel. They play a significant role in the Ladle Refining Furnace (LRF) process, contributing substantially to conversion costs.

Steel grades with stringent titanium (Ti) restrictions, typically aiming for maximum Ti levels of 30ppm or 50ppm, are particularly sensitive to the presence of Ti, as excess Ti can lead to the formation of harmful inclusions such as TiN or TiCN, negatively impacting fatigue life.

To address the high costs associated with Ferro alloys used in these Ti-restricted grades, a study was conducted focusing on optimizing alloy usage. By employing Response Surface Methodology (RSM), we created overlaid contour plots to balance both cost and titanium levels, ensuring compliance with customer specifications. Additionally, a Process Decision Program Chart (PDPC) was utilized to identify potential risks and develop mitigation strategies.

The optimization efforts led to a significant reduction in Ferro alloy costs, achieving notable savings. This outcome not only adhered to the required titanium specifications but also substantially lowered the overall conversion costs, demonstrating the effectiveness of strategic Ferro alloy optimization.

**Key words: Ferro alloys, Ti Restriction, Response surface regression, Cost, Dual response optimiser**

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# High flux pellet production with use of limestone & dolomite fines for high pellet burden operation.

Abstract

Fluxed iron ore pellets play a crucial role in enhancing the efficiency of the iron-making process while minimizing its environmental impact by reducing the need for raw flux and equivalent coke in the blast furnace. However, these pellets are susceptible to spalling during induration. Key controllable factors include the choice of alternative fluxes (such as olivine), binder type, green pellet size, and temperature fluctuations during induration. If not properly managed, these factors can cause in-process spalling. Additionally, spalling may result from green pellet composition and the furnace's temperature profile.

The use of iron ore with high loss on ignition (LOI) and raw fluxes like limestone and dolomite is known to increase internal pressure during the drying and early preheating stages (250 to 750$^0$C) due to LOI release. Increasing flux composition by adding more limestone is also known to increase internal pressure during the preheating stage (750 to 1100$^0$C).

This presentation will explore the optimization of various processing parameters that have enabled the use of non-beneficiated, low-quality iron ores to produce high-flux, high-basicity pellets, maximizing pellet burden in the largest blast furnace in the country.

# Revamping BOF Converters at Durgapur Steel Plant: A Successful Project Implementation

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Abstract:

Durgapur Steel Plant (DSP), a Steel Authority of India Limited (SAIL) facility in West Bengal, has been a key player in India's steel industry since the late 1950s. Its Steel Melting Shop (SMS) features three Basic Oxygen Furnace (BOF) converters, each with a 130-ton capacity, achieving a total crude steel production of 2.5 million tons per annum (Mtpa). Installed between 1994 and 1995 by M/s Mannesmann Demag, Germany, these converters have completed over 50 campaigns, totaling approximately 93,000 heats.

However, extensive use of these converters led to several operational issues: -

- **Reduced air Gap between trunnion ring and converter shell:** The radial air gap between the trunnion ring's inner face and the converter shell has decreased from 170 mm (design) to 95-100 mm due to trunnion ring deformation. Metal leakage in the past has led to poor conditions affecting all converters.
- **Shell Swelling**: Noted in the top cone and barrel areas, requiring frequent repairs.
- **Eccentricity in Trunnion Shafts**: Resulting from trunnion ring deformation.
- **Non-Coaxiality of Trunnion Pins**: Along with shifting non-drive trunnion bearings due to shell and trunnion deformation.
- **Angular Deformation**: Observed in both drives trunnion pin axes.
- **Drive System Issues**: The converter drive can no longer function with a single motor.
- **Power System Deficiencies**: Lack of an emergency power system and reliance on an entirely DC system.
- **Bottom Stirring:** Non-functional with damaged infrastructure.
- **Secondary Emission Control**: Not available to meet current pollution standards.

To address these issues, a comprehensive revamp of the BOF converters, bottom stirring system, and the introduction of a new secondary emission control system were undertaken. The Centre for Engineering and Technology, Ranchi (CET), SAIL's in-house consultant, led the feasibility study, prepared technical specifications, managed the tendering process, finalized contractors, and oversaw project execution and commissioning.

The project's objectives were twofold: address current constraints and ensure future sustainability and reliability. The revamp was necessary to comply with stringent pollution norms and improve operational efficiency. The project faced the significant challenge of sequentially replacing converters, each requiring a 55-day shutdown, within a 20-month implementation period while

maintaining production with two converters during erection and navigating COVID-19 constraints.

Key strategies for successful implementation included:

- **Rigorous Planning**: Detailed scheduling and resource allocation.
- **Effective Resource Management**: Ensuring availability of materials and expertise.
- **Constraint Handling**: Overcoming logistical and technical challenges.
- **Continuous Monitoring**: Tracking progress and addressing issues promptly.

Collaboration among the Steel Melting Shop, Project Department, CET, and other stakeholders was crucial for streamlined decision-making and adherence to project goals. Specialized tools and methods were employed during execution. Despite space constraints, technical risks, and pandemic-related disruptions, the project achieved significant milestones, including a reduction in the anticipated shutdown period.

The project's success highlights the importance of meticulous planning, effective communication, and adaptive strategies in overcoming technical and logistical challenges, demonstrating the value of collaborative execution and continuous improvement in managing complex industrial projects.

# Improvement of Conveyor Efficiency by In-house Conveyor Deign to utilise fines in Iron making

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**Abstract:**

Corex iron making technology is a process used to produce liquid iron from iron ore and other raw materials, developed as an alternative to traditional blast furnace methods. It was developed by the German company Voestalpine and has been in use since the early 1980s. The Corex process is considered more environmentally friendly and efficient compared to conventional blast furnaces. Corex technology is flexible in terms of the types of iron ore and coal it can use, making it adaptable to different raw material sources.

In the Corex coal screening process, the utilization of all three screens simultaneously was hindered due to the high percentage of coal fines, which impacted operational efficiency. To address this issue, improvements were made to the coal fines conveyor system through an in-house design initiative. The conveyor's carrying capacity was increased from 250 tonnes per hour (TPH) to 350 TPH, and the belt width was expanded from 800 mm to 1000 mm. These modifications aimed to better handle the high volume of fines and enhance overall screening effectiveness. The enhanced conveyor capacity and wider belt are expected to improve the flow of material and optimize the screening process, allowing for more efficient use of all three screens and better management of coal fines and utilisation in Corex.

**Key words** : COREX, Screening, Conveyor design, Iron making.

# Improvement of Ridging Resistance in the Titanium stabilized ferritic stainless steel 409L grade in the 2B finish

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**Abstract**

Grade 409L is a titanium-stabilized ferritic stainless steel with approximately 11% chromium, commonly used in automotive exhaust systems due to its low thermal expansion, cost-effectiveness, formability, corrosion resistance, and high-temperature oxidation resistance. However, it is prone to ridging, a surface defect characterized by parallel elevations and valleys along the rolling direction (RD), which can significantly affect the quality of the final product. Ridging resistance in the 2B finish is measured by the ridging index (ranging from 1 for light ridging to 4 for deep ridging) and surface roughness (Rz) values, assessed after stretching samples by 20% in the rolling direction using an Utensil Testing Machine. The ridging index is determined through visual comparison with reference samples, while surface roughness is measured with a roughness meter.

The 409L grade is processed through a Steckel Mill without an Electromagnetic Stirrer (EMS) during casting, resulting in a low equi-axed zone (10-20%) in the slabs and poor ridging resistance. Initial trials, including reducing the number of passes in the Roughing Mill from 7 to 5 and maintaining a finishing temperature below 750°C, did not improve ridging resistance.

Significant improvements were achieved by adjusting the finishing temperature after hot rolling at the Steckel Mill to 780-810°C. This adjustment resulted in a notable reduction in both ridging index and Rz values. The percentage of material with ridging indices of 1 and 2 increased to 95%, compared to 40-50% before the adjustment. Additionally, the Rz value decreased from 20-30 microns to 10-18 microns. Following these modifications, no ridging-related complaints were reported, demonstrating the effectiveness of the temperature adjustment in enhancing ridging resistance in the 2B finish and improving overall product quality.

**Key Words:** Ridging, Finishing Temperature, Ridging Index, Surface Roughness (Rz), Microstructural Homogeneity, Formability, High-Temperature Oxidation Resistance

# Optimization of Hot metal Chemistry in Steel Converters before Oxygen Blowing to improve the overall performance in BF-BOF steel making.

In an era of fast developing and depleting natural resources, the iron and steel making industry has had to come up with many innovations to overcome the challenges. Currently, Hot metal pre-treatment is more or less limited to desulphurization in most of the integrated steel melting shops. The need of the hour is to improve the overall performance of BF -BOF route by absorbing low grade iron ore to produce hot metal and to produce a better steel.

In the proposed process, our reagent can be added into the converter along with scrap. Hot metal optimization (chemical reaction) takes place at the time of charging hot metal into the converter. By the time the hot metal pouring gets completed, we will get the desired metal chemistry by virtue of the reactions ongoing in the converter. The initial slag can be poured out before oxygen blowing. Thus, we can reduce the oxygen blowing required in the converter. Our method involves almost no CAPEX, since there is almost no change in existing process other than the reagent addition to the converter. We have carried out industrial trials of the same, and the results are encouraging. Moreover, there is also a yield improvement in the hotel metal. Some blast furnaces in India produces high Mn hot metal as high as more than 2%) and problems in SMS converters as a result of higher slag volumes. Our product can help use these ores for steelmaking as well. Table 1 gives a brief about the efficiency of our process. we can see how we can target specific compositions of metal chemistry by modifying the amount of reagent used. Moreover, the consistency is verified by observing the similar values across 5 samples. This method of hot metal optimization is a way for steel makers to obtain a competitive edge in the industry, with its ease of use and proven results.

With the proposed technology, we have the benefits of lower CO2 emissions per ton of steel produced, lower slag Volume and flux usage, yield improvement and higher usage of high Mn iron ore in Blast furnaces.

<table>
<tr><th></th><th>Metal Chemistry</th><th>Si</th><th>Mn</th><th>Ti</th><th>Remarks</th></tr>
<tr><td rowspan="5">Target: Reduction in Levels by 70%</td><td>Pre-Trial</td><td>1.01</td><td>0.527</td><td>0.079</td><td rowspan="5">Avg Si reduction : 77%<br>Avg Mn Reduction: 69%<br>Avg Ti reduction: 75%</td></tr>
<tr><td>Post Trial Sample A</td><td>0.256</td><td>0.173</td><td>0.021</td></tr>
<tr><td>Post Trial Sample B</td><td>0.227</td><td>0.161</td><td>0.019</td></tr>
<tr><td>Post Trial Sample C</td><td>0.221</td><td>0.156</td><td>0.019</td></tr>
<tr><td>Post Trial Average</td><td>0.2347</td><td>0.1633</td><td>0.0197</td></tr>
</table>

Table 1: Trial Results showing reduction in Si, Mn and Ti levels to desired values

Key words: hot metal chemistry, pre-treatment, Optimization of Hot Metal Chemistry in converter

# Study of Reduction kinetics of iron ore using carbon free sources: Developing a pathway for Green Ironmaking

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To address the rising global carbon footprint, the iron and steel industries are transitioning towards more sustainable practices, such as utilizing carbon-free sources like hydrogen. In this context, the current study aims to analyse the reduction kinetics of hydrogen-based reduction of lean iron ore, focusing on the effects of gangue content, isothermal temperature, reduction time, and gas composition. Experiments were conducted isothermally at 800°C, 900°C, and 1000°C with 20 vol% $H_2$ for a 10-minute reduction. Further experiments were performed by varying the $H_2$ volume percentage to 10% and 30%, and adjusting the reduction time to investigate their impact on the degree of reduction. Phase transformations from Hematite to Magnetite, Wüstite, and finally to Iron were verified using X-Ray Diffraction (XRD) techniques. The ultimate goal is to enhance reducibility and metallization while minimizing the carbon footprint, contributing to the advancement of green steel technology. Future work will focus on exploring reduction kinetics in varying particle sizes, particularly using iron pellets, to further optimize this process.

**Keywords:** Hydrogen, Reduction Kinetics, Isothermal Heating, Degree of Reduction,

# Reduction of Slag jam formation for Si-based grade in Steel ladle

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**Abstract**

In the steelmaking process, the ladle furnace (LF) plays a critical role in refining molten steel, with the steel ladle serving as a large, heat-resistant vessel lined with magnesia-based refractory materials. Despite its durability, during the processing of calcium-silicate-based slag, a common issue arises: slag sticks to the ladle's walls and bottom, leading to significant build-up. This accumulation can cause delays in ladle preparation and result in the carryover of residual slag into subsequent heats. The primary cause of this issue is the formation of high melting point crusty slag during lifting from LF and gets hard slag during casting process, which further exacerbates the problem by making the slag more difficult to remove from steel ladle.

To address this, a silica-based ladle covering compound (LCC) was developed in collaboration with a supplier. This compound is specifically formulated for use with silica-based steel grades and is added during the lifting stage from LF. The addition of the silica-based LCC reduces the slag's basicity, effectively lowering its melting temperature. This adjustment ensures that the slag remains fluid throughout the casting process, thereby minimizing the build-up on the ladle walls and bottom. As a result of implementing this new practice, the frequency and severity of slag build-up have been drastically reduced. This improvement has led to more efficient slag dumping and significantly faster preparation times for ladles in subsequent steelmaking operations, enhancing overall process efficiency.

Keywords: Steel ladle, Ladle jam, Ladle Covering compound, Ladle preparation

# High strength weather-resistant cold rolled coils for solar photovoltaic panel application

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**Abstract**

SAILCOR is a weather-resistant structural steel grade produced in form of hot rolled (HR) and cold rolled (CR) coils at Bokaro Steel Plant (BSL) of SAIL. In order to explore the usage of this special grade of steel in solar power industry for manufacture of supporting steel structures like columns, rafters and bracings of solar photovoltaic power panels, with enhanced property requirement of yield strength (YS) ≥ 350 MPa and total elongation of 20% minimum, the development of customized SAILCOR grade CR coils was undertaken at BSL. Trial heats of 300 tonnes were made through BOF-LF-CC route and the as-cast slabs were hot rolled and processed into 3.4 mm (thickness) x 1280 mm (width) HR coils in Hot Strip Mill (HSM). The HR coils were subsequently pickled and cold rolled to 1.6 mm (thickness) x 1252 mm (width) CR coils in Tandem Cold Rolling Mill-I (CRM-I) followed by batch annealing under protective hydrogen atmosphere using specially-designed annealing cycle. The corrosion performance of the customized variant of weather-resistant SAILCOR grade steel was evaluated comprehensively through standardized corrosion testing procedures involving anodic polarization, salt fog and atmospheric corrosion testing and compared with IS 2062 E250BR+Cu and IS 2062 E250BR steels. Under anodic polarization testing in 3.5% sodium chloride (NaCl) solution, the customized SAILCOR grade steel was found to exhibit 4 times superior corrosion resistance over IS 2062 E250BR grade of steel. The customized variant of SAILCOR steel also showed marked reduction in loss of thickness owing to corrosion penetration, sluggish corrosion kinetics and impeding of corrosion rates vis-à-vis IS 2062 E250BR+Cu and IS 2062 E250BR steels over prolonged exposures comprising more than 7 months of atmospheric outdoor exposure testing conducted as per ASTM G50 and over 3 months of 5% NaCl salt fog exposure testing conducted as per ASTM B117.

Keywords: weather-resistant steel, corrosion

# Study on hard pushes in aged coke oven batteries during the metallurgical coke production of an integrated iron & steel plant

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## Abstract

**:** In coke oven batteries of an integrated iron & steel plant, metallurgical coal blend is carbonised in absence of air at around 1050°C with a coking period of around 18 hours in coke oven battery to produce metallurgical coke. During carbonisation, the volatile matter present in the coal converts into coke oven (CO) gas by means of destructive distillation and leaving a residual coke in the oven. This CO gas is collected into gas collecting mains and sent to gas cleaning for further processing. During coke pushing, a ram on pusher side pushes the red hot coke from the coke oven through door extractor via. DE guide into a dry quenching car. The pusher ram current is an indicator of the power required to push the coke out of the oven. If the pusher ram current drawn is higher, the power required for ram motor is more – which indicates a sign of hard push. Persistent hard pushes in the oven leads to oven stickers and affect the service life of oven heating walls. The chance of occurrence of hard pushes in aged batteries is very high. In the present work, different factors affecting the hard pushes in aged coke ovens were studied & their probable root causes were determined by continuous monitoring of amperage profiles of pusher ram motor currents, changes in charge coal blend composition (volatile matter, moisture, grain size distribution, ash), oven conditions (heating walls temperature, wall/sole deformations, etc.), average coking period etc. In this study, around 1,61,489 pushing`s with more than 100 industrial coal blends (with % hard coking coal from 35 to 72%, % soft coking coal from 28 to 65%, % indigenous coking coal from 0 to 25%,) were monitored over a period of 17 months. Various control measures namely cross wall & end vertical temperature corrections, auto proportioning of coal charge blend, charge coal height distribution in oven, thorough oven inspection including sole & jamb brick area (bulge/narrow, graphite depositions, etc.), etc. were done. Due to continuous monitoring & control measures, % of hard pushes w.r.t. number of pushing's decreased from 6% to 2.3% (in Battery-1 from July-23 to Mar-24), 2.8% to 0.4% (in Battery-2 from July-23 to Feb-24), 6.5% to 1.1% (in Battery-3 from June-23 to May-24), 7% to 1% (in Battery-4 from March-23 to April-24), 4.5% to 2.1% (Overall from Feb-23 to May-24). The results showed that around 16 ovens (in Battery-1), 2 Ovens (in Battery-2), 10 ovens (Battery-3), 9 ovens (Battery-4) were identified as sensitive to hard pushes during this period. This study reveals that heating wall deformations on pusher side/coke side, heating walls temperature, ram/guide position, high level of coal charge weights, green coke formation due to low temperature in heating walls, deviation in coking period, etc. are the most important factors for affecting the hard pushes. This study helps in early identification of the ovens prone to stickers and to safeguard the service life of coke oven batteries.

**Keywords**: coke oven battery, coal carbonisation, coke pushing, hard push, sticker oven.

# Development of BILLET 100 in MMSM

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## Abstract

New product development is the main factor of economic progress in building the economic competitive advantage. It deals with the whole practice of creating a new product or process, or improvements in the existing products and commercialization of existing products a means to attain competitive gain. Innovation is the main driving force in order to sustain in the competitive world. Companies across the world are faced with changes to both the production technology and service organization. The product life cycle has never been so short as now, therefore, new product development is one of the most important business tasks. Using only the traditional methods of increasing competitiveness, for example, cost reduction, it is not possible to remain on the market. Only a consistent approach and the development of creative ideas are the factors, which help a company to successfully operate.

The paper discusses about the evolution of BILLET 100 (**BLT 100**) section, its roll pass schedule design and quality in MMSM at Visakhapatnam steel plant in order to fulfil the market demand especially in TLT sector & automobile forging industries and to serve the customer with delight and increase the proud customer base.

The Medium Merchant and Structural Mill (MMSM) of RINL **is** a single strand, two high, torsion free, continuous universal hot rolling mill having 20 numbers of housing less stands (horizontal, vertical and combination) in place with a capacity of 0.85 MTPA that produces long products in the category of billets (Rounds and Squares) and structural (Angles, Beams, Channels, and Flats) in varied dimensions and caters to the different industries like automobile, general engineering, bright bar and re-rolling industries (TLT sector, automobile etc.) across the globe. The input bloom size and charging temperature are 250X250X6000mm$^3$ and room temperature respectively. The discharging temperature is 1200°C and the finishing rolling temperature is 950°C. Gas fired walking beam type of two numbers of furnaces each with a capacity of 130 TPH are used for reheating the cold blooms. Mixed gas with a calorific value of about 2200Kcal is used as fuel. The mill is upgraded with Level-1 and Level-2 automation systems.

**Key Words:** - Torsion-free, Strand, Stand, Two High, Housing Less, Hot Rolling, Horizontal, Vertical, Combination, Bright Bar, Automobile, Bloom, Billet, Structural, Round, Square, Roll Pass, Universal, TLT, Walking Beam, Calorific Value, Mixed Gas, Kcal, Level-1 & 2.

# Pelletization of magnetite feed produced from a low grade iron ore by reduction roasting

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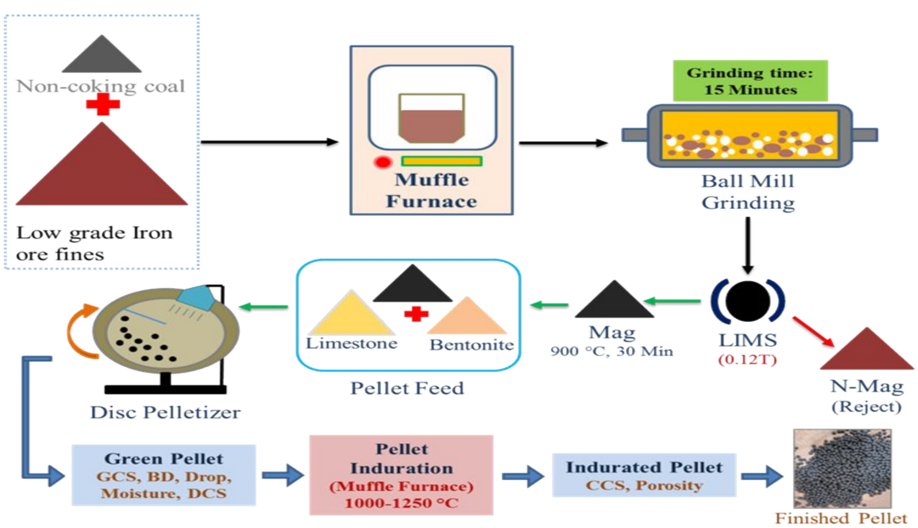
## Abstract

Using low-grade iron ore reserves is critical to meeting future requirements and ensuring environmental sustainability, necessitating extensive study to develop a technique to determine the path to sustainable use. One method that works well for extracting high-grade iron value from low-grade iron ore deposits is reduction roasting. The next step in using these concentrated fines to produce iron and steel is pelletization. This study detailed the use of low-grade iron ore fines to produce high-grade iron ore pellets after the low-grade iron ore fines underwent reduction roasting and magnetic separation. The low-grade iron ore contained 53.1% Fe (T), collected from a mine dumping in Barbil, Odisha. The reduction roasting tests were carried out in a lab-scale muffle furnace and were planned using Taguchi's L9 experiment design. Following magnetic separation, a pelletization study was conducted on the magnetite produced from the roasted sample. The results of the roasting studies showed that the ideal roasting temperature and duration were 900 °C for 30 minutes, yielding the highest yield and recovery of 76.3% and 86.3%, respectively. The pellet obtained at the ideal roasting temperature and duration had 311.2 kg/pellet CCS, 29.7% porosity, and 63.6 % TFe at an induration temperature of 1220 °C and a retention period of 5 minutes.




Key words : Low grade iron ore, reduction roasting, magnetite, pelletization

# Investigating the Integration of Hydrogen and Biochar in Iron Ore Pellet Reduction Process

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## Abstract

The iron and steel industry are a major contributor to global greenhouse gas emissions gas emissions primarily due to the use of carbon-based reducing agent. The World Steel Association estimates that the industry contributes between 7 to 9% of the world's $CO_2$ emissions. Additionally, the decline in fossil fuel reserves further necessitates the search for alternative reducing agent. With the goal of decreasing the carbon footprint associated with conventional steel making process, the present research investigates the potential of a mixture of hydrogen and biochar as a reducing agent for the direct reduction of iron ore in search of sustainable alternatives process. First, reduction will be conducted on high-grade iron ore pellets in a horizontal tubular furnace at temperatures ranging from 900-1100ºC. Comprehensive characterisation utilizing scanning electron microscopy (SEM) and X-ray diffraction (XRD) will come next. These techniques will make it easier to comprehend the phase changes and microstructural changes that occur during the reduction and cooling procedures that follow. While SEM will give detailed images and analysis of the microstructure to highlight morphological changes, XRD will be used to identify the phases present. The reduction process will be examined by a thorough kinetic analysis that will be conducted after the characterisation. This investigation will aid in the undertaking of reaction processes and rate determining steps, as well as provide insight into the efficiency and practicality of using hydrogen and biochar mixture as reducing agent. The results of this study will help create a more environmentally friendly method of producing steel by using a mixture of hydrogen and biomass as a competitive substitute for conventional full pledged carbon-based reducing agents.

Keywords: Direct Reduced Iron, Hydrogen, Biochar, Kinetic Analysis.

# Section Size Effect on Tensile Properties of Platinum Aluminide Coated Directionally Solidified Ni Base Suparalloy CM247LC

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## Abstract

The desire for weight reduction and use of advanced metal cooling schemes to improve gas turbine engine efficiency tends to drive design towards thinner airfoil walls. The metal thickness in the aerofoil section of a typical HPT blade of advanced aero gas turbine engines varies in the range of 0.5-3.0 mm. PtAl coatings, which are applied on these components for providing oxidation protection, are known to be brittle and, therefore, reduce the load bearing cross section of the component. Such reduction in load-bearing cross-section degrades the mechanical properties of the superalloy component. In the present study, the tensile properties of 0.5, 1.0 and 2.0 mm thick flat specimens of DS superalloy CM247LC in uncoated and bond coated conditions have been evaluated. An increase in strength (YS and UTS) with increase in section thickness was observed at RT and 870°C for both uncoated and coated specimens. Application of Pt-Al coating did not affect the strength and ductility of coated alloy at RT and 870°C. The strength (YS and UTS) of uncoated and bond coated alloy was comparable at RT. However, the strength and ductility of coated alloy was marginally higher than uncoated alloy at 870°C.

Keywords: Pt-aluminide coating; tensile properties; fracture; superalloy.

# Development of Defence-Grade Round Bar Materials for Bomb Shell, Shell Body, and Projectile Body Applications

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## Abstract

In a significant advancement in the field of defence materials, four defence-grade round bar materials, with diameters of 120 mm and 150 mm, have been developed for M/S Elbit Land Systems in the export segment, in collaboration with Blue Stamping & Forging Ltd. These round bars were produced through a precise steel- making and rolling process, with a strong emphasis on maintaining steel cleanliness and achieving stringent mechanical properties.

The round bars, designed for critical military applications such as bomb shells, shell bodies, and projectile bodies, were subsequently subjected to further extrusion and processing by the customer to meet the final application requirements. The steel- making and rolling processes were meticulously controlled to ensure the materials exhibited the necessary strength and microstructure, essential for their performance in extreme operational conditions.

Extensive testing and validation confirmed that the produced materials meet or exceed the required specifications, demonstrating superior performance in terms of strength, toughness, and microstructure. This development highlights the importance of precision in material production, contributing to the reliability and effectiveness of modern munitions.

This paper addresses the specific needs of M/S Elbit Land Systems and represents a significant achievement in defence materials engineering, offering advanced solutions that enhance the operational capabilities of military munitions.

key words: Defence grade material, Export segment, Extrusion

# Development of high strength & lightweight material to enhance the mobility of defence vehicles

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## Abstract

Lightweight defence vehicles are crucial in military operations because their increased mobility and speed enable swift deployment and agile maneuvering across diverse terrains. Developing high-strength steel grades at reduced thicknesses is currently seen as a key solution for creating lightweight defense vehicles. This paper discusses the development of hot-rolled high-strength steel for defense applications. Using Quality Function Deployment (QFD), the customer requirements were translated into technical specifications. The Nb & Ti based chemistry is used to achieve the required strength. Design of Experiments (DOE) is conducted to optimize the slab reheating temperature (SDT) and coiling temperature (CT). Optimizing SDT is required to dissolve all the Nb and also to reduce coarsening of austenite grain at high temperature. This is followed by precipitating NbCN in the Pancaked austenite to avoid recrystallization of the austenite grains. Then cool in ROT to achieve fine ferrite grains with nano precipitate of TiC through step cooling. Trial is conducted with CT of 610 °C & 580 °C to achieve the required properties. Microstructure study reveals fine ferrite grains with distribution of TiC precipitates. The tensile test, bend test and hardness were carried out to validate the customer requirement.

# Study on oxidation behaviour of Nb20Mo20Ti20Cr20Al15Si5 refractory high entropy alloy

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## Abstract

Recent findings suggested that the refractory high entropy alloy offers promising prospects for high temperature structural materials. New structural alloys that can survive extreme temperatures with good oxidation resistance and mechanical properties are required in applications such as in energy sector and aerospace industry. Refractory high entropy alloys have the potential to meet the material characteristics suitable for high temperatures. However, their poor oxidation resistance at elevated temperatures limit their applications.

In the present work investigation on the effect of the alloying elements (Si) on the microstructure and oxidation resistance of $Nb_{20}Mo_{20}Ti_{20}Cr_{20}Al_{20}$ alloy is studied. A new alloy composition $Nb_{20}Mo_{20}Ti_{20}Cr_{20}Al_{15}Si_5$ was prepared by vacuum arc melting of the pure elements. The SEM analysis of as-cast alloy shows dendritic, inter-dendritic regions and secondary-phase regions. Preferential segregation of Mo at dendritic regions, and Ti, Cr, Si at inter-dendritic regions has been observed. The distribution of Nb and Al is found to be uniform throughout the microstructure. The vacuum annealing of the as-cast alloy at 1500°C for 7 hours, resulted in the dissolution of the dendritic structure. The annealed alloy showed dual phase microstructure comprising of a solid solution phase and $(Nb,Ti)_5Si_3$ phase, as analysed by EDS.

The iso-thermal oxidation behaviour of the alloy was tested in static air environment at 800-1200°C for time varying from 1-100 h. The alloy showed superior oxidation resistance up to 50 hr at 1200°C. The cross-sectional analysis of the oxide revealed the formation of $TiO_2$ as the predominant outer oxide layer. Furthermore, other refractory elements (like Cr, Nb) are present in the $TiO_2$ structure as confirmed by EDS analysis. The inner oxide layer contains mixed oxides of $Al_2O_3$, $TiO_2$ and $SiO_2$.
Silicide based coating was developed using pack siliconizing process on $Nb_{20}Mo_{20}Ti_{20}Cr_{20}Al_{15}Si_5$ alloy substrate. The coating was formed using a pack consisting of $10NH_4F$-10Si-$80Al_2O_3$(wt.%) at 1100°C for 8h under flow of Ar gas. The BSE-SEM analysis indicated the formation of about 90 µm thick silicide-based coating on the specimen. The EDS analysis of the coating indicates the presence of multiple elements in the di-silicide phase; Mo-4.5at. %, Nb-12.1 at. %, Ti-10.1at. %, and Cr-7.4at. %.

key words: High entropy alloy, Oxidation, Coating, Refractory metal

# A Novel AA6061 Composite Reinforced with Mechanically Alloyed Titanium Aluminide via Friction Stir Processing: Development and Characterization

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## Abstract

Current research work emphasizes on the development of particulate titanium aluminide (TiAl), an intermetallic class of material, through mechanical alloying (MA) from elemental powders and usage of same as reinforcement in AA6061 aluminium matrix to enhance its mechanical and tribological performance. TiAl, being a light weight, strong and abrasion-resistant material, is found to be a suitable candidate to replace dense ceramic-based reinforcements in aluminium composite. Friction stir processing (FSP), a well-established surface severe plastic deformation tool, is used to develop the composite in this study. Several strategies on improving the stirring action and particle distribution during FSP is employed and their scientific effect is studied in detail. Microstructural evolution was studied through scanning electron microscopy (SEM) combined with electron backscattered diffraction (EBSD) analysis which revealed uniform particle distribution of reinforcement in the friction stir processed (FSPed) zone with 88.23 % reduction in grain size of composite as compared to base material. Hardness studied showed an increase in the hardness by 33% for composite material as compared to un-reinforced FSPed material, showing the positive effect of reinforcement alone on the mechanical strength of the material. Tensile results showed an improvement in yield tensile strength from 156 MPa in base to 186.8 MPa in the composite material without significant compromise in the ductility 26.86% for composite and 28.14% for base. Mechanisms aiding uniform particle distribution, and the reasons for improvement in mechanical performance of the developed composite is discussed in detail with the help of microstructural studies and post-deformation fractograph.

**Keywords:** Titanium Aluminide, Aluminium matrix composite, Mechanical alloying, Friction stir processing, Grain refinement, Mechanical behaviour.

# Exchange Coupled Nanocomposite Permanent Magnets for Prospective Applications

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## Abstract

Permanent magnets (PMs) are indispensable for defence, space, nuclear, aerospace and automotive sectors. Magnet research today is concerned with improving the performance of PMs based on various hard magnetic phases while reducing the dependence on any critical materials used. Current advances in the understanding and characterization of nanoscale magnetic phenomena, along with materials engineering at the micron and nanoscales, led to new types of PMs with enhanced energy product values. One way to improve the performance of PMs by nanostructuring is hard/soft exchange coupled magnetic nanocomposites. Atomic-scale magnetism does not support substantial improvements of permanent magnets beyond the existing intermetallics such as $SmCo_5$ and $Nd_2Fe_{14}B$, but adding a soft phase to a hard phase in a suitable nanostructure improves the performance of permanent magnet superior than that of the hard phase (Fig. 1a). In light of the above, considerable R&D efforts have been made on the processing of exchange coupled $SmCo_5$/Fe and Mn-Al/Fe nanocomposite magnets; wherein $SmCo_5$ and Mn-Al contributing themselves as hard magnetic phases with large coercivity; while Fe acts as soft magnetic phase with large magnetization. Novel process strategies such as magnetic field-assisted milling, spark plasma sintering and magnetic field-assisted sputter deposition were employed for attaining the fine-grained microstructure with exchange coupled bi-magnetic phases. From an application perspective, the aforementioned nanocomposite magnets were processed in the form of bulk (Fig. 1b) and thin film and they were characterized with respect to structure, microstructure and magnetic properties. The metamaterials approach such as those adopted in this study exemplifies the materials-by-design strategy and makes it possible to produce permanent magnets not encountered in nature.

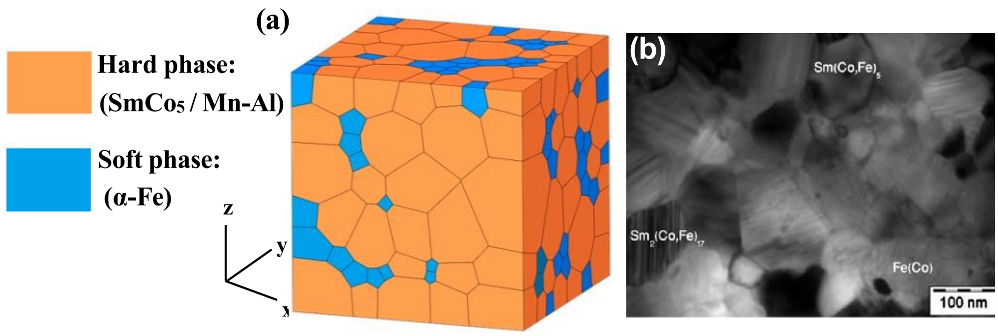


Fig.1: (a) 3-D microstructure model for hard/soft magnetic nanocomposite and (b) a typical TEM microstructure of spark plasma sintered $SmCo_5$/Fe nanocomposite magnet.

Keywords: Nanocomposites; Permanent magnets; Spark plasma sintering; Sputter deposition.

# A Study on static spheroidization of direct energy deposited Ti-6Al-4V alloy

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## Abstract

Titanium (Ti) alloys are well-established in the aerospace and defense sector due to their command in fatigue and creep resistance, high fly-to-buy ratio, superior corrosion resistance, and mechanical stability at operational temperature conditions [1]. It transforms allotropically into two crystal structures i.e. the one stable at room temperature (RT) is known as α-phase (hcp; P63/mmc) and the second one is the β (bcc; Im3m) phase, which forms upon crossing the transus temperature ($T_{\beta}$). They are associated with the Burgers' orientation relation (BOR) such that $\{0001\}_{\alpha}||\{110\}_{\beta}$ and $\langle 11\text{-}20\rangle_{\alpha}||\langle 111\rangle_{\beta}$ [2]. Amidst other Ti alloys, the Ti-6Al-4V (Ti64) falls in the (α+β) category, consisting of ~96% by volume of α (hcp; P63/mmc) and ~4% by volume of β (bcc; Im3m) at RT. It is eminent for its ability to provide diverse mechanical properties, particularly for structural applications with tailored microstructures achieved by employing thermo-mechanical processing (TMP) conditions. The resulting microstructure bear significant heterogeneity and, therefore, are a focus of research. Recently, considerable work has been done in the spheroidization of Ti alloys via various additive manufacturing (AM) techniques. Spheroidization studies on Ti64 alloys deposited via the Direct energy deposition (DED) method have emerged as one of the most promising candidates for attaining the tailored properties for fabricating components post static heat treatments. However, it adds more complexity to the spheroidization kinetics responsible for the heterogeneity. Therefore, through this presented work, the aim is to study the effect of various heat treatments on the DED-built Ti64 part and its response toward the heterogeneous spheroidization and associated kinetics that might contribute to overcoming the current limitations in the AM processes.

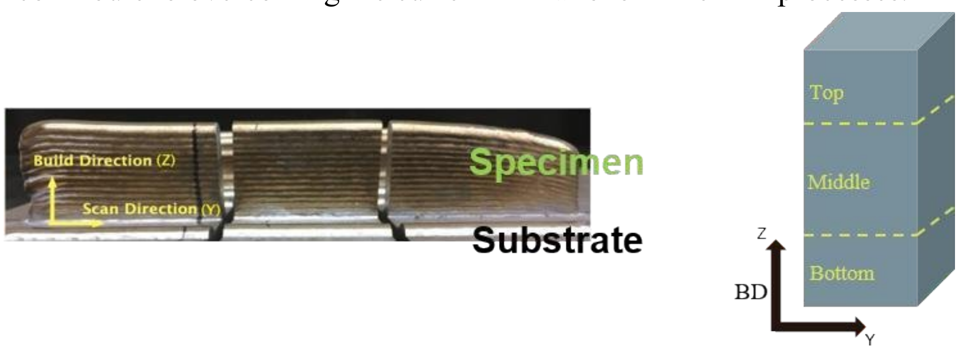


Fig. 1: Figure shows the DED deposited Ti-6Al-4V block (left), and its representative schematic (right) depicting the top, middle, and the bottom sections.

key words: Titanium alloys, Additive Manufacturing, Spheroidization, Microstructure, Heat treatment.

# Effect of face sheet material on flexural deformation behaviour of aluminium hybrid composite closed-cell foam core sandwich panels

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## Abstract

High-performance foam-core sandwich panels are highly in demand for structural as well as defence applications. In the current work, nano particles reinforced Aluminium hybrid composite closed-cell foam core sandwich panels were made through adhesive bonding. Advanced high strength fabrics (Kevlar/ Carbon fibers) were used as face sheets with different combinations. Sandwich panels were made using multiples layers of face sheets. For the comparison purpose bare foam and only fibers were also tested. The performance evaluation of the developed foam-core sandwich panels was carried out under flexural loading (3-point bending). Interface between the foam core and the face sheets was studied through electron microscopy.

Results demonstrate that the flexural properties of the foam-core sandwich panels are much superior to the bare foams. Further, the flexural rigidity and flexural strength were significantly high in case of Double layer Carbon Fiber sandwich panel (DCF). Whereas, specific energy absorption is high for Double layer Kevlar fiber sandwich panel (DKF). Deformation mechanisms were understood with the help of videographs recorded during testing. Flexural rigidity and energy absorption were calculated empirically and compared with the experimental data. Detailed discussion was made on failure mechanisms of the individual fibers in a fabric and this phenomenon was corelated to the overall deformation mechanism of the foam core sandwich panels. These results demonstrated the usefulness of high strength fabrics as face sheet materials for making high performance foam-core sandwich panels. This study helps in better designing and making of high performance Aluminium hybrid composite foam core sandwich panels.

Keywords

Aluminium hybrid composite closed-cell foam, high strength fibers, flexural deformation, deformation modes, energy absorption.

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# Investigation of Laves phase dissolution and Homogenization kinetics in IN718 with varying Si content through a combination of characterization and calculations.

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## Abstract:

IN718 with high Si-scrap offers cost-saving potential, but microstructure control is vital to prevent micro-segregation and Laves phase formation. To achieve this, a homogenization treatment is employed. In this study, as-cast IN718 containing 0.2 and 0.4 wt.% Si were subjected to experimental investigation at 1100, 1150, and 1175 °C for 12, 36, 60, and 96 hours. A unique characterization and analysis scheme ascertains the extent of solute redistribution in the as-cast and heat-treated alloys. Using an area-grid scan method, around 2000 points were examined, allowing data collection from dendritic and inter- dendritic regions. Composition data were ranked, sorted using WIRS and plotted against solid fractions, generating concentration profiles. Homogenization extent was evaluated by observing changes in delta values, representing the difference between maximum and minimum solute concentrations, as a function of temperature and time. Furthermore, a diffusion-based homogenization model was developed, which predicted the degree of homogenization and Laves phase dissolution.

Key words : INCONEL 718, HOMOGENIZATION, AEROSPACE, DIFFUSION MODEL, SILICON

# Investigation on effects of long-term heat treatment on coating properties in cold sprayed Ni-base superalloys

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## Abstract

The present study examines the effects of post-processing long-term heat treatment on the microstructure and mechanical properties of cold-sprayed (CS) coatings fabricated from Inconel718 (IN 718) powder. The CS coating was subjected to 750℃ for a duration of 168 h for post-processing. The study employs a combination of Synchrotron X-ray diffraction (XRD), hardness, and micro-tensile tests, together with a thorough analysis of the results, to investigate the microstructural and mechanical responses of the cold sprayed coating. The utilization of heat treatment resulted in a substantial decrease in the levels of porosity of the coating implying the enhancement of metallurgical bonding between the individual splats. The process of ageing treatment results in a combination of precipitation hardening, caused by the formation of intermetallic ($\gamma''$ and $\delta$) phases and MC carbides, and a reduction in the work-hardened microstructure through recovery. The coatings applied by spraying exhibited a decrease in cohesive strength and toughness. Additionally, a significant difference in tensile characteristics of the CS coatings was seen in the sprayed coating, which was one of the primary objectives of the study. The post-processing resulted in an improvement of both the cohesive strength and ductility of the coating by causing the indicated changes in the microstructures of the coating. This presentation comprehensively explains all the significant findings.

Keywords: Cold Spray; Cohesive Strength; Failure Strain; Anisotropy; Inconel 718

# Exploring Lightweight Steels for Armor Applications

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**Abstract**

The present study involved the design, microstructural analysis, and mechanical characterization of two austenitic lightweight steels (Steel A and Steel B) for armor applications. Thermo-Calc software was employed to design the compositions of the steels and simulate their phase diagrams. Steel A and Steel B have densities of 6.68 g/cm³ and 6.94 g/cm³, respectively, which are 15% and 11% lower than the conventional MARS steel grade. X-ray diffraction studies confirmed the presence of austenite and B2 phases in Steel A and only the austenite phase in Steel B. Under hot rolling and annealing conditions, Steel A exhibits a yield strength (YS) of 1015 MPa, an ultimate tensile strength (UTS) of 1285 MPa, an elongation of 16.7%, and a hardness of 456 HB. In contrast, under the same conditions, Steel B exhibits a yield strength of 435 ± 7 MPa, an ultimate tensile strength of 732 ± 10 MPa, and a total plastic elongation of 58%. Tensile tests were performed on the steels at intermediate strain rates from $10^{-3}$ $s^{-1}$ to $10^{0}$ $s^{-1}$ to determine their strain-rate sensitivity. A Charpy V-notch impact test was performed on a Steel B sample, yielding an impact strength of 133 J/cm². The findings of this research could be used to further optimize the design and processing of lightweight steels for use in armor applications.

Keywords: Lightweight steels; Austenite; Tensile properties; Armor applications

# Challenges in realization of Titanium closed-die forgings for application in liquid engines for Indian Space Programme

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**Abstract**

Titanium alloys are increasingly used for liquid rocket engine components due to their exceptional strength-to-weight ratio, corrosion resistance, and ability to withstand cryogenic temperatures. In the Indian space program, titanium closed die forgings are extensively used for manufacturing gas bottles, injectors, and engine components, and structural parts for cryogenic stages. Key alloys include Ti- 5Al-2.5Sn, Ti-6Al-4V, Ti-4.5Al-3Mo-1V, Ti-3Al-2.5V each selected based on their performance in ambient to cryogenic environments. A few of the forgings are illustrated in Fig 1. However, achieving titanium closed die forgings for such critical applications poses significant challenges.

One primary challenge is the complexity of forging titanium alloys, driven by their low thermal conductivity and sensitivity to temperature changes. Titanium's tendency to form alpha and beta phases based on chemical composition results in a narrow forgeability window. Therefore, precise optimization of parameters such as heating and cooling rates, forging load, and strain rate is essential for each titanium grade to avoid issues like cracking, deformation, or undesirable metallurgical changes. Presence of such defects can lead to severe consequences during engine operation. Also, the melting envisages aerospace quality Ti sponge, with compaction followed by double VAR melting to meet stringent gas control to ensure toughness at cryogenic temperatures. These processes demand meticulous planning and execution throughout the production process.

Titanium alloys exhibit high chemical reactivity, making uniform heating and oxidation control challenging during forging. They also have a propensity to absorb hydrogen, leading to potential hydrogen embrittlement and catastrophic failure under cryogenic temperatures. This necessitates specialized heating techniques in controlled, protective atmospheres, which add complexity and cost to the manufacturing process. Additionally, the intricate geometries of liquid engine components often require complex die designs, posing challenges in fabrication and maintenance. Persistent issues such as die wear and cracking, exacerbated by titanium's abrasive nature and thermal cycling, further complicate the process. Furthermore, meeting precise dimensional tolerances and surface finish requirements adds to manufacturing complexity. Closed die forging route envisages grain flow along the contour of the product depicting superior mechanical properties.

In summary, while titanium closed die forgings offer substantial benefits for enhancing liquid rocket engine performance and reliability, their realization remains a technically challenging endeavour requiring meticulous planning and execution at every stage of production.


Fig. 1: Titanium closed die forgings developed for liquid engine

**Keywords:** closed die forging, forging, ELI, liquid engine, Titanium

# SMAART MATREALS-SHAPE MEMORY ALLOYS

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## Abstract

Shape materials are smart materials finds wider application in Defence, Aerospace, Medicine and host of other applications. The Alloy takes its name that it remembers its original shape at a pre-determined temperature .

The prominent three types of alloys are Nickel-Titanium Alloys, Copper-Nickel-Aluminium, and Copper-Zinc Alloys.

The most commonly used alloy is NICKEL-TITANIUM-alloy called NITIND and has excellent mechanical and electrical properties.

The presentation will cover details of various shape memory alloys, its chemical and mechanical properties the mechanism behind the the change of shape.The presentation will details the manufacturing facilities for production of NICKEL-TITANIUM Shape memory alloys for Aerospace application, the raw materials used for the production of the alloy, VACCUUM MELTING and VACCUM ARC re-melting , FORGING, ROLLING, ELECTRO DISCHARGE MACHINING(
EDM) process to manufacture a shape memory component of the Aircraft.

The presentation will cover various tests and inspection carried out and final fitment of the component on the Aircraft. -

# Optimization of NiFe-Based Superalloys for Enhanced High-Temperature Performance

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## Abstract

NiFe-based superalloys are critical in applications requiring exceptional high-temperature stability and resilience under severe operating conditions. These alloys are typically solid solution-hardened with a face-centered cubic (FCC) structure and feature a microstructure comprising a distribution of Gamma prime ($\gamma'$), Gamma double prime ($\gamma''$), and small amounts of carbide precipitates, embedded within a Gamma ($\gamma$) matrix phase. The performance of these superalloys is meticulously enhanced through the addition of alloying elements such as aluminum (Al) and titanium (Ti), which stabilize $\gamma'$ precipitates, while chromium (Cr), niobium (Nb), and molybdenum (Mo) contribute to solid solution strengthening and improve resistance to high-temperature corrosion and oxidation. In this study, model Ni-Fe-Cr-Mo-Nb based superalloy compositions were investigated with varying percentages of Fe, Cr, Mo, and Nb, while maintaining constant levels of $\gamma'$ stabilizers (Al and Ti at 1 wt%). The objective was to determine the effect of these alloying elements on the microstructural phase attributes and mechanical properties. The findings include a composition phase diagram, creep strength variation, and Continuous Cooling Transformation (CCT) curve, demonstrating a strong dependence of alloying elements on primary and secondary phase attributes, such as $\gamma$, $\gamma'$, $\gamma''$, and secondary carbides. The systematic investigation revealed the nucleation and growth kinetics of each phase in relation to the variations in Fe, Cr, Mo, and Nb content. A data-driven approach was employed to optimize the alloying elements, leading to the synthesis of superalloys with improved performance. The properties of the synthesized superalloys were correlated with their microstructures to understand the underlying micromechanisms responsible for the enhanced properties, providing critical insights for advanced high-temperature applications.

**Keywords:** NiFe-based superalloys, high-temperature stability, data-driven optimization, microstructure-properties correlation.

# End Milling Impact on Chip Formation during Metal Cutting of Al 2024 Thin Walls

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## Abstract

This work explored one further reason on the nature of cutting force during end milling. Up milling and down milling are two possibilities in end milling which is widely used during machining to realize aircraft components. The cutting force signature for up milling and down milling exhibited differences: presenting the nature metal cutting and the science of chip formation. The existing industrial growth, seeks intelligence to automation, where-in, the intention riders to the parameters were sought in addition to the parameters of processes. This helps in modeling the metal cutting for virtual environment envisaging the reality.

The resolved components of cutting forces, exhibited a sinusoidal pattern in up milling. However, the down milling exhibited a direct correlation to the engagement and disengagement of the cutter. This pattern was observed in the normal component ($F_y$) of the cutting force. The chips were analyzed with the detachment portions and fractures reported in up milling. However, the down milling had a clean tail of the chip. A sample experiment with radial depth of cut 1 mm, feed rate of 200 mm/min and spindle speed of 1000 rpm was performed on Al 2024 billet with an intention to achieve thin walls. The end mill cutter appeared to provide a guide all along the down milling for the chip formation. In up milling, the moment created by the cutter through the cutting edge leads to the fracture of the chip during metal cutting. The inflexion in sinusoidal pattern during up milling was explained with a moment about its rotational axis created by the cutter. The moment-plot is found to match to the two components viz., (i) inflexion part of the cutting force and (ii) the fracture initiation of the chip. The impact involved during up milling action during thin wall machining was reported.

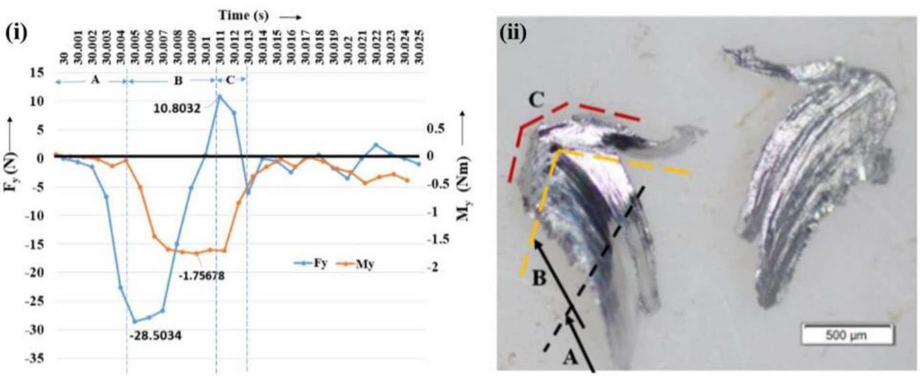


Fig. (i) Normal cutting force, Fy vs Moment (My) (ii) Zones in chips of up milling

Key words: Chip formation, End milling, cutting forces, moment

# Study of Reverted Austenite Evolution during Ageing in Maraging Steel M-250

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## Abstract

Maraging steel, known for its soft martensitic phase, undergoes a controlled diffusion process during aging, resulting in the reversion from martensite (α) to austenite (γ). It was demonstrated that reversion kinetics can be enhanced by the choice of ageing parameters. This leads to improvement in work hardening, toughness and ductility with minor sacrifice in the strength of the material. This improvement is attributed to transformation-induced plasticity (TRIP) effect of reverted austenite (RA), along with the presence of precipitates. The enhancement in toughness leads to potential applications in the field of Aerospace, Military and Nuclear industries, specifically in Jet engine shaft, Cannon recoil spring, and Connecting rod etc. However, complete micromechanical understanding of this improvement requires systematic investigation into the stability of the reverted austenite under different aging conditions and its consequent effect on tensile properties. Therefore, in this incumbent work, Fe-18Ni based Maraging -250 steel is aged under different reversion conditions (500 ℃,540 ℃ and 580 ℃ for 10 and 24 hrs, followed by air cooling and water quenching) to achieve different volume fractions of RA. At 500 ℃, the RA fraction was observed to be about ~15 %, while in 540 ℃ it is ~25% and 580 ℃ is ~23-35 %. A uniaxial tension test was conducted to determine the stress-strain responses of these materials. The initial RA fraction showed a prominent effect on the respective tensile properties. At 500 ℃ aged, YS/UTS evaluated was highest at ~1620/1680 MPa whereas, at 540 ℃ and 580 ℃ it was 1560/1600 MPa and 1410/1480 MPa respectively. A simultaneous increase in ductility, with decreasing strength was observed i.e. 26, 28, 36 % at 500 ℃, 540 ℃ and 580 ℃ respectively. This indicated an increasing TRIP effect from 500 ℃ to 580 ℃. To confirm this, these were interrupted at different strains to determine the microstructure evolution during straining. Also, in-situ straining under synchrotron X-ray diffraction was carried out and phase fraction of RA calculated.

**Keywords:** Maraging steel, Reverted austenite, Heat treatment, Micro mechanical testing, TRIP effect

# A modified Ludwigson equation to describe the strain-hardening response of pure iron and 440C steels

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## Abstract

The strain-hardening responses of three single-phase steels (SS316, SS304 and High nitrogen steel (HNS)) and five multiphase steels (AISI 4340, 52100, 440C, Jackal Steel (JS) and Spade Steel (SS)) have been critically analysed and compared with Pure Iron in the present study. Strain hardening, often called work hardening, is the process by which the material's load-bearing capability rises due to plastic deformation and is usually characterised by a parameter called strain hardening exponent, usually denoted as 'n'. It is an important property that governs several types of degradation of metallic materials. Iron has a ferritic structure at room temperature, while SS304, SS316, and HNS are austenitic stainless steel. Multiphase steels have primarily tempered martensitic structures.

Several existing and frequently used empirical equations, such as Hollomon, Ludwik and Ludwigson, were used to explain the strain-hardening characteristics of these steels. Among these, the Ludwigson equation satisfactorily predicted the strain-hardening characteristics of austenitic stainless steels and two armour-grade steels (JS and SS). However, none of the above could adequately explain the strain-hardening characteristic of Iron and three-bearing-grade steels (AISI 4340, 52100 and 440C). A modified Ludwigson empirical equation suggested by some authors was tried and found effective for AISI 4340 and 52100 steel. However, it cannot convincingly explain the strain-hardening characteristics of iron and 440C stainless steel due to the negative departure of the experimental data from the ideal Hollomon line at low strain levels. To remedy this deficiency, the authors proposed a modified Ludwigson-type empirical equation for each of these materials, which accounts for the negative deviations of the experimental data from the ideal Hollomon relationship occurring at low strains. The suggested empirical equation satisfactorily explains the work-hardening behaviour of the 440C steel and Iron over the entire strain range. Results indicate that austenitic steels exhibit two-stage strain hardening behaviour. Contrarily, bearing-grade multiphase steels exhibit three-stage strain hardening behaviour. The strain-hardening behaviour of armour-grade multiphase steel such as JS and SS exhibits two-stage strain-hardening characteristics.

**Keywords:** Steel, Tensile testing, Strain hardening, Empirical equation, Modified Ludwigson equation

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# The Thermo-Mechanical Properties of $SrCeO_3$ for Modern TBC Applications

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## Abstract

Ceramic thermal barrier coatings (TBCs), particularly useful for insulating alloy parts in gas turbines and aircraft engines exposed to high temperatures, have been a subject of considerable research interest. Typically, TBCs are made from yttria-stabilized zirconia (YSZ), but YSZ is now considered inadequate for contemporary TBC uses due to its limited operational temperature range and relatively high thermal conductivity. $SrCeO_3$, belonging to the perovskite family and adhering to the chemical formula $A^{m+}B^{n+}O_3$—where the combined valence of cations A (m) and B (n) must equal 6 (m + n = 6)—has emerged as a promising alternative. Its attributes, such as phase stability, low thermal conductivity, and a moderate thermal expansion coefficient, make it suitable for TBC applications. This study explores the phase stability, thermo-physical properties, microstructure and lifespan of $SrCeO_3$ for potential use in thermal barrier coatings. $SrCeO_3$ has been synthesized using solid- state reaction route. The formation of a single orthorhombic phase in the resulting compound was verified via X-ray diffraction (XRD) analysis and refined using the Rietveld method under the Pnma space group. Thermal expansion measurements showed coefficients ranging from $7.95 \times 10^{-6}$ $K^{-1}$ to $11.32 \times 10^{-6}$ $K^{-1}$ between room temperature and 1200 °C. The material exhibited a Vickers hardness of 3.72 GPa. Additionally, thermal shock resistance was assessed through 100 cycles at 1200°C, demonstrating the material's potential for high-temperature applications.

**Key words**: Ceramic, Perovskite, TBC, Thermo-Mechanical

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# Advancing Waste-Derived Composite Material for Stealth Applications

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## Abstract

The present work aims on synthesizing the magnetic and dielectric material-based composites through a top-down approach tailored for stealth applications. The magnetic material is synthesized via sol-gel auto-combustion route, while the dielectric material is derived from waste. Structural and morphological analyses of the developed material have been done using X-ray diffraction (XRD), scanning electron microscopy (SEM), and Raman spectroscopy. Further, to explore the developed composite for electromagnetic performances, its permittivity and permeability characteristics are measured using a vector network analyzer. The absorption in the frequency, range of 8.2-12.4 GHz depends notably on the permeability and permittivity of the material. The developed material is cast into the form of rectangular pallets with the aid of binders for measuring the electromagnetic parameters. The microwave absorbing material in the 8.2-12.4 GHz frequency range plays a vital role in stealth technology. These materials are valuable in military applications such as reducing RCS, camouflaging the target, and preventing the EMI and EMC.

**Keywords:** Compatibility, Interface, Magnetization, Shielding.

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# Laser Surface Alloying Assisted Fe-Based Bulk Amorphous Powder Coating: Wear, and Corrosion Study

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## Abstract

Surface degradation occurs due to wear and corrosion of materials. To determine the performance and lifespan of the components, surface degradation is a major apprehension for industrial applications. The nuclear, defence, aerospace, automobile and ship-building industries major capital expenditure undergoes substantially every year for repairing of the components. The serviceable Cu- based, Fe-based steel components are often exposed to corrosion and wear environments. Hence, these industries require an effective surface modification technique to improve the performance of these components and to extend the serviceable life. Surface modification techniques for Cu-based, Fe-based is often performed by spraying and deposition process. But these techniques have disadvantages in respect of adhesion to substrate, processing time, temp. and cost.

In comparison to other coating processes, laser surface alloying is a better technique to produce coatings for high wear and corrosion resistance. In LSA use high energy radiation from an incident laser to use for melting of powder particles of carbides, oxides, nitrides, and borides etc. and a localized layer of the substrate in contact with the powders. In this process to obtain a higher wear and corrosion resistance, substrate free from porosity, cracks and also formed metallurgically bond with substrate. The advantages of LSA process for industrial applications are complex shape components repairing can do it on-site, environmentally friendly, portable, easily handling equipment's, fast production rate and better mechanical properties produced than other coating processes.

The present paper describes the development of a novel LSA coating process to be referred for wear and corrosion resistance applications. Fe-based powder with size range of 25 – 45 µm (spherical) is used as the precursor powder on maraging steel (Grade 350) steel substrate and processed with a continuous wave diode fiber laser of 4000 W power and powder feed rate 7 g/min. Structure-property evaluation of LSA coated substrate was carried out in terms of coating thickness (910 – 940 µm), hardness (≥ 1050 VHN), low porosity (≅1 mm), adhesion strength (≥ 40 MPa) & surface roughness (Rs ≤ 0.655 µm). Further form the wear resistance test using pin-on-disc method and corrosion resistance test using TAFEL method. LSA coated substrates exhibited low weight loss (0.0023 gm), low coefficient of friction (µ ≤ 0.3) and corrosion potential (- 440 mV) matching the requirement of naval materials, like commercially available maraging steel (Grade 250). In this process a wear and corrosion resistance surface layered free from porosity and cracking, is formed with excellent metallurgical bond with substrate.

Key words : Laser surface alloying, maraging steel, amorphous coating, wear resistance, corrosion life effects, high velocity oxygen fuel spraying, coefficient of friction etc.

# Thermo-Mechanical Processing and Microstructural Characterization of Zirconium Alloys Based Advanced Nuclear Fuel Cladding Materials for Extended Burn-up

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## Abstract

Zirconium alloy based cladding materials are preferred as structural material for thermal reactor applications due to low thermal neutron absorption cross-section, corrosion resistance, good mechanical properties in the operating range and formability. Reliable in-reactor performance of these structural materials under extremely harsh reactor environment of temperature, pressure and neutron fluence is largely governed by microstructural features like grain morphology, grain size distribution, crystallographic texture, nature and distribution of precipitates, etc. In general, fabrication route of these cladding materials consists of vaccum arc melting followed by series of thermo-mechanical processing steps. Thermo-mechanical processing (TMP) steps used for the fabrication of zirconium components are aimed at obtaining required dimensional tolerances and optimized microstructure. The in-core life of conventional Zr-Sn series cladding material is limited by corrosion and other hydrogen related degradation aspects. Therefore, in order to enhance the residency period of fuel assemblies and achieve higher burn-up, advanced material of Zr-1%Nb and duplex cladding are essential to be developed and establish the thermo-mechanical processing and phase transformation aspects.

This paper brings out the optimization of various aspects of thermo-mechanical treatment including cold pilgering and vacuum annealing for development Zr-1%Nb tubing and Zirconium alloy based duplex cladding. Detailed metallurgical characterization has been carried out using optical microscopy, scanning electron microscopy, EBSD, Transmission electron microscopy etc. to study microstructural features like grain morphology, grain size distribution, crystallographic texture, nature and distribution of precipitates, etc. The optimization of vacuum annealing parameters was found to be essential in order to achieve fine second phase precipitates which is essential for improve corrosion properties. The dominance of radial basal texture, essential for improved performance against hydrogen related degradation, ensured through suitable cold pilgering schedule. The hydride orientation fraction in radial direction has also been estimated.

**Key words:** Zr-1%Nb, Duplex cladding, microstructure

# High strain rate behaviour of different steels using dynamic indentation technique

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## Abstract

Several processes involving material deformation occur at strain rates that are well above the strain rates possible with standard mechanical testing procedures and equipments. The plastic deformation at high strain rates is encountered in many diverse areas like high-energy rate forming operations, impact events (like automobile bumpers or the impact of a projectile with an armour plate i.e. ballistic penetration of armour materials), solid particle erosion, high velocity sliding wear, and high speed machining etc. As the mechanical properties such as strength and ductility vary with strain rate, it is important to determine such properties under conditions that closely match the expected deformation rates in service. Thus, a detailed understanding of the important material properties, which control the plastic flow behaviour under dynamic loading i.e. at higher strain rate is important. Steel is one of the most extensively used materials for various engineering applications in different industries. The types of steels vary depending on the alloying content, microstructure, heat treatment etc. along with the properties.

In present study, the dynamic indentation tests have been carried out for different steel samples as target materials using non-deformable ball as indenter. The type of steel samples used for the study included single phase, multiphase bearing and armour steels. A tungsten carbide ball was propelled using gas pressure and allowed to impact on the steel samples over a wide range of impact velocities varying from 5 m/s to 140 m/s. The indentation resulted in formation of crater on the sample similar to that of brinell hardness test. The dimensions of the crater thus formed were measured to determine the dynamic hardness of these steels. The dynamic hardness of a material is determined as the resistance to deformation by impacting ball. The detailed results of this study will be presented and discussed.

**Keywords**: High strain-rate, dynamic hardness, steel, impact

# Influence of C/Ti ratio on Phase Transformations, Hot Deformation Microstructure, and Mechanical Properties of Nimonic 901 alloy

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## Abstract

Nimonic 901 is a Ni-Fe-Cr based age-hardenable superalloy primarily designed for producing parts that are subjected to higher operational temperatures up to 760°C. This alloy find applications in aerospace, nuclear and steam power plant industries due to its exceptional combination of high strength and oxidation resistance at elevated temperatures, which is basically derived from significant additions of Cr, Mo and Ti. The addition of Cr & Mo gives good surface stability and solid solution strengthening, whereas Ti contributes to strengthening by the precipitation of ordered γ′ ($Ni_3(Ti/Al)$) phase. Besides γ′, the 901 alloy also develops several stable and metastable secondary phases such as MC, $M_{23}C_6$, Sigma and Laves phase during processing and in-service exposure.

The present study aims at understanding the role of C/Ti ratio in defining the solidification behavior and subsequent hot deformation features of 901 alloy through microstructural investigations. It has been seen that the C/Ti ratio influence the phase fraction of the MC and Laves particles present in the forged material, which is attributed to the change in terminal solidification behavior of the 901 alloy from L→γ+MC in higher C/Ti ratio material to L→γ+MC+Laves phase in material with lower C/Ti ratio. Furthermore, the MC carbides & Laves phase that form in interdendritic regions during solidification would retain and arrange into broken particle stringers during hot forging and significantly influenced the mechanical properties of the material. It is observed that the evolution of primary carbide stringers in larger degree for higher C/Ti ratio material post hot forging has deteriorated the transverse mechanical properties in both as-forged and precipitation heat treated condition. The fractography studies have indicated that the formation and propagation of cracks along the carbide stringers due to the impingement of slip bands limit the tensile ductility & impact properties in transverse direction and void generation near carbides limit creep life. A CALPHAD based software Thermo-Calc has been used in the present study to identify the stability of different phases in 901 alloy, and the results have indicated that the MC based carbides are stable up to solidus temperature and are difficult to dissolve. In contrast, Laves phase is metastable and can be dissolved. So, in-order to improve the hot workabilty of 901 alloy, the present study also addresses the dissolution kinetics of Laves phase through systematic solutionization heat treatment studies. The results can be utilized to develop in-process homogenization heat treatment cycle before going for final forging reduction.

Overall, this kind of investigation marks necessary step towards optimization of alloy chemistry and deformation processes for producing technologically sound components.

Key words: Superalloy, Nimonic 901, Phase Transformations, Thermo-Calc, Carbide stringers, Laves phase

# Praseodymium Oxide to Praseodymium Chloride: A Chlorination Approach

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**Abstract**

The present study involves in a complete investigation into the production of praseodymium chloride ($PrCl_3$) from praseodymium oxide ($Pr_6O_{11}$) through chlorination process. The process draws on the chlorination of $Pr_6O_{11}$ to praseodymium chloride ($PrCl_3$) using ammonium chloride ($NH_4Cl$) as the chlorinating agent. The kinetics of the chlorination process were calculated by knowing the effects of temperature, reaction time, and the molar ratio of $NH_4Cl$ to $Pr_6O_{11}$ on the yield and purity of $PrCl_3$. The reaction was carried out in the temperature range of 250°C to 400°C under inert argon atmosphere. All the reactions were carried out in a horizontal fixed quartz tube reactor. Based on the reaction conditions, 97% yield of $PrCl_3$ was obtained. Characterization of the $PrCl_3$ performed using XRD, FE-SEM, EDS and ED-XRF. The results demonstrate that chlorination process is a viable method for producing praseodymium chloride with 97% yield having potential applications in advanced materials, magnet production, and other high- technology fields.

Key words: $PrCl_3$, Chlorination, Kinetics, Solid- Solid Reaction and Fixed bed Reactor.

# Effect of Cerium addition on transient oxidation behaviour of β-NiAl bond coats

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## Abstract

In the last three decades, "Reactive Element Effect (REE)" has gained significant attention due to its dramatic effect on oxidation behaviour of β-NiAl bond coats. A minor addition of reactive elements such as Hf, Zr, Ce, Y, Ta etc. results in significant improvement in oxidation resistance as reported in m any literatures. Reactive elements are those having higher oxygen affinity and larger atomic size in comparison to Aluminum. Though the effect is well known and quite popular in this field, however; the mechanisms proposed to explain this effect is still under observation.

In this work the effect of 1 atom % Cerium addition on transient oxidation behaviour of β-NiAl at 11000C is studied. The alloy samples were synthesized using Vacuum arc melting under Argon atmosphere. The samples were polished using standard metallographic practices and then oxidized in a muffle furnace. The samples were examined using scanning electron microscopy and x-ray diffractometer at different oxidation times. Aim of this study is to observe the change in elemental concentration across the grain boundary region and its effect on oxidation behaviour.

Keywords: Reactive Element Effect, β-NiAl, Cerium, oxidation resistance, elemental concentration

# Tool-life Studies in Laser-assisted Turning of IN625 alloy with Uncoated and CrAlSiN Nanocomposite Coated Tungsten Carbide Inserts.

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## Abstract

The need for high temperature materials is increasing with the growth in nuclear, aerospace, power and automotive sectors. The high-temperature materials such as Inconel 625 (IN625) alloy are difficult to be machined by conventional strategies due to their high strength and work-hardening properties. The surface finish, dimensional accuracy, and precision achieved in traditional machining processes are marginal and require frequent tool changes due to high tool wear rate. The present study investigates the machinability of IN625 alloy using uncoated and CrAlSiN nanocomposite coated tungsten carbide inserts in laser-assisted turning (LAT). The hot-hardness of the IN625 alloy was studied systematically and observed significant reduction in hardness beyond 850$^0$C. This aided in the selection of suitable laser power and process conditions for LAT experiments. The cutting forces in three mutual directions, maximum flank wear ($VB_{Bmax}$) and surface roughness ($R_a$), are the responses considered for analysis. The results revealed that a 9%, 70% and 59% reduction of cutting forces for uncoated tools, and a 31%, 77% and 69% reduction for CrAlSiN coated tools in radial or thrust ($F_x$), axial or feed ($F_y$), and tangential or cutting ($F_z$), directions were observed in comparison to conventional turning (CT). The maximum flank wear ($VB_{Bmax}$) and surface roughness ($R_a$) were observed to be reduced by 33%, 28% respectively for the uncoated tool, and 46% and 56% respectively for the CrAlSiN coated tool in comparison to CT. The abrasion and chipping are found to be the predominant wear mechanisms in CT and the adhesive wear was found to be predominant in LAT. Subsequently, tool life was evaluated and compared as per ISO 3685:1993 standard. The results showed 40% and 160% increase in tool-life for uncoated and CrAlSiN coated tools respectively in LAT in comparison to conventional turning.

Key words: Laser-assisted machining, turning, IN625, Tool-life, Tungsten Carbide, CrAlSiN, Maximum flank wear.

# Thermomechanical Fatigue Behaviour of Single Crystal Ni Base Superalloy

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## Abstract

Single crystal Nickel-base superalloys are used for fabricating aerofoil castings (blades and vanes) of modern gas turbine aero-engines through vacuum investment casting route. As these components experience severe temperature gradients during service, in order to mimic the service loading conditions, thermomechanical fatigue (TMF) behaviour of a single crystal Ni base superalloy has been investigated in the present study. Two temperature intervals viz. 500°C ↔ 850°C and 600°C↔ 950°C, corresponding to the service application of the superalloy, were selected for investigating TMF behaviour. TMF behaviour was studied at various mechanical strain amplitudes ranging from 0.5 to 1.0%. Out of the two features of as-cast materials viz., carbide particles and shrinkage pores, carbide particles were found to be influencing the crack initiation phase of the superalloy.

Keywords: Thermomechanical Fatigue, Ni base superalloy, Carbides.

# Studies on Microstructural and Mechanical Properties of Squeeze Cast Al-Mg-Mn-Sc-Zr Alloy

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## Abstract

The addition of rare earth elements (REEs) in aluminium alloys enhances physical and mechanical properties of the alloys. Scandium (Sc) added Al-Mg alloys offer 4-5% reduction in density as compared to the conventional Al-Cu (AA 2xxx) alloys. Addition of Sc refines grain structure during casting, enables precipitation hardening via formation of $Al_3Sc$ phases, and stabilizes grain boundaries. Sc-containing Al-Mg alloys with a minor addition of Zr have shown great potential for use in the aircraft fuselage structure owing to their excellent strength, ductility, corrosion resistance, and weldability. In the present study, Al-Mg-Mn-Sc-Zr alloy were prepared by melting and casting of pure Al, Al-2%Sc, Al-5%Zr, Al-20%Mg, and Al-10%Mn master alloy ingots. Gravity die casting, and squeeze casting were adopted to cast the molten Al-Mg-Mn-Sc-Zr alloy. The structural and microstructural characterization of the developed alloys were performed using X-ray diffraction, optical, and scanning electron microscopic techniques. The mechanical response of the Al-Mg-Mn-Sc-Zr alloys were evaluated at room temperature using tensile testing at a strain rate of $8 \times 10^{-4}$ $s^{-1}$. The coefficient of thermal expansion as a function of temperature up to 500 °C was evaluated using thermo-mechanical analyzer. The optical micrographs and scanning electron micrographs of Al-Mg-Mn-Sc-Zr alloy show the presence of FCC-Al matrix, β-$Al_3Mg_2$ and $Al_3$(Sc, Zr) phase. The tensile test results show yield strength of 116 MPa in as-cast and 150 MPa in T6 condition for Al-Mg-Mn-Sc-Zr alloy. Similarly, the ultimate tensile strength is 226 MPa with an elongation of 10% in the as-cast condition and 283 MPa with an elongation of 11% in the T6 condition. The coefficient of thermal expansion of the Al-Mg-Mn-Sc-Zr alloy at ambient temperature is $13.5 \times 10^{-6}$ /K in the as-cast condition and $13 \times 10^{-6}$ /K in the T6 condition. Al-Mg-Mn-Sc-Zr alloy has a great applicable prospect in terms of its use in the aircraft fuselage structure.

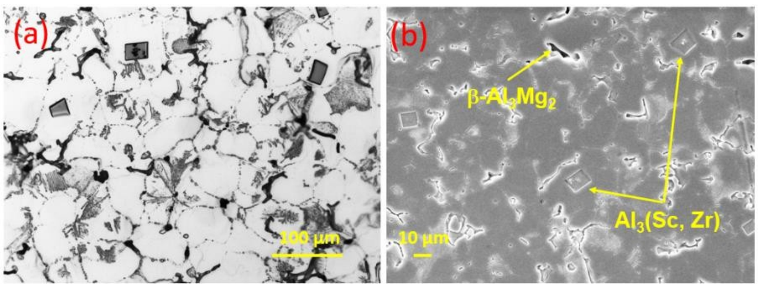


Fig. 1: (a) shows the optical micrographs of Al-Mg-Mn-Sc-Zr alloy and (b) shows the SEM images of Al-Mg-Mn-Sc-Zr alloy respectively.

keywords : Rare-earth added Al alloys, Aerospace alloys, Wrought alloys, Squeeze casting, Precipitation hardening

# Quality Control through Destructive testing during manufacture of Complex & Critical Nuclear forgings

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## Abstract

Nuclear energy is one of the prominent sources of Green energy power production in the world. Indian Government has also taken focused steps in generating higher quantum of electricity in the country through this route in the near future. Nuclear reactors use heat produced in atomic fission to boil water and produce pressurized steam. This steam is routed through the reactor steam system to spin large turbines blades that drive magnetic generators thus producing green electricity. Typically, one such nuclear reactor consists of four Steam Generators (SG) which are used to generate the steam required for electricity generation. Each SG is fabricated by welding several critical nuclear grade forgings which are required to be manufactured with highest levels of quality in destructive & non-destructive testing. Destructive testing is a crucial step in ensuring quality of the said nuclear grade forgings which includes:

Tensile tests (RT and elevated temperature)
Impact tests at various temperature
Drop-weight tests
4. Hardness
5. Microstructure
6. Grain size
7. Inclusion content
8. Chemical analysis
9. Gas analysis

Total number of destructive tests required to qualify a single forging is around 250 Nos.,
The specimens are tested in as-supplied condition as well as in Simulated Post Weld Heat treatment (SPWHT) condition to ensure mechanical properties are satisfactory in both supplied & even after Post Weld Heat Treatment (PWHT) condition. PWHT is required to be carried out after welding various components during the fabrication process but in simulation PWHT of forgings addition cycles for repair is also considered. Generally, this SPWHT is a multi-step cycle with intermediate soakings at ~550°C and 600°C with specific heating and cooling rates which takes around five days to complete. Each forging has to undergo several complex tests viz., Room temperature and High temperature tensile tests at design temperature of the equipment ~ 350°C, Sub-zero impact tests to determine the Fracture Appearance Transition Temperature (FATT) and Drop weight tests to determine the Nil Ductility Transition Temperature ($T_{NDT}$) to ensure the forging has adequate toughness and numerous chemical and microstructure analysis to check the chemical compositional uniformity as well as metallurgical uniformity across the entire volume of the forging. To ensure the accuracy, reliability and authenticity of the test results, adequate care has to be taken during sampling, sample preparation, machine calibration, Training of testing personnel and proper audits and accreditation of the testing laboratory. This paper outlines the criticalities of the destructive tests involved in testing of nuclear grade forgings and testing methodology adopted by L&T Special Steels and Heavy Forgings laboratory to ensure reliable results every time.

Key Words: Nuclear, Heavy Forgings, Drop Weight Testing, $T_{NDT}$, Fracture Appearance Transition Temperature (FATT), Destructive testing.

# Uranium mineralogy and its impact on the leachability of U from the Geratiyon-ki-Dhani ore sample of Rajasthan

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## Abstract

Uranium fission-derived green energy ranks as the second most abundant clean energy source characterized by its high energy density, low land and carbon footprint. Mineralization of U occurs in geologically favorable settings, with hard rock deposits serving as a significant source. The extraction of U from primary resources solely depends on hydrometallurgical techniques viz. leaching, purification, and precipitation. These hydrometallurgical processes primarily controlled by gangue, the mineralogy of U is of equal significance.

Mineralization in Geratiyon-ki-Dhani (GKD) ore is related with albitite which are red colored due to presence of iron. Gangue mineralogy of GKD consists of abundant albites+quartz (85.58%), calcite (3.44%), biotite+chlorite (2.41%) and tourmaline. Ore minerals comprise refractory U bearing phases (5.43%) viz. (1) Davidite, (2) Brannerite and (3) U-Ti-Fe complex along with rutile+titanomagnetite (2.92%) and chalcopyrite (0.03). Despite davidite being the predominant U mineral, it produced less dense alpha tracks on LR-115 film in comparison to brannerite, attributable to its lower mole percentage of U. Heavy media separation conducted with methylene iodide (sp. gr. 3.33) resulted in the majority of U being concentrated in the heavy fractions, with the exception of the coarse (+70#) light fraction. The unusual trend observed in this coarse light fraction is due to the close association of davidite and calcite, as confirmed by microscopic investigations. Atmospheric agitation leaching resulted in poor leaching efficiency ca. 70% due to presence of refractory phases. Pug and cure leaching were found to be effective with ca. 90% leach recovery. Post leaching, leach residue was examined in microscope showing remnants of davidite, rutile and fewer titanomagnetite indicating refractory nature of these U-Ti-Fe bearing minerals. Leachability of U in GKD is dictated by refractory mineralogy.

**Keywords**: Geratiyon-ki-Dhani, Refractory U mineral, Pug & Cure leaching.

# Microstrucutral Characterization of Fe-Cr-Ni-Mn-C based Cast Lean-Duplex Stainless Steel with different Heat treatment conditions.

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## Abstract

14X18H4r4 is a Russian based Fe-Cr-Ni-Mn-C Cast-Lean Duplex stainless steel that is extensively used in the intricate engine parts at Cryo temperature applications of the satellite launch vehicles. Duplex stainless Steel takes the advantages of the both Ferritc and Austenitc grade properties, exhibits good strength and good corrosion resistance.This steels were developed to reduce the inter granular corrosion problems in the high carbon austenitc Stainless steels. In the current study, different heat treatments with different cooling mode were conducted to understand the Cr-carbide precipitation and its effect on sensitization and intergranular corrosion behaviour. Heat treaments were carried out at 1060°C for 1hr followed by Furnace cooling, Air cooling and Water cooling. Hot Isostatic Pressing (HIP) operation was also performed for defect healing. Hot Isostatic pressed sample shown lamellar carbides between the Austenite and ferrite interface and preferentially inside the delta ferrite phase. Furnace cooled specimen showed more lamellar type and less discrete type carbides. Air cooled specimen showed less lamellar type and more discrete type carbides. Water quenched specimen revealed only discrete carbide particles. Water quenched specimen heat treated at $1150^0$ C not shown any carbide and fully dissolves all the carbides in the matrix.

Key words: Duplex Stainless Steels, 14X steel, Heat treatment, HIP, Cr-carbide precipitation.

# Micro-segregation Behavior of Direct Energy Deposited Haynes 282 with Varied Component Thickness

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## Abstract

Metallic additive manufacturing (AM) as a mainstream technique for the fabrication of complex geometrically metallic components laser cladding with rapid prototyping into a solid freeform fabrication process. It has attracted extensive interest in many high temperature applications as aero-engines, land-based gas turbines and ultra super critical power plants. However, additive manufacturing provides very high cooling rate during solidification, thereby leading to strong elemental segregation at different length scale for thin and thick components. Deposit thickness for thin parts has a more significant impact on the microstructure and subsequent room (RT) and elevated temperature (650 °C) tensile properties compared to thick parts. Thick builds when subjected to conventional heat-treatment which can effectively homogenize the microstructure transition from columnar-dendritic grain structure presented in the as deposited (AD) condition to recrystallized equiaxed grain structure, which results same mechanical properties as conventional values reported in literature for IN718. In contrast, thin parts maintaining columnar grain features during same heat-treatment conditions which shows better yield strength because of large amount of residual stresses left but lower ductility is the reflection of delta phase present in the microstructure

Current study for Haynes 282 is to show the capability of the directed energy deposition process to manufacture homogeneous components with varying thickness for high temperature application after a proper heat treatment, compared to as-deposited materials and their effect on the performance of the materials in as received and heat-treated conditions.

**Keywords:** Ni based superalloy, Additive Manufacturing, Segregation, Thickness variation

# UNDERSTANDING THE EFFECTS OF Cr CONTENT ON ISOTHERMAL OXIDATION BEHAVIOUR OF HIGH Nb CONTAINING γ-TiAl ALLOYS BY CO- RELATIVE MICROSCOPY

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**Abstract**

Gamma Titanium Aluminides (GTAs) are promising candidates for replacing Ni-based superalloys in aerospace applications due to their low density and superior high-temperature properties. However, these alloys lack oxidation resistance at elevated temperatures.[1][2] Many strategies were explored to enhance this property, but the studies are mostly limited to ternary systems with a limited amount of 4th alloying element and low temperatures (up to 900 $^{o}$C).[3][4][5]

This study investigates the effect of Cr content on the oxidation resistance of Ti-45Al-8Nb (GTA-0Cr) at 1000 $^{o}$C. 5 variants of GTAs {GTA-0Cr, GTA-(2, 4, 6, 10)Cr-0.2B}[6] were oxidised isothermally for 100 hours in dry air. It was found that a stable and compact oxide scale enriched with Cr was formed in the GTA-10Cr, whereas other variants showed spallation. Raman spectroscopy studies suggest the presence of Nb-based oxides, while XRD patterns reveal the presence of TiN & AlNbO4 in all variants except GTA-10Cr. Results from the current study will be correlated to understanding the oxidation behaviour of this new alloy system and will be presented in the paper.

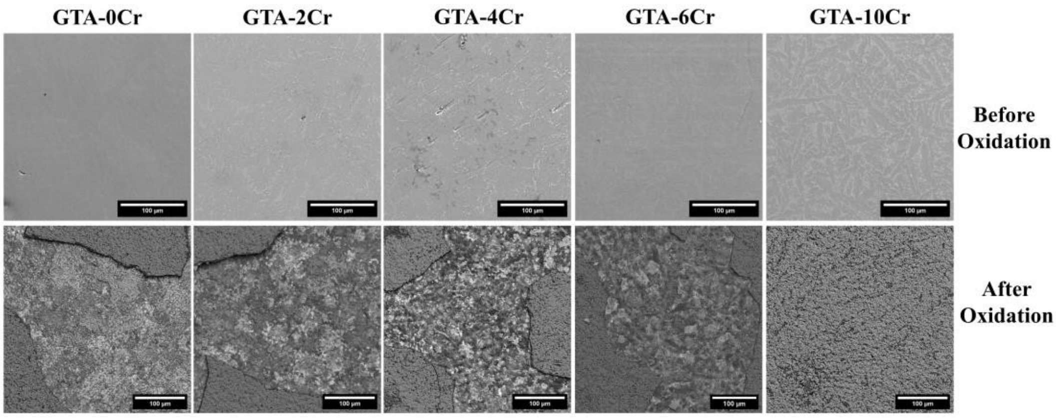


**Image: SEM micrographs - before and after oxidation**

**Keywords:** γ-TiAl, high-temperature oxidation, co-relative microscopy

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# Effect of heat-treatment on hardness and microstructure evolution of armour steels

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## Abstract

Armour steels are ultra-high strength steels, which derives their high hardness and strength from quenching and tempering treatment. However, the temperature at which austenitization and tempering is carried out determines the optimum combination of mechanical properties. In addition, during the heat treatment of thick sections, there is a possibility of gradient cooling due to difference in cooling rate at centre and surface. Hence, a-prior knowledge of hardenability of the steel is important to decide the feasibility of developing thicker sections of these steels for various applications. Further, not only mechanical property but ballistic performance of the steel is one of the key indicators to qualify armour steels for different applications.

In this present work, two different armour steels namely Rolled Homogeneous Armour (RHA) steel and High Hardness Steel (HHS) was selected for the study. The austenitization temperature was varied to study its effect on hardness in as-quenched/as-tempered condition. Further, tempering temperature was varied for a given austenitization temperature to understand its effect on hardness and microstructure evolution. To study the hardenability of these steels standard Jominy End Quench tests was carried out followed by measurement of hardness.

Key Words: Armour steels, Ballistic Performance, Austenitization, Tempering and Hardenability.

# Chemical Milling of titanium alloy tubes for improvement of transverse ductility.

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**Abstract**

Titanium alloys are widely used in Nuclear, Space & Defense sectors, due to their high specific strength, excellent corrosion resistance and weldability. Titanium alloy tubes are manufactured by various passes of thermo-mechanical processing steps. Multiple passes of cold pilgering with intermediate vacuum annealing followed by chemical milling / acid pickling & finishing operations are carried out to get the required final size. After final stage fabrication, these tubes are subjected to stringent mechanical, metallographic & NDT testing. Flattening test is one such test carried out to ensure the ductility of tubes under compression. Owing to the work hardening & adhesive properties of the titanium alloys many surface imperfections & micro cracks are generated during the cold working process. These surface imperfections reduce the transverse ductility of tubes and results in failure of the tubes in the flattening test. Once the flattening test specimen is found visible cracks during the test, the ductility of tube is considered unqualified, and leads to rejection of the tube without further rework. This paper describes the root cause for formation of surface imperfections and chemical milling method for improvement of transverse ductility of titanium alloy tubes.
Different experiments were devised to understand the root cause and phenomena of surface imperfections during cold working by varying % cold work, Q-factor, feed rate etc. Various metallographic techniques were utilized to study the effect of cold working parameters on the morphology of surface imperfections. Further, new process of preferential ID chemical milling process was introduced to remove the surface imperfections Several experiments were carried out by varying the parameters of pickling solution like flow rate, ratio of [HF]/[HNO3], Titanium ion concentration, temperature for optimization of the process. Metallographic analysis of the chemical milled tube samples was found to be free from surface imperfections and 100% acceptance was obtained in flattening test. Various grades of titanium alloy tubes of different sizes varying from 5 mm to 45 mm meeting all the mechanical, metallurgical & NDT testing were supplied to nuclear, defense & space sectors.

Key words: Titanium alloys, ductility, flattening test, acid pickling.

# Towards the phase stability of Lanthanum Phosphate coating deposited by thermal spray methods

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**Abstract**

Owing to its low thermal conductivity, high melting point and inert behaviour towards reactive metals, Lanthanum phosphate (LaPO4) appears to be a promising coating material for thermal protection applications. To develop and study the same, the free-flowing powder (particle size range 20-45 µm) for the coating purpose was developed using spraying drying. Thermal Sprayed (Plasma and Flame spray) LaPO4 coating using the developed powder along with the optimized processing window for coating deposition is established to avoid unwanted phases which may form during a high-temperature coating deposition process. The superior coating deposition efficiency is found under the optimized deposition conditions. Further, the formation of unwanted phases in the coating was completely avoided. The deposited coatings have been tested for thermal cycling, and flame spray coating results show no spallation. Similar results under simulated high pressure and temperature conditions were observed. Overall, the research finding provides a more comprehensive understanding of powder development and coating deposition technology seems to be promising for the adoption of LaPO4 as a coating material.

key words : Thermal spray, Thermal Barrier, coating, FESEM

# Tailoring the High Temperature Micromechanical Behavior of Inconel 718 using Significant Microstructural Modification

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## Abstract

Inconel 718 is a precipitation hardened Ni-based alloy which is widely used in the turbine engine application with operating temperature below 650ºC. Excellent properties of these high temperature alloys can be traced back to its unique microstructure consisting of FCC matrix, intermetallic precipitates γ′ (gamma prime, Ni3Al/Ti) and γ′′ (gamma double prime, Ni3Nb). Other brittle phases such as δ (delta, Ni3Nb) and carbides can be beneficial or detrimental depending on their location and distribution. The strong correlation between processing (heat treatment parameters), underlying microstructure and the resulting macroscopic properties, presents an avenue for achieving the Inconel718 with desired macroscopic properties attained by tailoring the microstructure. In the present work, we made a sincere effort to improve the upper limit of service temperature (~650ºC) for these polycrystalline Ni-based superalloys without compromising strength and ductility. Increase in the upper limit of service temperature paves the pathway for higher turbine inlet temperature and thereby increasing combustion efficiency and reducing the carbon emission from the aviation sector.

We adopted various heat-treatment strategies for achieving a deeper understanding of the correlation between heat-treatment parameters, evolved microstructural features and the resulting deformation behavior. By varying aging time at different stages and studying effects with and without solution treatment and delta precipitation shown a significant variation in the size, shape (morphology), volume fraction, location and distribution of the intermetallic precipitates. The microstructural evidence is collected from various materials characterization techniques including optical microscope, scanning electron microscope, energy dispersive x-ray spectroscopy, backscattered imaging. The resulting micromechanical behavior was verified by conducting micromechanical testing, such as uniaxial tension, creep tests with varying strain rates at both room temperature and elevated temperatures. Eventually, these experimental observations related to microstructures and micromechanical behavior enabled us to correlate the process-microstructure-property aspects of these Ni-based superalloys.

A physics based micromechanical model for the Inconel 718 has been developed to simulate and predict the deformation behavior for operating conditions and complicated boundary conditions (BCs) which are nearly impossible to test through experiments in terms of materials, resources cost, and time consumed. It has been developed as a UMAT under the framework of Abaqus which consists of deformation mechanisms observed in experiments. It follows the concepts of crystal plasticity and is able to capture the influence of factors related to operating conditions such as temperature, crystal orientation (texture), grain-size influence, strain rate dependence, cyclic softening and kinematic hardening. The proper working of the model has been validated against experimental observations related to materials characterization and macroscopic deformation behavior.

key words: Inconel 718, Micromechanical modelling, Precipitate strengthening

# Strengthening by primary, secondary and tertiary gamma prime in 720Li alloy

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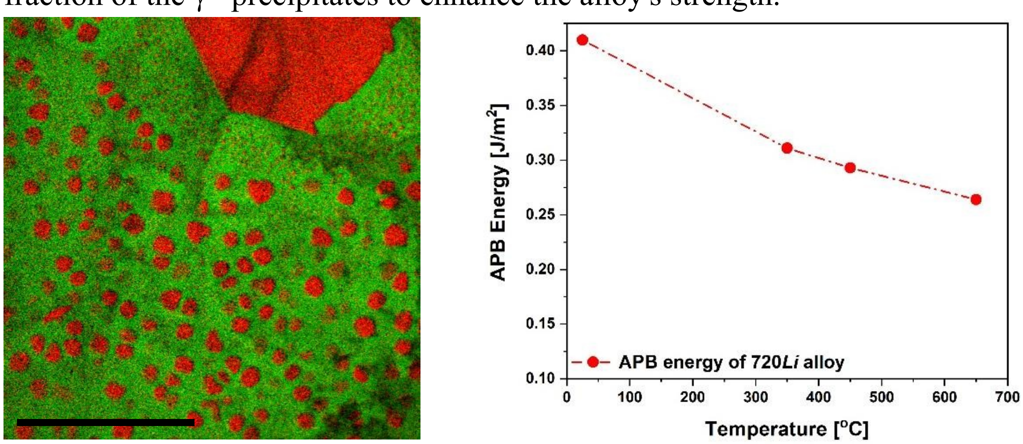
## Abstract

Nickel-based superalloy 720Li is a promising material for manufacturing aero-engine gas turbine disks due to its excellent high-temperature strength, maintaining integrity up to 650°C. The alloy's high temperature strength is primarily derived from its γ'-precipitates, which vary in size and are classified as primary, secondary, and tertiary γ'. The average sizes of these precipitates are 1.5 µm, 105 nm, and 12.5 nm, respectively. An energy-filtered TEM (EF-TEM) micrograph (Fig. 1a) illustrates the size distribution of the primary and secondary γ'. The presence of these three types of γ' precipitates leads to distinct dislocation configurations, where weak or strong coupling dislocations shear the γ'-precipitates based on their size. To understand the individual contribution of each γ'-precipitate type to the alloy's yield strength, the shear stress required to deform them was calculated. The antiphase boundary (APB) energy, a key factor in determining γ' shearing, was measured using the weak beam TEM technique and is shown in Fig. 1b. The APB energy was calculated up to 650°C, beyond which the deformation mechanism transitions from APB shearing to stacking fault shearing. By considering the APB energy, the sizes of γ'-precipitates, and dislocation line tension, the critical shear stress (τCRSS) required to shear the primary, secondary, and tertiary

γ' was determined to be $\tau^{Primary}_{CRSS}$ = 81.54 MPa, $\tau^{secondary}_{CRSS}$ = 24 MPa, and $\tau^{tertiary}_{CRSS}$ = 79.3 MPa, which correlates well with the alloy's room temperature yield strength. As the temperature increases, the discrepancy between the calculated and observed yield strength grows, likely due to changes in deformation behaviour. This study provides valuable insights for optimizing the size and volume fraction of the γ'- precipitates to enhance the alloy's strength.




(a) (b)

Fig. 1: Showing (a) EF-TEM image of secondary and tertiary [redacted]', and (b) APB energy of 720Li alloy with respect to temperature.

# Real-Time TEM Insights into Austenite Reversion Dynamics in Bainitic Steel During Heating

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**Abstract**

Austenite reversion in bainitic steel is a critical phenomenon influencing the mechanical properties and phase stability of advanced high-strength steels. This study investigates the microstructural evolution and reversion kinetics of austenite during heating below the inter-critical temperature in bainitic steel. Utilizing in-situ heating transmission electron microscopy (TEM), the reversion process was observed in real-time, revealing the nucleation and growth mechanisms of austenite from retained bainitic ferrite. The analysis highlights the role of carbon diffusion and the influence of alloying elements such as Mn and Si on the stabilization of reverted austenite. Additionally, the formation of stacking faults and growth faults during the reversion process was characterized, providing insights into the underlying mechanisms that govern phase transformation. These findings contribute to a deeper understanding of the austenite reversion process, offering valuable guidance for the design and thermal processing of bainitic steels to optimize their performance in demanding applications.

**Keywords**: Austenite reversion, Bainitic steel, In-situ TEM, Phase transformation

# Eliminating Edge Waviness Issue in High Strength Dual Phase Hot Rolled Grades for Cold Rolling at Hot Strip Mill Kalinganagar

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## Abstract

Newly developed hot rolled Dual Phase (DP) grades for further cold rolling were encountering severe shape issues post hot rolling.

The shape issue was edge waviness on both edges of the hot rolled coil post coiling when they were opened for surface and shape inspection at the Coil Dividing Line. (CDL).

This was resulting in coil parting and led to poor coil weight for further cold rolling applications. (Approximately 30% of the coil length was affected).

A scientific study was done to understand the microstructural changes being encountered by grade during hot rolling along with comprehensive study of the hot mill process parameters.

An innovative yet cost effective approach to encounter this problem was thought of and trialled in various campaigns.

Better than expected results were obtained and this resulted in full coils being dispatched to the end customer (Cold Rolling Mill) without any loss due to parting at HSM.

The paper captures the journey of this team to overcome and eliminate this problem of shape.

**Keywords:**
Hot Rolling Flat; Work Roll; Finishing Mill ; Crown , Dead Flat Rolling Curve

# Continuous Monitoring of Flue Gas in two furnace from single Oxygen Analyzer

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## Abstract

The Hot Strip Mill (HSM) makes hot rolled strips (Coils, Sheets & Plates) from cast slabs. In HSM, the slabs are reheated in oxidizing furnaces atmosphere at a high temperature before hot rolling. HSM TSJ has three furnaces, namely Fce#1, 2 and 3. Fce #1 and #2 are recuperative types and Fce#3 is regenerative type. Manual gas sampling of flue gas to check for oxyzen % took place from the recuperative zones of Fce #1 and #2 which were prone to STF hazards and gas exposure while opening the sampling point. Sampling used to happen thrice a week. Recuperative zones are at remote locations and hard to access and prone to gas exposure and burn which may lead to injury. So, it was decided to install a continuous monitoring of Oxyzen analyzer in the waste gas circuit of reheating furnace. Hazards related to manual sampling of flue gas from the waste gas circuit has been eliminated and lead indicator monitoring helps in reduction of excess air and improvement in yield with reduced scale generation. Also, continuous measuring system reduced the cost incurred in deploying an employee for flue gas sampling and analysis.

Fig. 1: Laser based oxygen analyser

**Key words** : Oxyzen analyzer, flue gas, reheating furnace, Hot Strip Mill, etc.

# Reduction in flying scales during descaling through in house primary descaler hood modification

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## Abstract

When steel is heated in the course of rolling or heat treatment, the reaction of oxygen on the hot metal surface inevitably produces a very hard oxide layer, known as scale. This scale not only affects the appearance but also the quality of the material. For the production of high-quality hot-rolled products, it is therefore essential to remove these impurities from the surface. In hot rolling mills, descaling equipment ensures high surface quality. During descaling, the material surfaces are sprayed with water under high pressure to blast off and completely remove the scale. These scales fly off with great velocity and fall on mill floor and roller motor cables making it susceptible to fire. Modification was done in the primary descaler hood by extending the hood and using removable flappers so that the scales are contained within the hood and doesn't fly off, there by improving safety.

Fig. 1: Primary descaler hood


Fig. 2: Use of removable flapper

key words : Primary, descaler, scales, flapper

# Optimisation of cooling parameter to minimise scale formation during hot rolling of low carbon electrode wire rod

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**Abstract**

Scale formation not only impacts product quality but also significantly affects processing efficiency and downstream operations. This study investigates the influence of cooling rate and process conditions on scale formation and subsequent mechanical descaling efficiency in the production of low carbon electrode wires. Controlled hot rolling experiments were conducted with varied cooling parameters during Stelmor cooling, resulting in the formation of predominantly oxide layer of Wustite (FeO) with less transformed magnetite. In contrast, the conventional method showed the presence of magnetite ($Fe_3O_4$) and haematite ($Fe_2O_3$). Surface characterization using X-Ray Diffraction (XRD) complemented these observations. Mechanical descaling trials were performed to evaluate the effectiveness of scale removal. The study found that modifying the cooling rate during Stelmor cooling led to a significant 30% reduction in scale compared to conventional cooling methods. Furthermore, optimized cooling parameters resulted in a minor increase in tensile strength by 3 MPa. Implementing these optimized cooling parameters offers competitive advantages in low carbon electrode wire rod production, ensuring that the final product meets high standards for quality and performance. These findings underscore the importance of precise cooling control in industrial processes to enhance both operational efficiency and product integrity.

**Key words : Oxide layer, Descaling, Stelmor**

# Characterization and Control of Splash mark on the surface of Hot dip Zn-Mg-Al Coating

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## Abstract

Zn-Mg-Al steel, an alloy coating consisting primarily of zinc, aluminium, and magnesium, represents a significant advancement in corrosion-resistant steel coatings. The inclusion of magnesium enhances the coating's self-healing properties, significantly reducing corrosion rates compared to traditional galvanized steel. Despite its advantages, the implementation of Zn-Mg-Al steel faces significant challenges related to surface defects. One notable surface defect in Zn-Mg-Al steel coatings is splash marks.

Splash marks in Zn-Mg-Al steel coatings are a critical surface defect that can significantly impact the aesthetic and protective properties of the material. These marks, which appear as irregular spots or streaks on the coating surface, result from various issues during the coating process. Understanding the causes, implications, and mitigation strategies for splash marks is essential for improving the reliability and performance of Zn-Mg-Al steel in various applications. In the case of this metallic coating type, Top dross generation at the Zinc pot and snout area are more in comparison with conventional GI and GA which will increase the probability of this defect. EDS and SEM analysis of splash mark defects in Zn-Mg-Al steel coatings are done to examine the surface morphology, elemental composition, and presence of contaminants, this analysis helps to identify the root causes of splash marks and informs the development of targeted strategies to improve coating quality and performance.

Addressing the issue of splash marks in Zn-Mg-Al steel coatings requires a comprehensive approach, including optimizing Wiping Medium, Pressure, distance, height and angle. Also keeping the snout and pot area clean is essential. Pot level maintenance influences the consistency of the coating application, and improper levels can contribute to defects such as splash marks. By focusing on these areas, the quality and performance of Zn-Mg-Al steel coatings can be significantly improved, ensuring their effectiveness in various demanding applications.

**Key words : Zn-Mg-Al coating; Splash marks; Coating defect; Surface Quality**

# Reduction of Yield Strength variability in 420LA Steel: Design & Process Optimization

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## Abstract

Variability in the mechanical properties especially Yield Strength (YS) of steel strips significantly affects the structural performance of manufactured components. This study focuses on finding root cause of YS deviation issues in Cold Rolled steel 420LA, a High-Strength Low-Alloy (HSLA) grade widely used in the automotive sector for chassis reinforcement.

A comprehensive statistical approach complemented by machine learning model on the Mass Production Data (MPD) was employed to analyse the effect of design (chemistry) and process parameters at hot strip mill and continuous annealing line. Pearson correlation coefficients and variance analyses were utilized to identify critical parameters that significantly impact yield strength. Based on the analysis, variation in Nitrogen exhibited correlation with YS. In addition to chemistry, parameters such as RMX (Roughing Mill) Temperature at HSM, cooling rate & soaking temperature at CAL (Continuous Annealing Line) show significant relation with yield strength. Microstructural analysis further validates the influence of these process parameters. It was observed that batch exhibiting pearlite banded structures in the rolling direction show variable yield strength along the length of the coil compared to the batch with more homogeneous microstructures.

To reduce variability in YS, Ti/N cycles were employed during CAL process. Further optimization and fine tuning of parameters to maintain the cooling rate brought down the YS variation from 70-90 MPa to 20-30 MPa .

**Key words : HSLA, YS, CAL, HSM, Ti/N**

# Improvement of Gauge Variation in DP980 Steel Grade

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**Abstract**

In the manufacturing process of Dual Phase 980 grade steel, a critical issue of gauge variation affecting approximately 200 meters of inner diameter of the cold rolled coil was identified, leading to significant material yield loss, surface imperfections, and equipment damage. Microstructural analysis of samples from regions exhibiting high and low gauge variations revealed distinct differences in phase fractions. The results indicated an abundance of ferrite or upper bainite in regions with thinner gauges indicating a very low cooling rate. These phases, characterized by lower hardness compared to lower bainite, tempered martensite, and fresh martensite, are more susceptible to deformation under identical rolling forces in Cold Rolling. Analysis of the gauge graphs unveiled a recurring pitch matching the outer diameter of the Hot Rolled coil. Further evaluation focused on identifying sources of external heating.

Through systematic trials and detailed analysis, it was discerned that the gauge variation originated from the saddle heating due to thermal transfer from the hot coil. To validate this finding, coils were tested by directly lifting them post-coiling (from down coiler) using a crane, bypassing the saddle transfer of coils to storage area of hot rolled coils. Remarkably, no gauge variation was observed in coils lifted by crane, affirming the role of saddle heating in generating gauge irregularities. Given the practical challenges of lifting all coils via crane, we intend to implement specialized cooling techniques to maintain the saddle temperature within optimal limits post-coiling. In conclusion, this study highlights the critical impact of post-coiling thermal management on gauge variation in DP 980 grade steel. By identifying and addressing the root cause of saddle heating, significant improvements in product quality and material yield were achieved. This research underscores the importance of meticulous process control and thermal management strategies in enhancing manufacturing outcomes in advanced steel grades.

**Key words : Hot Rolling, Cold Rolling, Ferrite, Bainite, Heating Rate**

# Reduction of flange cracking during forming operation in Cold Rolled 590R grade

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## Abstract

Cold rolled steel sheets are significantly used in Automobile industries are known for its part criticality. Different grades of steels are utilised in different parts application and in that Re-phosphorized steel which is used for Reinforcement parking brake application requires intricate formability. So, with addition of phosphorus the material exhibits very good elongation and high R-value in high strength grades (i.e. 590 MPa grade) compared to mild steel grades. But still stretch flange cracking is a concern during forming stage of part production. In this paper steps involved in the reduction of stretch flange cracking are discussed. Cold rolled steel having minimum Tensile Strength 590 MPa with yield strength minimum 390 MPa steel and Elongation minimum 18% has a phase structure of Ferrite + Pearlite + Precipitates where annealing is carried out above Ac1. While forming, this grade material tends to form cracking near flange regions. To resolve the issue, various analysis has been carried out and observed that multiple reasons were leading to stretch flange cracking in this material. In one of the case, it was observed that hole expansion ratio of the not good parts was lower & leading to cracking near hole regions, based on MPD data & detailed analysis, one of the element %S reduced. Further conclusion drawn by studying MPD & comparing with good & not good batches, coils with higher yield strength were more susceptible towards cracking. During data analysis, it was found that process parameter i.e. SS temperature & Ti content to be most effective in controlling YS. SS temperature was increased to control YS below 530 MPA & Ti range restricted to 0.0080 max. With this changes, the performance of the grade was significantly improved & the issues were resolved.

**Key words : Cracking, stretch flange, HER, YS**

# Surface Defect: Pinpoint Uncoated Pock Marks on Pre-Painted Galvalume Surface

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## Abstract

Pre-painted galvalume (PPGL) is a versatile material that fulfils almost all external requirements for roofing and siding, with variety of aesthetic features, various colors, shades, and profiles. A common issue in production of PPGL is often observed as pinpoint uncoated surface due to the defect in the base Galvalume (GL) surface. This paper studies the significance of pinpoint uncoated pock marks and the causes of their occurrence.

Pock mark can be described as small concave deformity formed during the cooling of GL sheet when a GL bubble burst and leads to formation of a fissure. The density of this defect depends on various production parameters mention in this paper. Scanning Electron Microscopy (SEM) Micrograph images show no paint application and loss of GL coating thickness in the region of the pock marks, which is expected to further reduce Salt Spray Test (SST) life leading to red rust at an early phase of service life. Repainting possibilities and height of fissure have also been observed by SEM at lab scale as well as mass production level. Coated pock marks have also been analysed for further understanding of the coating systems and the effect of their generation during processing of PPGL product.

The extent of pock mark can lead to variety of issues post production. Mitigation of this defect shall help in improvement of the product quality, leading to spotless PPGL surfaces with improved SST and service life.

**Key words : Galvalume; Pock mark; Pre-painted; Pinpoint uncoated**

# Development of Prepainted ZM steel for High Corrosion Resistance Industrial Roofing

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**Abstract**

A vital part of any industrial building is the roofing which contributes to the efficiency and safety of the operations while shielding from the weather. It acts as the first line of protection against weather-wind, sun, rain, and snow. A well-built roof can resist wind uplift, offer thermal insulation, and stop water leaks while making the building more fire resistance and serve as a platform for a variety of electrical and mechanical devices. Metal roofs can be installed quickly and are strong enough to withstand harsh weather conditions and fires.

Conventionally galvanized (GI) and Galvalume (GL) coated steel is used as a substrate for material used for roofing applications. The major challenges with this material is the corrosion life of the product. In highly corrosive environment such industries with corrosive particle emissions, or in coastal areas with high levels of moisture and salt, chemically aggressive processes or materials inside the building, or when there are corrosive external environments, the material has to be replaced within 3 to 4 years. Enhancing corrosion resistance can save energy, lower consumption, and safeguard the environment in addition to extending the service life and lowering the total cost of ownership of roofing materials. The development of Prepainted Zn-Mg (PPZM) steel takes advantage of the superior protection provided by Zn-Mg (ZM) coated product and further improves its by providing additional barrier coating in the form of paint. PPZM material even after 6000 hours of extensive SST testing does not show any red rust, thus allowing better service life and reduced cost of replacement and reinstallation. This allows the product to sustain much harsher environment at a much lower coating weight and enhanced aesthetics with reduced cost and frequency of maintenance, repair and replacement. The material shows superior scratch resistance due to improved hardness of substrate and is formable to the required shape with good bending radius.

This paper seeks to discuss development of PPZM for cost sustainable, and better corrosion properties for industrial roofing application.

Key words : Prepainted; Zn-Mg coating; corrosion resistance; galvalume

# Minimizing the Cracking defect in Automotive body panel made from CRCA-IF Grade

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**Abstract**

Components in Automotive Car body applications will have high and critical draw requirements. Especially exposed panels will have stringent requirement of surface and shape along with good formability.

While forming the component sporadic cracking and shape deviations observed in CRCA – IF Grade supplies in thinner Gauge (0.60 mm thickness) at one of the automotive customer. As the defect could observe while final forming stage of component making Customer was facing production losses, monetary losses and delivery issues.

In response to customer feedback, a detailed data analysis has been carried out for 200 data points using statistical tools and microstructural analysis done using SEM. The SEM analysis does not reveal any inclusions or microstructure issues. Product parameters include Mechanical properties (YS, UTS, %EL, r-bar), Process parameters considered from Steel making (Mould level fluctuations, Scarfing), Hot Rolling process (FT, CT), Cold Rolling (Reduction %), Annealing Temperatures, annealing speed, Skin pass (%Elongation) and customer die parameters considered for data analysis to find out the root cause. Out of the data analysis, cracked components data analysis observed with high amount of free carbon in comparison with good components indicate that %Ti is not sufficient to fix the carbon.

Hence the chemistry is revised with increasing the % Ti to fix the Carbon. The material with the new design was not observed with free carbon and the incidences are reduced drastically near to zero.

Key words : Cracking, free Carbon, %Ti, Automotive BIW, Scarfing, Annealing

# REDUCTION IN PRESS DENTS IN COLD ROLLED IF STEEL SHEETS FOR AUTOMOBILE INDUSTRY

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**Abstract**

Press dents, a common defect encountered in the production of cold rolled Interstitial Free (IF) steels, present a significant challenge due to their small size (approximately 5 μ) and the difficulty in detecting them through conventional online inspection methods. These defects typically manifest post-forming, leading to potential quality issues and needs to enhance product reliability and customer satisfaction. Current manufacturing practices rely heavily on online inspection systems to detect surface defects; however, press dents often evade detection due to their minute dimensions and the limitations of existing inspection technologies.

The dent portion has been analyzed using SEM, EDS (Energy dispersive spectroscopy), WDS (Wavelength dispersive spectroscopy) for the presence of any foreign substance and layer by layer analysis also carried out using the GDOS (Glow discharge optical spectroscopy) study. There were no entrapments and internal source of defect, only the soft surface of strip is found to be more prone for dent. To address this issue, this study investigates modifications in the Continuous Annealing Line (CAL) process parameters specifically to enhance surface hardness and visibility of press dents after stoning. By increasing the Skin pass mill (SPM) elongation and reducing the annealing temperature, the aim was to optimize material properties and to reduce the defect. The increase of SPM elongation by 1% makes the surface harder for forming operation. Furthermore, reducing the annealing temperature contributes to increase in yield strength of the material which enhances the property. The effectiveness of the study is validated by press simulating the blank sample and verifying the presence of defects, without compromising on the formability requirement of material.

In conclusion, the investigation into reducing press dents in cold rolled IF steels through CAL process parameter modifications underscores the transformative potential of applied research in addressing critical manufacturing challenges. By bridging the gap between theory and practical application, this study contributes to advancing quality assurance protocols and setting benchmarks for excellence in steel manufacturing.

Key words : Press dents, IF steel, Surface resistance, Spectroscopy, SPM

# Reduction of Stretcher Strain in Low Carbon Steel

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**Abstract**

Stretcher strains, also known as Luders bands, are a significant challenge in the production of low carbon steel, particularly for materials with a thickness of less than 0.7 mm. These localized deformations arise due to insufficient cold deformation, specifically when the required elongation during the Skin Pass Mill (SPM) process is not attained. The primary cause identified is the use of high diameter SPM rolls, which fail to achieve the necessary elongation for thin materials, even when subjected to high roll forces of up to 600 to 700 tons.

To address this issue, an optimization approach was implemented by replacing the high diameter SPM rolls with low diameter rolls. Remarkably, this adjustment allowed for the required SPM elongation to be achieved with significantly lower roll forces of 300 to 350 tons. This change effectively reduced the incidence of stretcher strains in the thin low carbon steel sheets. The optimization led to the elimination of Luders bands, thereby improving the surface quality and mechanical properties of the final product. This study highlights the importance of roll diameter in the SPM process and demonstrates a practical solution to enhance the performance of low carbon steel in thin gauge applications.

Key words : Stretcher strains, Skin Pass Mill, Elongation

# Analysis of Fe-Zn phase morphology on powdering and flaking in galvannealed automotive steel

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## Abstract

Here in this paper we have investigated the powdering and flaking defect generated in galvannealed steel by analysing the coating cross section and surface morphology. We have characterized the cross section morphology of zinc coating on the interstitial free drawing grade steel by Optical and SEM microscopy. The relationship between the coating morphology and the defect are established. The galvanizing and annealing process parameter are optimized to achieve desired coating morphology suitable of low powering and less flaking.

In the characterization different phases in Zinc coating viz. zeta, delta and gamma layers are analysed. The thickness and composition of the phases are determined by the SEM and EDX analysis. The correlation between the coating layer composition and thickness with the galvanizing and annealing parameter are done at different levels of DOE. The coating morphology hence achieved at different DOE levels are correlated to the level of powdering and flaking.

Powdering particle formation by intracoating failure to produce particles and accumulating in the bead areas during press forming, while this problem was investigated by scan electron microscope and x-ray diffraction methods; it was revealed higher the gamma phase. This was controlled by controlling diffusion of %Fe into intermetallic layer. Whereas, flaking formation of at particles by decohesion of the coating substrate interface to produce particles, this problem is due to excessive zeta phase on the surface which offered higher co-efficient of friction and resulted in the decohesion of the layer. This was controlled by the good control of glavannealing and after pot holding conditions at Continuous Glavannealing Line.

Key words : Powdering, Flaking, Phases

# Impact of cold treatment on the Bake Hardening Index of Bake Hardenable Flat galvanized steel

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**Abstract**

In this paper we have studied the impact of cold treatment parameters of galvanized flat steel by Skin Pass Rolling on the Bake hardening index of Interstitial Free High strength steel. Bake-Hardenable are generally low-carbon steels engineered to achieve increased strength through a post-forming heat treatment process known as baking. The Bake Hardening Index (BHI) quantifies the increase in yield strength that occurs in BH steels after the baking treatment. The baking process here considered is heating the tensile sample at temperatures ranging from 170°C to 220°C for approximately 20 to 30 minutes. This treatment induces additional hardening through the precipitation of carbon atoms and pinning of C atoms at the dislocation sites.

Skin pass elongation plays a significant role in influencing the Bake Hardening Index of BH grades of steel. By skin pass elongation dislocation density is increased which enhances the bake hardening response, leading to higher BHI values. This effect is critical for achieving the desired strength improvements in BH steels used for various automotive and structural applications. In the experimental trial the BHI values are studied by varying the SPM roll force and the SPM Strip tension. Based on the result the SPM roll force and strip tension are optimized to achieve desired BHI as per application requirement.

Key words : Bake Hardening Index, Interstitial Free High strength

# Impact of Chloride Content on Loose-Scale Formation in Hot Rolled Coils

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## Abstract

The presence of loose scale on hot rolled coils (HRC) poses significant challenges in steel manufacturing processes. During the hot rolling of steel, oxide scale forms due to high temperatures and exposure to air. This scale enhances corrosion resistance by protecting the steel from moisture and oxygen. However, elevated chloride levels in the ROT (Runout table) water can penetrate this protective barrier, leading to the formation of corrosive iron chloride compounds. These compounds initiate pitting corrosion, which compromises the integrity of the steel.

Top of Form

Bottom of Form

This experimental study investigates the influence of ROT water chloride content on loose-scale formation on the HRC surface. Controlled experiments were conducted and chloride levels were varied to assess their impact on scale adherence and appearance. Additionally, the research examines the surface morphology of samples exposed to varying chloride concentrations to evaluate material integrity in corrosive environments. The effectiveness of inhibitors, including the Nalco corrosion inhibitor, is evaluated in mitigating surface defects and improving the surface quality of the HRC products. Comparative analysis of samples immersed in chloride water with and without the inhibitor provides insights into how these additives affect surface characteristics under corrosive conditions. Key findings from the results show that elevated chloride levels have a pronounced effect, especially in higher thicknesses. The analysis provides valuable insights into the effect of inhibitors on the composition of scale, thereby influencing product quality. This underscores the importance of ROT water quality for maintaining product surface integrity.

Top of Form

Bottom of Form

**Key words** : Loose scale, Nalco corrosion inhibitor, Hot rolled coils, Corrosion resistance

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# Reduction of waviness defect in Hot Rolled Flat Steel Product

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**Abstract**

Flatness issues such as waviness in hot rolled products can be attributed to a various factor in the hot strip mill (HSM). Uneven stresses throughout the strip are one of the main causes, as they can cause the strip fibre to elongate differently and consequently result in flatness issues. Excessive rolling speed can exacerbate this problem by causing the strip to flutter and become wavy. Waviness can also result from an unequal thermal gradient across the strip during the cooling process. A hot-rolled sheet coil often reveals symptoms of poor flatness, such as wavy edges. Therefore, understanding and addressing these issues is crucial in the production of hot-rolled products.

Majority of flatness defects result from mill setting deviations or from shifting thermal conditions during the ensuing cooling processes. Hot-rolled strip flatness can be measured using IMS graphs located after final strand finishing strand no.7. However, the flatness graphs provided by IMS® technology is not always accurate as the shape of the strip may deteriorate once the strip is cooled after Runout table (ROT). Hence it is pertinent in HSM to correlate the factors which influence the shape of the strip and take counter measures accordingly.

In the Present study various parameters viz. backup rolls life, work roll profile, SDT (Slab dropout temperature), Pair-cross angle, cooling pattern in ROT were studied especially in thickness greater than 4 mm and width greater than 1500 mm in the strength ranging from 250 Mpa to 350 Mpa yield strength. It was found that higher Backup roll tonnage, pair cross angle in conjunction with work roll profile have major effect on the waviness. After results validation and revising the rolling protocol for the grade width and thickness (GWT) considered in the present study, defect percentage reduced from 7% to 1.9%.

**Key words : Hot Rolled Coil, Waviness, Thermal Gradient, Work & Backup Roll**

# Mitigation Strategies for Tertiary Scale Formation in Hot Rolled Steel Production

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**Abstract**

The surface quality requirements for automotive steel grades are becoming increasingly stringent, placing significant pressure on Hot Strip Mills to closely control relevant process parameters. Formation of Tertiary scale on steel surfaces during hot rolling has a direct impact on the surface quality of the final flat steel products used in critical automotive applications. This scale often creates whitish or blackish Pitting after Pickling, leading to downgrading of the material. However, achieving the optimal Finish Rolling Temperature (FRT) to balance roll ability and surface finish while controlling tertiary scale is particularly challenging part. This issue is especially prevalent when rolling thinner sections (t < 2.2 mm). Therefore, controlling this scale at the hot strip mill stage is crucial to prevent significant losses in downstream processes.

This research focuses on identifying and controlling hot strip mill process parameters to prevent tertiary scale formation in low-carbon steel during hot rolling. Scale growth depends on instantaneous surface temperature, exposure time, and, to some extent, the steel grade's chemistry. Tertiary scale formed before finish rolling results in rolled-in scale (RIS) after pickling. Optimizing Finishing Mill Entry Temperature (FMET), the descaling efficiency of the Finishing Scale Breaker (FSB), the distance between the FSB and the finishing mill entry, and Inter-Stand Cooling (ISC) based on the rolling section has significantly reduced rejection rates. Sustaining these procedures ensures consistent product quality and enhances customer satisfaction

**Key words** : Tertiary scale, Hot rolling process, Descaling, Pitting, Pickling

# Study of the mechanical property variations in Ti-Nb HSLA Steel grades

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**Abstract**

HSLA Steels gained their importance especially in the last three decades due to their ability to retain Toughness while improving the strength (both YS & UTS) significantly with even small addition of alloying elements such as Nb, V & Ti, which are identified as micro-alloying elements. These characteristics widely utilized in critical components in automobile, defence sectors, Where consistency in mechanical properties are prime requirement, But ensuring consistent mechanical properties in mass production remains challenging due to temperature sensitive interaction of alloying elements, formation of precipitates such as TiN, TiC and NbC The size, distribution, orientation, nature of precipitation of these precipitates are governing factors for mechanical properties.

This abstract proposes solutions through a multifaceted approach. Firstly, it stresses optimizing and calibrating equipment and automation models at the level 1 & 2 to ensure precise measurements, addressing limitations in handling surge and jerk readings in key parameters, RMX*, FET*, FT*, CT*, Run Speed, Thread Speed and Thickness. Secondly, strategic sampling from transformation stages. Alongside length, width, and thickness-wise coil samples. This is followed by detailed characterization of precipitate characteristics and microstructure analysis, pivotal for developing comprehensive learning models elucidating relationships between precipitate behavior and mechanical properties. Lastly, it explores error propagation methodologies, emphasizing the need to understand nature and propagation of errors and mitigate error impacts across production stages. All these efforts contributes to development of detailed SOP for process control.

Key words : RMX – Roughing mill exit temperature, FET : Finishing mill entry Temperature, FT-Finishing mill exit temperature, CT : Coiling Temperature.

# Reduction of Ovality in as-hot rolled coils of 22MnB5 Steel Grade

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**Abstract**

22MnB5 steel grade is used to manufacture side impact beams for Passenger Vehicles, which demands high strength (~1400 MPa) to provide better crashworthiness, coupled with minimum elongation requirement of 10% to absorb kinetic energy during side collision. Tempered martensitic structure is the ideal microstructural for ensuring these properties. 22MnB5 steel grade is designed to have relatively low strength (~550 MPa) in as-hot rolled condition to facilitate smooth execution of slitting, forming and subsequent Electric Resistance Welding. Subsequently, these are subjected to induction hardening process followed by quenching and tempering to get homogenous martensitic microstructure.

Typically, these steels contain alloying elements which increases hardenability, primarily C 0.13- 0.22 %, Mn 1.0 -1.6 % along with minor addition of boron. The enhanced hardenability is evidenced by the rightward shift in the Continuous Cooling Transformation curve. This rightward shift causes delay in the start of austenite transformation that gets extended till the coiling operation in Hot Strip Mill (HSM) thus leading to Ovality issue (difference between major & minor axes >15 mm) **[Fig.1]**. Hence, the main objective of this study is to eliminate Ovality/ Coil Collapse in as-hot rolled condition by ensuring the completion of austenitic phase transformation to atleast 80% at Run-Out Table of HSM itself.

The HSM process parameters that facilitate an early start of the transformation were identified primarily Finishing Delivery Temperature, Coiling Temperature and Cooling cycle. Finishing temperature was aimed much closer to $Ar_3$ temperature to facilitate early ferrite nucleation at same cooling rate. The coiling temperature was also reduced aiming increase in the ferrite phase fraction. Trials were conducted with revised process parameters, which resulted in an improved coil shape with ovality less than 10 mm. The percentage of transformed austenite, calculated using JMatPro software, was found to be in the range of 80-82% post process design adjustments.

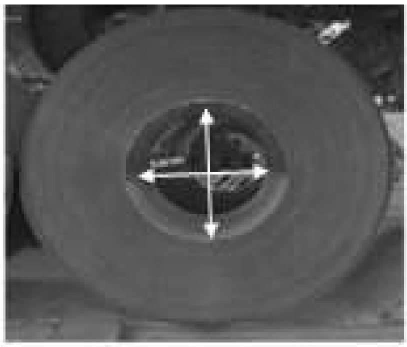

**Fig. 1. Figure showing collapsed coil in as-hot rolled condition**

**Key words** : Martensite, Ovality, Hot rolling, Phase transformation

# Optimizing hot rolling parameters to achieve high strength in Vanadium-based grades by using Taguchi method

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## Abstract

Vanadium-based High-Strength Low-Alloy (HSLA) steels are extensively utilized in various applications because of their exceptional strength, toughness, Weldability, and ability to retain strength after normalizing treatment. In the automotive industry, axle coverings are made using vanadium-based HSLA grades to retain their strength after hot forming. The steel grade is mainly strengthen by precipitation of micro-alloy elements and supported by grain refinement. It's critical to optimize the processing conditions in order to obtain better strength and minimize cost.

This paper investigates the influence of key hot rolling process parameters on yield strength and grain size for vanadium-based microalloyed steel, which is critical for automotive axle cover applications, and determines the optimal parameter levels using the Taguchi method. For this purpose, the parameters such as Slab dropout temperature (SDT), Finishing Temperature (FT), and Coiling temperature (CT) were chosen, with three levels considered for each temperature. Total nine experiments were conducted using an orthogonal array based on the Taguchi method. Analysis of variance, signal-to-noise ratios, and grey relational grade were calculated to optimize yield strength and grain size for vanadium-based microalloyed steel. It was observed that the SDT of 1170°C; FT of 880°C; and CT of 610°C are the optimum parameter values producing better strength and grain size.

**Key words** : Hot Rolling, V-HSLA steel, Taguchi method, ANOVA

# Optimization of Edger roll usage to reduce the edge seam defect in ULC steels

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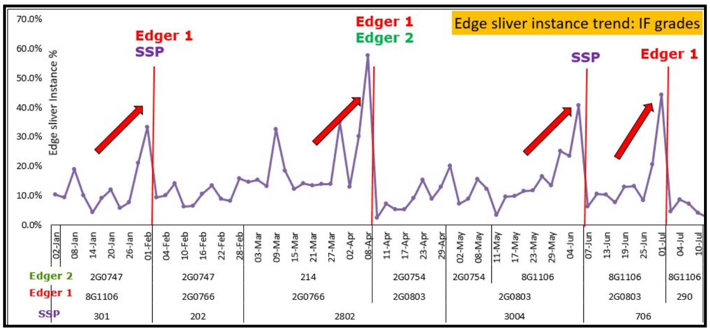
## Abstract

Edge seam defects are predominantly observed in titanium-stabilized ultra-low carbon (ULC) steels. These defects arise when slab corners cool much faster than the center, causing the corners to enter the ferrite zone while the center remains soft. This differential cooling leads to uneven deformation and overwrapping at the boundary, resulting in edge seams. Vertical edger rolls, inclined from top to bottom, push these defects toward the center of the top surface. Although edges are typically trimmed up to 15 mm to remove these defects, our plant has experienced a sudden increase in edge seam defects even after trimming, particularly before edger roll changes. This increase correlates directly with higher edger roll tonnages, where roll wear increases the edger angle from 3° to 3.48°. Based on defect analysis, the working tonnage of the edger roll was reduced from 10 Lac tons to 5 Lac tons. This study explores the relationship between edger roll wear and edge seam defect incidence, proposing adjustments to edger roll maintenance and operation to mitigate these defects and enhance product quality.



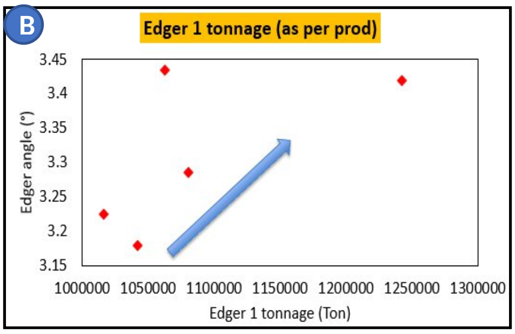




Fig. 1A: Edge sliver instance, 1B: Edger roll angle after usage

**Key words** : Edge seam, Edger roll, Slab corner

**Presenting Author** : Srimon Narayanasamy P

# Production of High Strength Hot Rolled Coils for Automobile & EME segment.

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## Abstract

High strength low alloy steels are used commercially with increased strength, toughness, formability and weldability for a variety of critical applications, such as long and cross members of auto chassis, pre-engineered building (PEB) structures, high mast lighting poles, wind poles, welded pipes etc. To meet these requirements, special quality hot rolled formable grades such as HSFQ (High Strength Formable Quality) 450/550 & IS 5986 Fe 540R have been developed at Rourkela Steel Plant (RSP).Combination of micro-alloying and mastery of processing parameters on final properties ensuresniche customer's requirement.

New grades of hot rolled steelswas developed and optimized utilizing an effective combination of solid solution and precipitation strengthening,resulting in a good ferrite grain refinement. This had an attractive combination of strength and formability which is typically quantified as high elongation (25 % min) coupled with lower YS/UTS ratio (0.80-0.85). Controlled thermomechanical processing has an added advantage of achieving the desired mechanical properties with a lean alloy design. in HR coils. But, the effective application of these steel demands good internal soundness and cleanliness to arrest the cracking susceptibility of the finished products during successive forming / welding operations.

HSFQ-550/450 & IS 5986 ISH-540R grades, has a unique combination of very high strength (UTS: 500-600 MPa and YS: 310-400 MPa) along with reasonable % EL (20-30) for its forming properties. Micro-alloying with Nb,V and Ti helps to achieve the desired properties by obtaining the required microstructures in the hot rolled coils.

This paper exemplifies the innovative alloy design and synergistic effect of Nb, V & Ti during controlled processing exploited to alleviate these problems at RSP. In-house trials had led to process optimization which led to a low-cost solution for current demand in higher strength to weight ratio in Automobile and EME sector.

**Keywords** HSFQ, IS 5986, Hot Rolling, Fine Grains, Strength and Ductility.

# Improvement in productivity of high carbon wire rods at WRM

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## Abstract

A modern wire rod mill has maximum rolling speed of 115m/s. This mill demonstrates versatile capabilities, like rolling a spectrum of special quality plain steel wire rods, including low carbon, high carbon, and alloy-grade steel, diameters ranging from 5.5mm to 22mm, additionally it produces TMT. However, challenges arose during the production of high carbon wire rods, particularly with regards to ensuring consistent mechanical properties at the front and tail ends. This resulted in the discard of 60 rings from each end that is total 120 rings per coil. The issue was more pronounced during the rolling of PC 115 grade, causing significant yield loss.

To overcome this issue a series of measures were taken. Initially, efforts were made to optimize the material temperature during the rolling process. Additionally, dummy rollers were removed from the cooling conveyor table to facilitate better airflow. Tail end losses were addressed by changing the PLC logic of metal tracking. For front end losses, sluggish valves in water boxes were identified as the main reason and suitable ON/OFF valves for water boxes were procured (fig1). Optimization of PLC logic was carried out by trials to reduce front and tail end loses to 30 rings each during normal production. These interventions resulted in a 50% reduction in end losses, significantly enhancing productivity of this mill

**Fig. 1: Fast response valve at water box**

Keywords: high carbon, wire rod, end losses, PLC, fast response valve

# REDUCTION OF ROLL WEAR SCALE ON HOT ROLLED COILS

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## Abstract

The Roll Wear Scale (RWS) represents the major surface defect found in hot-rolled coils. This scale is primarily attributed to several factors. These include the formation of an oxide layer on the slab, thermal fatigue, mechanical stress and fatigue, and abrasion. To minimize the roll wear scale, we conducted an analysis of the data and identified several steps to implement during production. It was determined that roll gap lubrication (RGL) should be applied from the initial slab of the campaign, and anti-peeling measures are consistently in place. The slab's temperature is kept within the range of 900–950 °C at the mill's entrance (F1 stand). For production, rolls are utilized in a combination of Hi-Cr and HSS for thinner gauges, and for slabs with greater thickness (above 2 mm), HSS steel rolls are used. The descaler pressure is maintained at 230 bars upon entry and 330 bars upon exit. An additional descaler with a pressure of 40 bar is also installed at the F2 and F3 stands. By adhering to these measures, we were able to reduce the percentage of roll wear. In the initial trial, we observed a roll wear scale of 7% on the hot-rolled coils. After implementing the measures outlined above, we observed a roll wear scale reduction from 1% to 0% in the subsequent trials.

**Key words:** RGL-roll lubrication gap, anti-peeling, HSS-high speed steel, hi-cr- high chrome roll, rws- roll wear scale

# Enhancing Efficiency in Galvalume Production: Optimal Stirrer System for Dross Reduction

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## Abstract

This study investigates the implementation of SS316L stirrer system aimed at reducing dross formation in Galvalume production by addressing temperature deviations, controlling viscosity in the molten Al-Zn bath, and mitigating oxidation effects. Dross, a persistent challenge in galvanization, compromises bath efficiency and product quality due to uneven temperature distribution, inadequate alloy mixing, and oxidation of the molten metal.

Fluctuations in temperature significantly influence the viscosity of the molten metal and the kinetics of reactions, directly impacting dross formation rates. Higher temperatures can accelerate reactions leading to dross formation, while lower temperatures may slow them down. The SS316L stirrer system plays a crucial role in maintaining uniform heat distribution across the Galvalume bath, effectively minimizing these temperature variations. By preventing localized hot spots and ensuring consistent thermal conditions, the system mitigates conditions conducive to rapid dross formation.

Additionally, high temperatures and exposure to air cause oxidation of the molten metal, resulting in the formation of oxides such as zinc oxide and alumina. These oxides contribute to dross formation by accumulating on the surface. The optimized stirrer system helps mitigate oxidation effects by promoting thorough mixing of the bath, reducing the exposure of molten metal to air, and thereby minimizing oxide formation and subsequent dross accumulation.

Practical benefits of implementing the optimized stirrer system include substantial reductions in dross generation, leading to decreased material wastage and improved operational efficiency. By enhancing process stability and product consistency, these advancements support cost-effective manufacturing.

In conclusion, the SS316L stirrer system, coupled with effective process optimization, represents a significant technological advancement in Galvalume production. By addressing key factors influencing dross formation and oxidation, this integrated approach enhances product quality, reduces environmental impact, and strengthens market competitiveness in the global manufacturing landscape.

Key words: Dross reduction, Stirrer system, Temperature control, Viscosity management

# STUDIES OF INCLUSION AREA FRACTION OF BAR AT WRM

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**Abstract**

In the present paper, studies on the inclusion area fraction of bar (16/20MnCr5, & 20MnCr5 & HC82A) at different locations after rolling in wire rod mill. Controlling inclusions in steel bar is vital to ensuring excellent performance. Accurate identification of inclusion groups is crucial for assessing component quality and using statistical methods for comparison and discrimination. In this study, we analyzed and examined the inclusion size distributions in bar samples from the head, tail, and center of eight heats. The measurements followed the ASTM E2283 standard metallographic procedures. The bar samples were analyzed using a scanning electron microscope (Hitachi S-3400N) and the EDS technique to determine the types of inclusions present. EDS analysis of the bar sample reveals that the inclusion area consists primarily of Ca and Al oxides, Fe and Ca sulfides, and traces of Si, S, and other elements. According to the test results, the inclusion size distributions indicated that no new inclusions were generated during the liquid steel treatment process.

Based on the study and findings, corrective measures were taken to get new tundish furniture designs implemented. The inclusion area fraction was reduced by 26% of the bar without affecting the internal structure of the billet. It is recommended to use the new design of tundish for better continuous cleanliness.

Keywords: inclusion, area fraction, bar, EDS, tundish

# IMPACT OF TEMPERATURE ON HIGH CARBON STEEL ON STELMOR CONVEYOR TO PREDICT THE GRAIN BOUNDARY CEMENTITE

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## Abstract

A novel approach is using a portable thermovision camera to capture the surface temperature profile of wire rods at different points during the moving-stelmor air-cooling process. The cooling of wire rods is determined by the stelmor operation conditions. A series of temperature profiles were recorded at various locations to study the link between the temperature of the wire rod ring (edge and center) and the conveyor zone. Based on the temperature profile of wire rod, finding the temperature difference between edge to center is approximately 80°C. High-carbon grades need powerful blowers for efficient cooling, which refines the pearlite microstructure and imparts more strength. The stelmore conveyor laying head temperature and cooling pattern on stelmore conveyor at wire rod mill were also optimized to reduce the severity of grain boundary cementite (GBC) network in wire rods. To avoid GBC formation, the wire ring passes through the region between Acm and A1 as fast as possible. Based on the detailed results, corrective action was taken to fix the extra additional fan used for cooling in zone 1 to prevent cementite accumulation on the stelmore conveyor.

Keywords: Wire Rods, stelmor conveyor, thermovision camera, temperature, Grain-boundary cementite.

# A METHOD TO RESLOVES WEAK WELD DEFECT IN ERW TUBE MANUFACTURING PROCESS

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## Abstract

JSWBPSL contributes 74,000 MT of precision tubes to automobile manufacturers each year. The steps of a manufacturing process are as follows: forming, welding, sizing, and section shaping. These semi-finished hot-rolled sheets were produced using the compact strip production (CSP) and cold rolling mill (CRM) which produce steel sheets of various grades based on market demand, one of which is the new grade SPFH 590. Quality was commissioned due to its superior mechanical characteristics and contemporary market demands. However, the SPFH 590 grade did not pass either the weak weld or the drift expansion tests. In order to resolve the failures, various brainstorming strategies and approaches were used in an exhaustive analysis. Through proper investigation, a solution came out that greatly improved the efficiency and performance of the SPFH 590 grade with respect to the weak weld and drift expansion tests, thus meeting market standards. The underlying cause of these was the gap between the work coil and the electrical resistance welding (ERW) equipment. The work coil is a critical component that mechanically guides the tubes in the proper alignment for welding. This spacing was initially set to a predetermined measurement. It was found that spreading these components further apart successfully mitigated the issues associated with SPFH 590.

Optimizing this distance and other parameters between the work coil and the ERW considerably improved the SPFH 590 manufacturing process. This meets the market's stringent demands while avoiding prior failures. The change emphasizes the significance of process parameter adjustment in order to achieve desired material properties or product performance goals.

Keywords: CSP, CRM, ERW, SPFH 590 grade, forming, welding, work coil.

# Impact of tensile sample dimension and tensile testing parameter on the mechanical property of IF and IFHS galvanized steel

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## Abstract

Here in this paper we have experimented on the mechanical property of interstitial free and interstitial free high strength grade flat steel samples by varying the tensile sample dimension and the tensile test parameters. The size of tensile sample considered are the gauge length gauge width and gauge thickness. The tensile samples are prepared both in parallel and perpendicular to the rolling direction for the same location sample. The coating weight are stripped off before tensile test. The tensile test is conducted at different strain rates mentioned in ISO 6892-1:2016. A regression analysis is conducted to find the correlation in various strain rates and gauge dimension on the mechanical property. The fracture analysis is done on the broken samples to observe the impact of strain rate and gauge width on the fracture mechanism. It is observed that the tensile sample and the testing parameters impact certain mechanical property more as compared to others. The impact of tensile sample dimension is more significant on the total elongation while the strain rates are more sensitive for YS value. The study gives the understanding of the material behaviour at different loading conditions. The study helps in identifying the feasibility of the property requirement by the customers in different testing methodologies and tensile sample gauge dimension.

**Key words : Tensile Test, Testing Direction, Gauge length, IF Steel, IFHS Steel**

# Processing of Advanced High Strength Steels at Commercial Scale

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## Abstract

The development of advanced high-strength steels (AHSS), such as cold-rolled dual-phase steel, at a commercial scale, requires precise control over various process parameters. From the initial casting to the coil cooling in the hot-rolled condition, followed by cold rolling and continuous annealing, each stage significantly influences the final mechanical properties of the steel. Subsequent low-temperature annealing is also crucial for optimizing these properties.

Achieving the necessary formability and flange-ability, in addition to the desired tensile strength and phase composition, is essential for the practical application of AHSS. This work focuses on understanding the effect of hot rolling parameters on the subsequent cold rolling process of advanced high-strength steels. By examining these parameters, we aim to enhance the overall quality and performance of AHSS in commercial applications.

# Integrated Approach to Roll Force Optimization for Improved Steel Rolling Efficiency

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## Abstract

This research investigates the optimization of roll force in the production process of Thinner gauge (≤2 mm thickness) hot-rolled steel coils with an emphasis on achieving desired mechanical properties through Optimization of chemistry, slab length and thickness of slab before finish rolling. The aim was to optimize the roll force for energy efficiency, cobble, improve surface quality of hot rolled coils, achieve consistent mechanical properties and improve process stability.

Initially, the focus was on optimizing the chemical composition. To preserve mechanical properties while reducing roll force, niobium (Nb) was removed and manganese (Mn) content increased. Simultaneously, a specific range of slab length was identified to minimize variations in temperature across the length slab that could affect the rolling force distribution. Furthermore, the optimization of transfer bar thickness played a critical role in the rolling process. The initial trials with a higher transfer bar thickness were found to be suboptimal for producing coils in the desired thickness range. Reduction in transfer bar thickness led to a significant reduction in roll force across the stands. This adjustment not only facilitated smoother rolling operations but also contributed to achieving the desired thickness in the final product. The conducted trials provided comparative data on roll force across different stands. Trial with optimized chemistry and adjusted slab length and transfer bar thickness, showed lower roll force compared to the initial trial. This reduction in roll force was consistent indicating the effectiveness of the implemented optimizations.

Overall, the optimization in chemistry, slab length, and transfer bar thickness collectively contributed to a more stable rolling process. The mechanical properties of the rolled coils were within acceptable limits, and the overall coil shape was satisfactory. These findings highlight the importance of a holistic approach to process optimization in the steel rolling industry, ensuring both quality and efficiency.

Keywords: Steel, Hot rolling, Roll force optimization, Mechanical properties

# Development of SPFC590 HSLA grade through CSP & BAF route for CRCA tube product used in Automotive Segment

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## Abstract

Over the past few decades, there has been a significant focus on enhancing the structural characteristics of motor vehicles. As a result, various types of high strength steels have replaced many components due to their superior strength, fatigue, formability, ductility. Reducing fuel consumption, improving passenger safety, vehicle performance and carbon emissions are the topmost goals in current government plans across worldwide. One of the significant steps in the quest has led to the invention of the EV's. India being the largest two-wheeler market in the world, has seen substantial growth in the volume and sales of the two-wheeler EV over the past few years. The Manufacturing of these fuel-efficient EV's requires material with stiffness, strength, fatigue, formability and light weight. This has led to the rising demand of HSS steel (SPFC590 grade) requirement in tubular components such as Handel Bar, cross tubes and side tubes which will provide high yield strength for cold forming application with a good strength to weight ratio. These components are manufactured by subjecting the straight tubes to the processes such as bending, notching and drifting.

In this project, the focus area is to develop high strength (HSLA) CRCA tube product for automotive applications especially for 2-3wheeler EV vehicles.

The objective of this project is to develop JIS G3135 SPFC590 grade in CRCA for automotive tube applications through EAF-LRF-TSC-CSP-BAF route.

Trial taken to develop SPFC590 grade in CRCA tube by maintaining CTQ parameters of SMS and CSP to produce clean steel. Alloy design done considering CSP constraints by adding micro alloy (V, Nb, Ti), manganese, silicon, aluminum in low carbon steel to achieve desired mechanical properties. Mechanical properties achieved by fine ferrite grain size, precipitation (carbide, nitride), substitutional & interstitial strengthening and accelerated cooling during hot rolling. Annealing cycle of BAF process set to achieve desired mechanical properties in CRCA tube.

Mechanical Properties of trial achieved as per requirement in CRCA tube, and the tube successfully processed for automotive application. The CTQ parameters of SMS, hot rolling and cold rolling, annealing cycle and alloy design freeze for future supply.

Key words: High Strength Low Alloy, Electric Arc Furnace, Ladle Refining Furnace, Thin Slab Caster, CSP, BAF

# Serrated Edges in Full Hard Cold Rolled Sheet of Ultra-low Carbon Ti Interstitial-free (IF) Steel

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**Abstract**

Full Hard Cold Rolled (FHCR) sheets of interstitial-free (IF) steel exhibited zig-zag type edge cracks that were not detectable during the hot rolling stage but became visible during cold rolling. Presence of these defects, if left untrimmed, led to significant rejection of steels. To investigate the origin of these defects, whether from casting, hot rolling, or cold rolling, various experiments were carried out, including chemical analysis, stereo microscopy, optical and scanning electron microscopy, EDS analysis and mechanical tests like hardness and tensile tests. Microstructural examination of FHCR sheet revealed projected edges with tiny cracks associated with scale. Severely elongated and deformed ferritic grains at the edges were also observed. The presence of scale at the cracks confirmed that the defect originated during the hot rolling stage. Further examination of multiple samples of this steel from hot rolling stage (HR) showed elongated deformed grains with tiny cracks at the edges, while recrystallized and equiaxed grains were observed 30 to 40 mm away from the edge. The edge hardness (130 Hv) was found higher compared to areas away (94 Hv) from the edge. At low finished rolling temperatures (<850° C) at the edges, the steel cannot undergo dynamic recrystallization which prevents formation new strain free grains, and consequently results deformed elongated ferritic grains with higher hardness and low ductility. These tiny cracks and severe elongated grains with high hardness at edges in hot rolling stage resulted in serrated edges during cold rolling. To minimize this problem two measures were recommended. First, incoming slab temperature was increased 30° C, i.e from 1200° C to 1230° C. Second, the cooling of the hot rolled (HR) strip after finishing rolling was controlled by reducing the water flow in the initial headers of the laminar cooling system, allowing sufficient time for the grains at the edges to recrystallize.

**Key Words:** Serrated Edges, Elongated grains, Hardness

# Consistent Supply of Zero Defect Electrode Quality Grades to M/s Lincoln

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**Abstract**

**The existence of the modern world is highly dependent on the electric arc welding which is one of the oldest processes for joining of the metals. Welding process is necessary for various engineering activities and in the production of several manufactured products. It is a fusion process of joining metals and is used in every field all over the world.**

The wire for the coated electrode is normally of low carbon steel which is popularly known as electrode quality (EQ) steel.

The paper discussed the efforts made by the team to produce High Quality Electrode Grades which is supplied to M/s Lincoln at a potential of 600 Mt/Month. Many process improvements were undertaken at manufacturing Units particularly Mills parameters were relooked and standardized. Reheating Furnace Soaking Zone Temperature was maintained between 1130 – 1150 C. Laying Head Temperature was maintained between 820 – 830 C and Uniformity to be maintained in Laying Head pattern to ensure no bunch formation.

This proactive approach has zeroed down Quality Issue in these grades. This is how we supplied Zero Defect Products to Customer. Revision of Standards was done and has been incorporated in SOP and Work Instructions.

key words: Cold Headed Quality, Upset Test, Zero Rating

# Reduction of Inline Scratch Rejection in Garret Rolling at WRM of TSG

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## Abstract

Wire Rods are of different sizes which is obtained by Block Route(5.5 mm to 18.5 mm) and Garret Route(20 mm to 25.4 mm). Scratch line defects in steel can impact various components depending on the application and the severity of the scratches. Scratch was generated in **Garret Route** of Wire Rod Mill. Precision components like pistons, crankshafts, camshafts, and connecting rods can suffer from scratches, impacting their performance and durability. Many Premium Customers like Omega, Arkkays and Microturners demand Zero Scratch Defect. Scratch Defect can increase Friction, wear, leakage issues and weaken structural integrity by acting as stress concentrators.

First of all, Scratch generating points were mapped and identified. Total of 5 points were identified at different locations. Causes of scratch were analysed. Many preventive and Rectification actions were taken such as Water Box 19 base strengthening and alignment for correcting the misalignment at Water Box Nozzle. Switch Pipe Funnel & Base material was modified to softer grade and Inner Diameter increased from 45 mm to 50 mm. Deviator Box alignment and stopper fixed. Trumpet Guide arrangement was modified. All these modifications were done & implemented.

Plan was implemented in Mid of Mar'24 and after that Scratch issue is almost nil.

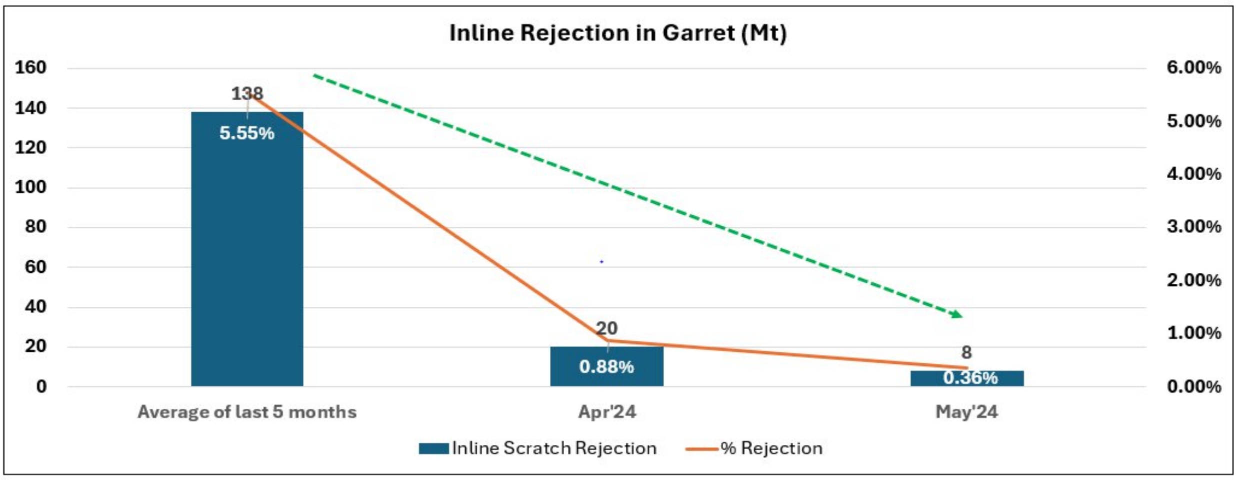


Fig. 2: Results

Key words: Garret Route, Block Route, Scratch

# Surface modification of rolled Steel using Plasma spray of NITINOL

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## Abstract

The surface of hot rolled steel is weaker due to the heat applied, which weakens the metal and prone to surface degradation when it comes for direct application. The surface modification can be done using plasma technology. Plasma spray is one of the thermal spray coating techniques, in which a very high energy source is used to melt the substrate particles and project them onto a finished surface. The molten particles accelerate and on impact with the surface cool down and solidify due to heat transfer between the substrate particles and the surface. Hence by repeated accumulation, they form coatings consisting of a layered structure. Thermal spray of NITINOL (NiTi) on steel enhance the surface properties such as wear resistance, thermal barrier, bio-compatibility. In this work we have thoroughly examined the current techniques to coat NiTi alloy on different metal substrate by plasma spraying. Furthermore, we have also studied the mechanism and process parameters associated with plasma spraying. The various use of plasma spraying in different scenarios has been discussed. It is found that, various properties exhibited by the substrate material due to nitinol coating is feasible for the structural materials commercialization.

**KeyWords:** Steel, Plasma Spraying, NITINOL, Surface Modification

# Improving edge quality of Hot rolled Coils in 11%Cr dual phase Ferritic Stainless Steel (X2CrNi12)

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## Abstract

11%Cr-0.02C is a dual phase grade belonging to ferritic stainless steel group which is widely used in fabrication of railway wagons due to its higher strength to weight ratio and corrosion resistance. It is a sustainable material as after a long service life, there is a very little loss of material due to corrosion. During manufacturing of hot rolled coils from continuous cast slabs, edge cracks were frequently observed thereby leading to unwanted trimming and subsequent yield loss.

In order to minimize this defect, effect of different rolling parameters, like re-heating furnace discharge temperature, mill roll force & strain rate on edge crack was analysed. It was observed that higher roll force and higher draft in each pass was leading to higher strain rate on the material.

To reduce the strain on material, it was decided to modify the pass schedule at roughing mill. After rolling the material with the suggested changes, edge crack occurrence was minimized in hot rolled coils. It was also observed that the average roll force and draft in each pass of rolling also decreased which resulted in lower strain rate in material. This resulted in reducing wastage of material due to trimming losses thereby improving the yield of the final product.

**Keywords:** Ferritic Stainless Steel, Edge Crack, Roll Force, Strain Rate.

# Influences of Heat Treatment on the Quality of Heavy Plates

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## Abstract

The requirements of heavy plates in terms of enhanced strength and wear resistance have greatly increased in recent years. Driven by this demand for extra high strength steel plates required for specific application by the downstream industries, heavy plate manufacturing have undergone an evolution from a mass-produced commodity to a specialty product. Depending on the application and the sheet metal geometry, the heat treatment carried out need to be individually adapted. The cooling (quench) speed as well as the use of special alloy trace elements has an influence on the quality of heat-treated plates.

Years back the term “heavy Plate” used to cover a thickness range of 6 mm to 150 mm. With the advent of newer technological usage, the range have widened in both direction. In today’s world the thickness range , in general, is considered as 2 mm to 250 mm.

In order to keep up with the stringent quality requirement of final properties, it is no longer sufficient keep the main alloying component in a narrow tolerance range. In addition, the determination of cooling rate during solidification from the liquid phase as well as the introduction of trace elements for metallurgical properties play an important role.

# Processing Strategies to Develop Third Generation AHSS for Automotive Applications

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## Abstract

The first generation advanced high strength steels (AHSS) such as dual phase, martensitic and a part of complex phase and TRIP steels are extensively used in the automotive industry for the weight reduction. The difficulty arise with the first generation AHSS is their reduction in ductility with increase in strength. Although second generation AHSS such as austenitic stainless steel, twin induced plasticity (TWIP) steel and low density induced plasticity (L-IP) steels give superior strength and ductility, they hardly get place in the automotive industry due to high alloying content, weldability issue with dissimilar metal joining and cost of production. Hence, third generation AHSS are gaining attention to the automobile manufactures. Third generation AHSS are characterized by their ultra high strength and superior ductility to get the product of ultimate tensile strength and total elongation greater than 30 GPa. %. The attractive properties of such steels helps in manufacturing automotive components of thinner sections to reduce the overall weight of the automobiles resulting improvement of fuel efficiency, reduce $CO_2$ emission and gives greater safety.

In the present study various processing routes such as single and two stage quench and partitioning (Q&P), quench and tempering (Q&T), austenite reverted transformation (ART) were employed to a commercially available TRIP assisted steel to achieve third generation AHSS properties. The microstructure of the steel was correlated with the mechanical properties. To further enhance the mechanical properties, a newly developed lean medium manganese steel was subjected to ART treatment providing attractive mechanical properties suitable for automotive industry. The steels superior properties are due to the presence of retained austenite produced by the unique processing routes which aided the strength and ductility by TRIP effect while deformation in addition to the ferrite, bainite and martensite as the other phases present in the steels with various proportions. The benefits and limitations of each processing route is discussed for the development of the third generation AHSS.

**Key words:** Third generation AHSS, Unique processing routes, Microstructure, Mechanical Properties, TRIP effect

# Optimizing Hot Billet Charging in Bar Rolling Mills to Reduce Gas Consumption

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## Abstract

The BRM-2 reheating furnace (RHF) at JSW Steel is designed with a capacity of 220 tons per hour (TPH) and utilizes mixed gas as fuel. The gaseous heat rate, defined as the "Mixed gas consumption (in Gcal) per ton of billet discharged," is a critical metric for operational efficiency. To achieve an average billet exit temperature of 1000°C, the furnace consumes an average fuel rate of 0.235 Gcal per ton of billet processed. A plant-level energy study identified several factors affecting the gaseous heat rate, including billet charging temperature (hot charging percentage), furnace utilization (enhancing heating capacity), and combustion efficiency (proper air-to-fuel ratio). Notably, for every 10°C change in the inlet billet temperature, there is an impact of 0.003 Gcal/T on fuel consumption. It is well established in the literature that increasing the hot charging percentage significantly reduces gas consumption. To achieve this, a time study was conducted to monitor the temperature of billets from the SMS3 caster to the BRM2 furnace charging door. The study revealed that billet temperature dropped below 350°C within 5 hours and 30 minutes. To mitigate this heat loss during transit, a series of insulated hoods were installed over the 6-billet roller table, extending the temperature sustainability to 6 hours and 15 minutes.

Additional measures to reduce furnace gas consumption include the development of a Standard Operating Procedure (SOP) encompassing a heat casting plan, maximized utilization of Caster-1 in SMS-3, and streamlined casting sequencing in SMS-3 with rolling grades in BRM-2. These actions have been systematically implemented to enhance the efficiency of the reheating furnace. The optimized hot billet charging process has led to a significant reduction in gas consumption, contributing to overall energy efficiency and cost savings.

| KPIs | UoM | FY22 | Dec'22 | Jan'23 | Feb'23 |
|---|---|---|---|---|---|
| Production | t | 7,52,724 | 1,15,547 | 1,10,343 | 97,446 |
| Hot charging % | % | 40% | 42% | 48% | 52% |
| Slope | GJ/t per 100% | 0.39 | 0.39 | 0.39 | 0.39 |
| Fuel cost | INR/Gcal | 2,538 | 2,538 | 2,538 | 2,538 |
| Cost savings due to fuel saving due to hot-charging impact | **INR Cr** | | **0.05** | **0.21** | **0.28** |

**Key words** : bar mill, hot slab charging, energy efficiency, cost optimization.

# Increase of Finishing Stand Pass Life by Using Composite Rolls

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## Abstract

JSW Steel Vijayanagar works operates a Bar Rod Mill (BRM) with a capacity of 1.2 MTPA, producing TMT bars for various applications. The quality of TMT rebars is significantly influenced by the performance of rolling rolls in the TMT bar mill, particularly in the finishing stands where projected ribs and identification marks like the manufacturer's logo, grade, and section are introduced. Traditionally, Spheroidal Graphite (SG) Iron rolls are used in the finishing stands for 25mm and 32mm bars, featuring an acicular structure and a hardness of 67-73 Shore C. However, excessive wear in the finishing pass necessitates frequent replacements, with the average pass life being 500-600MT for 25mm and 700-800MT for 32mm bars.

To address the issue of low pass life, composite rolls have been introduced in the finishing stands. These composite rolls (Fig 1) consist of Tungsten Carbide (WC) rings with binders such as cobalt, nickel, and chromium, comprising 30% of the material. Tungsten carbide is renowned for its exceptional wear resistance, which has resulted in a tenfold increase in pass life compared to SG iron rolls. The implementation of these composite rolls in the finishing stands has significantly extended pass life and reduced mill downtime, thereby enhancing overall productivity and efficiency.

This transition to composite rolls demonstrates a strategic improvement in roll performance, contributing to higher quality TMT bar production and operational cost savings. The increased durability of tungsten carbide rings ensures longer intervals between roll changes, minimizing disruptions and maintenance requirements. This advancement underscores the critical role of material selection in optimizing rolling mill operations and achieving superior product quality in the steel industry, also increase in roller pass life by 10 times with good surface finish.

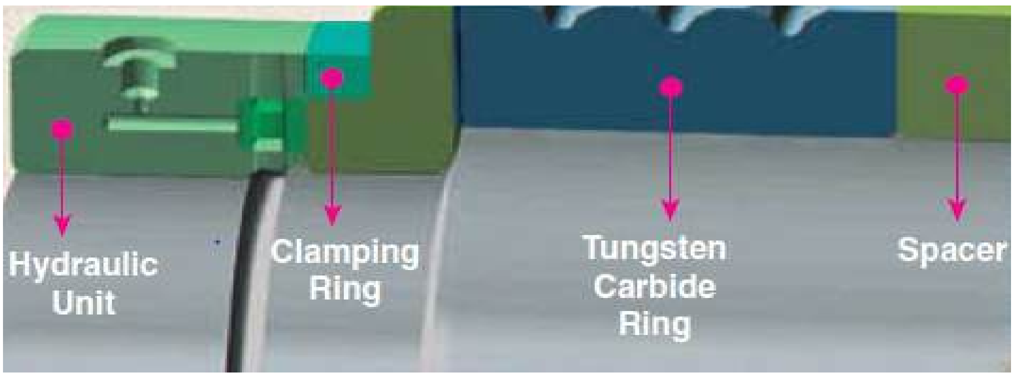


Fig. 1: Composite Roll arrangement

**Key words:** TMT bar Mill, Rolling, Roll, Composite Roll, Pass life

# Alloy Design and Processing of High Strength Hot Rolled Steel Coils for Automotive Structural Components

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## Abstract

The automotive industry from all over the world has been constantly pursuing development of new design and materials for achieving reduced weight and improved crash performance of vehicle. High strength steels owing to their higher strength with moderate forming capacity favour application of thinner gauge sheets, reducing overall weight of car and saving in fuel consumption. Besides high strength, these steels also require superior formability and flangeability characteristics, high elongation, low YS / UTS ratio for applications in automotive segments.

The objective of the present work was to design and develop high-strength hot-rolled coils with an optimal alloy composition and process design using Thermo Mechanical Controlled Processing (TMCP). This approach aimed to achieve an attractive combination of strength and formability characteristics suitable for automotive structural components.

Steel heats were produced and cast into slabs measuring 220mm x 1510mm. The alloy composition was based on the principles of high-strength low-alloy steel, featuring a carbon content of less than 0.15 wt.%, manganese in the range of 1.2-1.3 wt.%, and micro-alloying additions (Nb+V+Ti) less than 0.08 wt.%. These slabs were hot rolled to thicknesses of 12.8 and 13.5 mm, and widths of 1725 mm and 1970 mm, respectively, in a Hot Strip Mill (HSM). The finish rolling temperature was maintained around 820-830°C, and the coiling temperature was approximately 580°C.Microstructural characterization revealed a fine ferrite and pearlite structure in the steel. The mechanical properties included a Yield Strength (YS) range of 500-545 MPa, Ultimate Tensile Strength (UTS) range of 580-675 MPa, and elongation percentages between 22-29%. This grade of steel is well suited for automotive structural components, particularly in load-bearing applications.

Keywords: Automotive Steel, Micro Alloyed, TMCP

# Optimization of Heat Treatment Cycle to Prevent Quench Cracks in 5150 Grade Rolled Steel Shafts

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## Abstract

Quench cracking in 5150 grade rolled steel shafts is a significant issue affecting the structural integrity of these components. This study investigates the root causes of quench cracks and proposes an optimized heat treatment cycle to eliminate these defects. Metallurgical analysis of cracked samples revealed a grid-like pattern in the microstructure, linked to issues during the quenching process.

Induction heating, widely used in the surface hardening of 5150 grade steel, introduces complex local thermal cycles that lead to rapid heating and cooling, resulting in significant metallurgical changes. Our study identifies that martensite tempered at 600°C can become overaged, forming coarse carbides along lath boundaries, leading to the grid patterns observed. This is attributed to carbide precipitation rather than chemical inhomogeneity. While tempering aims to form fine carbides within the martensitic matrix, excessive heating beyond the optimal tempering range results in coarse carbide formation within the ferritic matrix, negatively impacting the material's mechanical properties.

An optimized heat treatment cycle, involving hardening at 850°C with a 2-hour soak followed by tempering at 550°C for 4 hours, was developed. This cycle successfully eliminates the undesirable grid patterns and enhances the mechanical properties of the steel shafts. The study details the microstructural analysis methods and experimental trials conducted to reach these conclusions.

The time- and temperature-dependent microstructural developments observed in this study are directly applicable to induction hardening processes, providing a practical solution for improving the quality and durability of 5150 grade steel shafts. These findings offer valuable insights for manufacturers addressing similar quench cracking challenges, ultimately contributing to the production of more reliable components for high-stress applications.

**Key words** : heating rate, induction heat treatment, steel, 5150

# ITS RIM SPRAYING PATTERN AT WHEEL & AXLE PLANT, DSP

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**Abstract**

Durgapur steel plant produces EMU wheel and supplies it to the Indian Railways along with various types of other wheels like Broad Guage (BG) Coach, (Meter Gauge) MG Locomotive, (S Profile) SP Locomotive, WAG-9/WAP-5 etc. The wheels are forged, rolled and heat treated before machining. At this plant more than 7% wheels are rejected on account of hardness variation in EMU Wheels as Indian Railway Specification states that the difference between extreme hardness values within a batch shall not exceed 30 BHN.

At the wheel shop, rim spraying machine consists of one rotating disc and a water spraying hood that has 24 no. spraying nozzles all along its circumference. The hood has a fixed diameter of 1360 mm and is used for all types of wheels with varied diameters.

The locomotive wheels are having diameter of 1120 mm whereas EMU wheels of 982 mm in cold/ black state. The distance from nozzle tip to the tread of locomotive wheels is 120mm (i.e- 1360-1120 = 240/2) and 189 mm ( i.e- 1360-982 = 378/2 ) is for EMU coach wheels . So, in case of EMU wheel, the flat jet of water has to travel 7cm more to reach to the tread in comparison with Loco wheels (Fig 1). The purpose of effective quenching is veering off as the water jet is becoming more wide when it reaches to the EMU wheel tread. The water jet is also striking the hood roof as well as the wheel base after travelling longer distance.

Analysing hardness rejection pattern in different types of wheels, it shows that the locomotive rejections are always less than that of low diameter wheels.

To optimise this factor, in house fabrication was carried out for advancement of nozzles towards ‘EMU wheel tread’, (Fig 2). This resulted effective hood diameter of 1222 mm so as to have a nozzle to tread distance 120 mm for effective quenching like locomotive wheels.

These modification and optimisation led to hardness rejection from 7% to 5%; resulting improvement in productivity as well as quality.

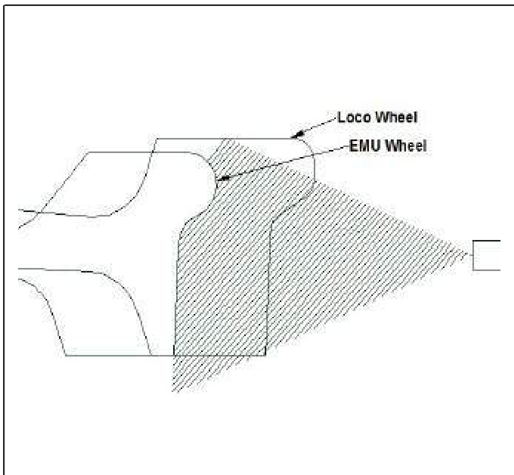


Fig 1: Water jet more wide in EMU wheel

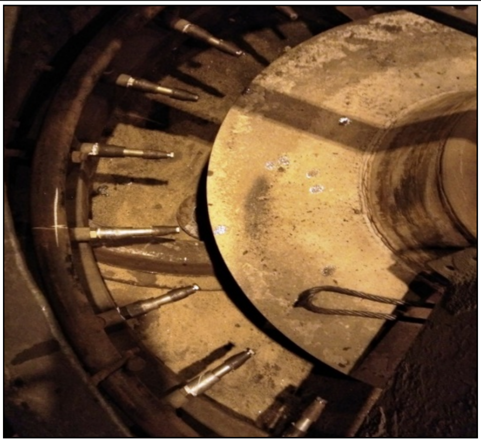

Fig 2: The modified hood with nozzle

# Crystal structure and morphology of carbides development upon heat-treating C alloyed CoCrFeMnNi high entropy alloy

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**Abstract**

This study investigates the precipitation of carbide phases in $CoCrFeMnNiC_x$ (x = 0.9 at. %) high-entropy alloys subjected to heat treatment at various temperatures. Detailed microstructural characterization was performed using optical and scanning electron microscopy, X-ray, and electron backscatter diffraction. Microstructural analysis revealed that at lower temperatures, carbides localize along grain boundaries and within grains, while at higher temperatures, they localize predominantly along grain boundaries, signifying their dissolution in the matrix as temperature rises. Above 1000°C, Cr-rich $M_7C_3$ carbides exhibit specific crystallographic orientation relationships with the FCC matrix: $(112)_{FCC}//(\bar{1}2\bar{1}3)_{M_7C_3}$ and $[\bar{1}10]_{FCC}//[10\bar{1}0]_{M_7C_3}$. Below 1000°C, along with $M_7C_3$ carbides, $M_{23}C_6$ carbides form, demonstrating cube-on-cube orientation relationships with the FCC matrix. Additionally, an increase in both lattice parameters and hardness of the matrix phase with rising temperatures indicates carbon dissolution into the matrix. Thermodynamic calculations further support these observations by demonstrating the decrease in stability of $M_{23}C_6$ and the increase in stability of $M_7C_3$ with rising temperature. It also predicted that the complete dissolution of carbides at specific temperatures, aligning with experimental observations and confirming distinct carbides and limited carbon solubility in the alloy matrix.

keywords: Interstitial high entropy alloys, Carbides, Thermodynamics, Orientation relationship

# Study of machining-induced surface integrity of silicon steel

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**Abstract**

Silicon steel is emerging as an alternative to ferritic and austenitic steels. This alloy steel has good strength, ductility, and good corrosion resistance. Recent study has shown that silicon addition can also be used to manipulate the phase composition. Low silicon content leads to austenitic microstructure, while high silicon content leads to formation of duplex microstructure. Surface of a component is the interface to its environment and hence several functional properties like wear, corrosion and fatigue characteristics are directly dependent on the surface integrity of the component. Since steel components are primarily manufactured by machining, it is important to understand the effect of machining-induced surface integrity.

In this work, we study the effect of alloy composition and machining parameters on surface integrity parameters like surface roughness, hardness, sub-surface microstructure and residual stress. Surface roughness was assessed through optical profilometry, and microstructural changes in the surface and subsurface regions were examined using SEM and EBSD techniques. The primary causes of microstructural alterations during machining are the generation of heat and the occurrence of significant plastic deformation. Residual stresses which arise due to thermomechanical stresses, were determined using the $\sin^2\psi$ method.

# Eliminating Center Looseness issue in Bearing Grade Bars

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## Abstract

The Blooming Mill (BLM) at JSW Steel Salem Works specializes in producing bars ranging from 65 mm to 200 mm in diameter and Round Corner Squares (RCS) from 55 mm to 265 mm. A major challenge has been rejections of roller products due to centre looseness in bearing grade materials. In order to improve the internal soundness of the rolled bars critical parameters influencing centre looseness, including furnace dwell time, furnace heating parameters, and rough rolling output size were studied. By employing hypothesis testing, these factors were systematically examined to understand their impact on product quality. Subsequently, a DOE methodology was applied to optimize these parameters, aiming to determine the most effective combination to minimize centre looseness.

For inputs sized at 340 x 400, the optimized process parameters were established as follows: a dwell time of 6 hours, a Pre-Heating Zone (PHZ) temperature of 950°C, a Heating Zone (HZ) temperature of 1180°C, a Soaking Zone (SZ) temperature of 1180°C, and an input size to the Horizontal Vertical (HV) mill of 191 x 191. For inputs sized at 250 x 250, the optimized parameters were determined to be: a dwell time of 4 hours, a PHZ temperature of 850°C, an HZ temperature of 1050°C, an SZ temperature of 1180°C, and an input size to the HV mill of 142 x 152. By extending the furnace dwell time and adjusting the temperatures in the heating zones, the internal integrity of the bars was greatly enhanced, effectively eliminating centre looseness. The effectiveness of these optimized parameters was evaluated using Ultrasonic Testing (UT) to measure internal soundness in the rolled products. UT, a non-destructive testing method, provided precise detection of internal flaws, thereby serving as a reliable measure of the improvements achieved. The results of UT demonstrated elimination of rejections due to centre looseness, reducing from 34% to 0%. The DOE approach was instrumental in identifying the critical factors and their optimal settings, leading to significant improvements in the internal structure of the bars. The comprehensive measures undertaken by modifying the reheating pattern and reduction pass schedules to address the issue of centre looseness in bearing grade materials have proven highly effective.

key words : Centre looseness, bearing grades, Hypothesis testing, DOE, UT.

**Determination of Coefficient of Friction at Higher temperature using Bending Under Tension machine**

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**Abstract**

Formability under the hot stamping process is significantly influenced by various input process parameters and tribological conditions, with friction being a crucial factor in determining the formability of components at elevated temperatures. Previous studies have shown conflicting results regarding the relationship between temperature and the coefficient of friction: some indicate an increase in friction with rising temperature, while others report a decrease. This study aims to resolve these discrepancies by analyzing the effect of temperature on the coefficient of friction using the Bending Under Tension (BUT) test. An L27 Taguchi array was employed for the experimental design, incorporating input parameters such as temperature, sliding distances, and velocities. This methodical approach allowed for a comprehensive examination of the interactions between these variables and their individual effects on friction. The experiments revealed that an increase in temperature, sliding velocity, and sliding distance generally leads to a higher coefficient of friction.

The Analysis of Variance (ANOVA) method was utilized to determine the statistical significance of the process variables on the friction coefficient measurements and to explore the interactions among these variables. The ANOVA results indicated that temperature significantly impacts the coefficient of friction. The Design of Experiments (DOE) methodology proved to be effective in systematically studying the effects of multiple variables and their interactions. In summary, the study confirmed that temperature is a critical factor affecting the coefficient of friction during the hot stamping process. Higher temperatures, increased sliding velocities, and longer sliding distances all contribute to an elevated friction coefficient. These findings have significant implications for the optimization of hot stamping processes, as controlling friction is essential for enhancing formability and ensuring the quality of stamped components.

key words : Hot Stamping, Friction, Bending Under Tension Test, L27 Taguchi Array, Temperature, Sliding Distance, Sliding Velocity, ANOVA.

# Optimizing Roll Usage in Hot Strip Mills: Repurposing Worn Intermediate Rolls to Reduce Costs and Downtime

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## Abstract

In the integrated steel plant of JSW Steel Limited, the Down coiler Pinch Roll is a critical component in the hot strip mill process, known for its frequent wear and high maintenance costs. Traditionally, these rolls are made either cast materials or cladding material which require regular cladding and replacement, leading to significant operational downtime and increased expenses. This paper presents a novel approach to mitigate these issues by repurposing worn-out intermediate rolls from the PLTCM (Pickling Line Tandem compact Mill) unit as pinch rolls.

The study explores the technical feasibility of adapting used PLTCM rolls—initially designed for intermediate processes—to function effectively as pinch rolls in the hot strip mill. By grinding and modifying these rolls, JSW Steel Limited aims to eliminate the need for frequent cladding, thereby extending roll life and reducing maintenance costs. This approach leverages waste rolls from PLTCM, turning them into valuable assets, which not only cuts material costs but also minimizes production interruptions.

Key benefits include significant cost savings, reduced downtime, and enhanced roll durability. Additionally, this practice supports sustainability by repurposing otherwise discarded materials. The paper provides a detailed analysis of the modification process, the operational impact, and the economic benefits derived from this strategy.

This innovative solution demonstrates a practical application of resource optimization and cost management in steel manufacturing, offering valuable insights for similar industries facing analogous challenges.

**Keywords:** Roll Optimization, Cost Reduction, Downtime Minimization, Steel Manufacturing, Sustainability, Resource Efficiency

# Elimination of Red scale during hot rolling of a low carbon wire rod grades

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## Abstract

In current work, red powdery scale generated during hot rolling of low carbon wire rod grade is investigated. Extensive plant trials based on Stelmor parameters are conducted to identify the controlling parameter for red scale during hot rolling. Laying head temperature, Conveyor speed and blower combinations are changed during trials and surface severity of red scale is captured. Detailed characterization in terms of scale thickness, scale loss percentage by acid pickling, tensile property and other microstructural aspects are done for each trial category to evaluate the overall impact. Result shows that higher laying head temperature and lower conveyor speed reduces the red scale. Scale thickness and percentage scale loss increases with increase in laying temperature. Blower selection is found as an important parameter in controlling the red scale. Based on trial findings, Stelmor parameters are optimized to achieve hot rolled property without red scale defect.

**Keywords:** Hot Rolling, Red Scale, laying head temperature, conveyor speed, blower selection

# Establishing manufacturing approach for the development of high-performance Al/Mg laminated composite clad sheets

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## Abstract

Magnesium (Mg) is the lightest structural metal available commercially, and it is widely used in the automotive and aviation industries to reduce vehicle weight, thereby enhancing fuel efficiency and lowering emissions. Additionally, Mg possesses excellent damping characteristics, superior fatigue life, good fracture resistance, and a high strength-to-weight ratio. However, Mg often exhibits poor corrosion resistance and inferior ductility/formability. Al has excellent corrosion property, very good formability/ductility and similar strength-to-weight ratio as like Mg alloys. Therefore, there is a promise to combine Al and Mg sheets into the Al/Mg laminated clad sheets (LCS) in order to obtain individual characteristics of Al and Mg in the Al/Mg LCSs with high strength-to-weight ratio and improved corrosion properties. Due to lightweight characteristics, the Al/Mg LCS has wide applications as a structural material in the aerospace and automotive industries. The performance of the Al/Mg clad sheets is mainly governed by the formation of good mechanical and metallurgical bonding at the interfaces. The main challenge for developing clad sheets is to avoid the formation of intermetallic compounds at the interface caused by the interatomic mobility of Al and Mg atoms, which deteriorates the clad sheet's mechanical properties. The present study is focused to establish a manufacturing methodology to develop a high-performance Al/Mg laminated clad sheets (LCS) with strength-ductility-bonding synergy. The manufacturing methodology includes large strain-controlled roll bonding-based thermos-mechanical processing followed by post processing. The developed Al/Mg LCSs showed significantly higher strength-ductility combination than its bare Mg and Al counterparts. The interfacial phases between Al and Mg were examined using XRD, and no intermetallic compounds were detected at the interfaces, confirming the excellent bonding in the Al/Mg LCS. Additionally, tensile and three-point bend and peel tests were performed to assess the mechanical properties and bonding characteristics of the Al/Mg LCS. The detailed planar and cross section microstructural characterizations were carried out using optical, FESEM and EBSD analysis to establish the scientific knowhow for obtaining strength-ductility-bonding synergy.

**Keywords:** Roll Bonding, Thermo-Mechanical Processing, Al-Mg Laminated Clad Sheet, Microstructure, Mechanical Properties

# Welding of Laser Powder Bed Fusion Manufactured Haynes 282 alloy: Microstructure and Mechanical Properties.

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## Abstract

Laser Powder Bed Fusion (LPBF) stands out as the most prevalent Additive manufacturing (AM) process for creating complex shaped parts, but it comes with inherent limitations like constraints on part size, high porosity levels, and inefficiencies in producing simple geometries in bulk quantities. As a strategic solution to address these constraints, the feasibility of producing complex-shaped parts by the LPBF process followed by welding with other additively manufactured or wrought parts to form the final component, is the topic of this study. This hybrid type of manufacturing technology has recently grown in significance within the domain of new-generation power plants, especially Ultra Supercritical (USC) power plants for accommodating intricate geometries such as compact-type heat exchanger cores. Investigation on microstructure evolution and mechanical properties of Keyhole TIG (KTIG) welded additively manufactured nickel-based superalloy Haynes 282 in as-built and heat-treated conditions has been done and noticed that weldability between additively manufactured and wrought Haynes 282 plates is well acceptable. Also, mechanical property deterioration in heat-affected zones (HAZ) is less in the LPBF-manufactured plate side compared to the wrought plate side. These findings will expedite the adoption of additively manufactured intricate shapes in USC power plants.

Keywords: Keyhole TIG, Laser Powder Bed Fusion, Haynes 282

# Characterization Studies on Wire Arc Additive Manufactured Functionally Graded Material (SS316L / Hastelloy C-276)

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## Abstract

Hastelloy C-276, a nickel base superalloy is the most popular material due to its excellent corrosive resistance and good strength at high temperatures. These properties make it suitable material for harsh and high temperature corrosive environments in industries like chemical processing, nuclear power plants, offshore oil and gas production. However, the high cost of raw material and fabrication using traditional methods makes it difficult for widespread applications. With the concept of Functionally Graded Material (FGMs) and advanced manufacturing processes like Wire Arc Additive Manufacturing (WAAM), the above-mentioned limitations can be reduced. In the present work, Gas Metal Arc Welding based WAAM process was adopted to fabricate FGM of Hastelloy C-276 on SS316L. WAAM process parameters were optimized for obtaining the FGM with defect free interface. Further microstructural analysis and mechanical properties evaluation were carried out. The micrograph revealed the defect free interface composed of predominantly columnar dendrites along the build direction. The hardness test revealed the interface region with intermediate hardness compared to SS316L and Hastelloy C-276 ensuring optimal elemental distribution at the interface in correlation with SEM-EDS analysis.

Key words: FGM, GMAW, Wire Arc Additive Manufacturing, Hastelloy C-276.

# Experimentally validated and empirically compared machine learning approach for predicting yield strength of additively manufactured multi-principal element alloys

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## Abstract

Traditionally, yield strength prediction relies on detailed and resource-intensive microstructural characterization combined with empirical equations. However, quantifying microstructural feature length scales for novel processes like additive manufacturing, which involves inhomogeneous hierarchical features, poses a challenge. The lack of accurate material constants for broader composition ranges further limits empirical predictions. This study proposes an alternative machine learning (ML) approach for predicting the yield strength of additively manufactured (AM) multi-principal element alloys (MPEAs) from the Co-Cr-Fe-Mn-Ni system by correlating composition, printing parameters, and testing conditions. The best-performing ML model achieved an accuracy comparable to that achieved using microstructural detail- driven empirical strengthening contributions. Printing and testing of multiple compositions (including novel ones) was carried out, and the validity of the ML approach was established. Stacking fault energy and lattice friction changes on varying the composition affected the yield strengths and the post-yielding deformation mechanisms. This data-driven approach directly relates yield strength to initial printing parameters, highlighting their significance and individual effects, such as scan velocity's direct impact and laser power's inverse impact on yield strength. This demonstrates ML's potential to guide AM processes, reducing the need for iterative experiments and enabling rapid exploration of compositional and printing spaces to achieve desired properties.
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# DESIGN AND OPERATIONAL PARAMETERS OF A 16.5 MVA SUBMERGED ELECTRIC ARC FURNACE (SAF) FOR FERRO SILICON PRODUCTION

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**Abstract**

Most of the Ferro-alloys are produced in Submerged Electric Arc furnace any where in the world due to its economical and qualitative aspects of the production. Proper design and operational technics play a key role in achieving better yield and moderate specific power of the Ferro-alloy products. Ferro-Alloys are mostly extracted from its oxide ores. Localized temperature is the most important factor for better reduction of oxides ores. A good electrode diameter with compactible pitch circle diameter is the main source for achieve high temperature. However not only these two parameters but also there are several electrical, mechanical and metallurgical parameters involved in to successful operation of Submerged Electric Arc Furnace. In this paper we discussed various mechanical, electrical and operational characteristics of Submerged Electric Arc Furnace. The designing of mechanical and electrical parameters in sub merged electric arc furnace are highly influences the operational parameters in Ferro-alloys production.

There are so many operational difficulties rises due to improper design parameters of the furnace. Among all of these the major problem is operational load is always not reachable to the theoretical load. That means the maximum load attaing is not achievable. Load factor mainly depends on resistance of the charge material. Resistance is mainly depending on current density. A proper design of electrode diameter provides adequate current density. Design of furnace diameter and depth depends on electrode diameter. Hence furnace design parameters are all interlinked with each other. If any parameter designed wrong its impact appears on the operational and process parameters. Proper design of the furnace reflects the good Power Factor (Cos Ø), optimum specific power, there by we can get good yield of the alloy.

Designing of submerged electric arc furnace is mainly based on the following requirements.

1. Total production required per day in tons (Tp).
2. Type of the product to be produced (Si-Mn, Fe-Mn, Fe-Cr, Fe-Si).
3. Average specific power of the product in kWh (Sp).
4. Power Factor of the process (CosØ).
5. Furnace availability for process in a year (fa).

These are the indispensable parameters to be considered at the time of submerged electric arc furnace design for Silico-Manganese Product. There is a little bit of changes in the design of Fe-Mn, Fe-Cr, and Fe-Si Products. The temperature attains for reduction of Ferro-alloys are shown as:

$\Delta$H for Fe- Si >Si- Mn > Fe-Cr >Fe-Mn

So that the reduction temperatures are vary for product to product. Hence the arc voltage, diameter of the electrode, pitch circle diameter, bath depth and diameter will be varying to product to product. Therefore, there is no common design parameter for all the products.

In this paper we discussed submerged Electric Arc Furnace design and operational parameters to produce Ferro-Silicon 75grade.

# A comparative study of additively manufactured vs wrought maraging 250 for various ageing parameters

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## Abstract

Maraging steels are low carbon Fe-Ni-Co-Mo based steels that exhibit combination of high strength and good toughness through the formation of intermetallics such as $Ni_3Mo$, $Ni_3Ti$ in tough bcc martensite matrix. They find wide applications in aerospace and defence sectors due to its unique combination of strength and toughness.

Additive manufacturing is widely gaining importance in which a CAD file is processed layer by layer to manufacture a 3D object. This technology facilitates the fabrication of customizable parts which can be tailored to suit the needs of shape or composition or shape and composition. Powder ba

The present work is aimed to understand the structure and properties of additive manufactured maraging steel 250. 10mmx10mm cylinders of maraging 250 were deposited using powder bed fusion technique. The microstructure shows lath martensite which is typical of maraging steels. Maraging steel gains its strength and toughness by ageing heat treatment. In the present work, additively manufactured maraging 250 was subjected to various ageing treatments by varying temperature (400 to 600°C) and time (2hrs-6hrs). Hardness was found to increase with increasing ageing temperature upto 500°C. Beyond 550°C reverted austenite formation was observed in the martensite matrix which decreases the hardness. The microstructural features of samples were evaluated using optical and SEM. A comparative study was also carried out w.r.t the microstructural features of additively manufactured maraging 250 with that of the wrought material.

Key words: Maraging 250, Additive manufacturing, ageing, reverted austenite

# High-performance triboelectric nanogenerator with ionic liquid processed polyvinylidene fluoride for energy harvesting application through an additive manufacturing technique

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## Abstract

In recent years, the growing demand for sustainable power solutions for flexible electronics, the Internet of Things, cloud computing, and artificial intelligence has become increasingly prominent. Additive manufacturing offers a means to create energy-harvesting devices with the necessary characteristics to meet these demands. This study focuses on fabricating flexible and transparent triboelectric nanogenerator (TENG) devices for energy harvesting by using ionic liquid-processed polyvinylidene fluoride (PVDF) and polyamide 6 through material extrusion. The research investigates the effects of varying ionic liquid concentrations (5%, 10%, 15%, 20%) on the formation of the electroactive β-phase in PVDF, as well as its impact on the dielectric properties and energy output of TENG devices. The results indicate that PVDF processed with 15% ionic liquid produces the highest triboelectric performance, with a peak output voltage of 180.5 V, a short-circuit current of 16.5 μA, and a power density of 3.42 $W/m^2$. The incorporation of ionic liquid into PVDF enhances the polar β-phase, increases the dielectric constant, modifies surface potential, and acts as a conductive medium for electrons from the surface to the bulk material, thereby boosting triboelectric charge density and improving TENG device performance. Additionally, the additive manufacturing process contributes to better surface contact between the two tribolayers by increasing surface roughness and ensuring uniform layer printing, which further enhances charge transfer and energy output. This study demonstrates the potential of fabricating flexible TENG devices using ionic liquid-processed PVDF through additive manufacturing, with promising applications in energy harvesting.

# Development of Gas-atomized Fe-Based Amorphous Alloy Powders and its 3-D Printed Products

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**Abstract**

The iron (Fe) based amorphous alloys have high research importance owing to its high elasticity and strength, good wear and corrosion resistance superior functional properties. The main drawback of these alloys is the difficulty of its bulk production, which is related to the necessity of rapid cooling rate for generating amorphous structure. It is conventionally overcome by the rapid solidification planar flow casting, generating thin (micron range) ribbons confined to specific magnetic core applications. Alternatively, with the advancement of material processing technology, the gas atomization technique has been adopted to process amorphous alloy ingots as spherical shaped powders, which are utilized for making bigger size (order of cm range) components by 3-D printing technique. In present research, the pre-alloyed FeCrMoBSiCP alloy ingots are processed as spherical powders (0-300 µm size range) by gas atomization technique. The powders are sieved by mechanical vibratory sieve shaker, sorting the powders of 25-93 µm size range for further characterization and discarding remaining powders. The developed gas-atomized powders possess smooth surface, high sphericity, and good flowability. The powders of below 63µm size range are completely amorphous in nature, while that of above 63 µm size range show crystallinity in amorphous matrix. The thermal parameters of supercooled liquid region ($\Delta T_x$), reduced glass transition temperature ($T_{rg}$) and ■, are derived as 50, 0.60 and 0.40, respectively, indicating high glass forming ability (GFA) of developed gas-atomized powders. Due to high GFA, the powders (53-80µm size ranges) are utilized for manufacturing the sample products (25⊘25⊘9 $mm^3$) by 3-D printing of direct energy deposition (DED) technique under different laser parameters. All DED printed samples are found with 65-75% amorphous structure along with major crystalline phases of $(Fe,Mo)_{23}B_6$ and α-(Fe, Mo) and minor phases of $Fe,Mo)_3P$, $(Fe,Mo)_3B$ and $(Fe,Mo)_3C$. The high magnification scanning electron microscopy (SEM) reveal crystalline phases in amorphous matrix, attributed to their compositional elements of EDS analysis. The amorphous matrix is also signified by its high microhardness values (813-932 $HV_{0.1}$) and the generation of cracks near indent point due to its brittleness.

# Effect of scanning strategy in laser-powder bed fusion of crack susceptible AISI M2 high speed steel

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**Abstract**

High-speed steel (HSS) contains high carbon (C) along with tungsten (W), molybdenum (Mo), vanadium (V), and chromium (Cr) as major alloying elements. AISI M2 is a W-Mo-based HSS known for its high hardness (700-800 HV) and wear resistance, even at elevated temperatures (500–600 °C). These properties are attributed to the presence of complex carbides and hard martensite. However, processing AISI M2, which has a high carbon equivalent, using laser powder bed fusion (L-PBF) is extremely challenging. Rapid solidification, martensite formation, and the presence of complex carbides during the L-PBF process generate significant residual stresses, leading to severe cracking and delamination of the printed part from the base plate. This work aims to study the effect of scanning strategies on residual stress development and its impact on the printability of crack-susceptible AISI M2 HSS. The study analyzes the effect of scanning strategies by varying the laser scan vector length, direction, and scanning sequence. The printed parts are then characterized by their microstructure and mechanical properties.

key words: AISI M2 high speed steel, laser powder bed fusion, path planning, residual stresses, tool steels

# Ferromagnetism in Bismuth Ferrite Nanoparticles via Jet Milling

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## Abstract

We report the magnetic behavior of multiferroic bismuth ferrites synthesized using milling-annealing processes. The antiferromagnetic behavior is tailored through the crystallite reduction of the nanoparticles. X-ray diffraction and Rietveld analysis were used to evaluate the crystallite size and microstrain of the crystal structure. Morphology was studied by scanning electron microscopy, and magnetic behavior was evaluated using vibrating sample magnetometry. The powders were obtained from crystal size reduction by milling process areundergone a heat treatment at 650°C. Relationships between microstructural transformationand oxidation-reduction reactions, as well as antiferromagnetic-ferromagnetic changes, are discussed. The changes in antiferromagnetic properties found by milling-pressure.

Keywords: Bismuth ferrite; Jet milling; Nanoparticles; Size effect; Ferromagnetism; Anti ferromagnetism.

# Synthesis of 1D and 2D material and its application as a SERS Substrate

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## Abstract

Surface-enhanced Raman spectroscopy (SERS) is an analytical detection technique which significantly increases the weak but structurally rich signal of Raman scattering. Two mechanisms, i.e., electromagnetic enhancement mechanism (EM) and chemical enhancement mechanism (CM), are used to describe the effect. EM mechanism counts for the dipole iteration between the analyte and metal surface, whereas CM mechanism counts for some special functional groups containing SERS substrate that can change its polarisation.

1D Materials like Silver nanoparticles (AgNP), Gold nanoparticles (AuNP) and 2D materials like Transition metal dichalcogenides (TMDC) have grabbed the attention of the researcher for their unusual properties, which make them suitable for SERS substrates. In the study, silver and gold nanoparticles were synthesised as 1D materials ideal for the SERS substrate, and MoS2 was studied as 2D material for the SERS substrate. Methylene Blue dye is used to study the SERS activity of the substrate. TEM, UV-Vis spectroscopy and SEM are performed to characterise its nanostructure. Raman spectroscopy is used to study the substrate's SERS activity. The mechanism behind the signal enhancement is discussed, and it is found that these substrates can serve as a biosensor.

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# Effect of Ti addition on strengthening and deformation mechanism of Ni-rich high entropy alloy synthesized via spark plasma sintering: An experimental and atomistic approach

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## Abstract

Due to the immense alloy designing compositional space, high entropy alloys (HEAs) exhibit unique single phase microstructure with outstanding mechanical properties such as superior strength and ductility synergy, excellent toughness and higher hardness. For the design of high performance HEAs, understanding the strengthening mechanisms and deformation behavior is crucial, which remain less explored till date. In the present study, effect of Ti microalloying on phase evolution, microstructural development, mechanical behaviors and deformation mechanism of novel $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) high entropy alloys (HEAs) synthesized via mechanical alloying and spark plasma sintering (SPS) were systematically investigated. The equilibrium phase formation by varying Ti content was predicted using Thermo-Calc software (TCHEA-4.2 database), indicates that the proposed HEAs exhibit single-phase solid solution at the sintering temperature of 1150 °C without presence of any brittle intermetallic phases, shown in Fig. 1(a). Phase analysis of the sintered HEAs envisaged the formation of face centred cubic (FCC) structured solid solution with minor amount of brittle Cr-rich and Mo-rich sigma (σ) phases along with essential $L1_2$ phase in the FCC matrix. Phase fraction of the σ phases deceases continuously with raise in Ti amount. Increasing in Ti content promotes continuous increase in number average twin boundary per grain i.e., ~2 per grain for 6 at. % Ti HEA (Ti-06) compared to other HEAs, ascribed to decrease in generalized stacking fault energy (GSFE), as shown in Fig. 1(b), estimated by performing molecular dynamics (MD) simulations. The calculated barrier energies and twinnabilities revealed that the addition of Ti increased the tendency of dislocation glide and deformation twinning. Ti-06 HEA exhibits excellent strength-ductility trade-off, where the yield strength and compressive strength reached up to 1458 ± 8 MPa and 2011 ± 12 MPa, respectively, with an appreciable fracture strain of 26 ± 0.3 %, shown in Fig. 1(c). Further, MD simulation was employed to model the deformation mechanism of current HEAs under compressive loading. The results show formation of continuous stacking fault networks including intrinsic stacking faults, extrinsic stacking faults, deformation twins and dislocations along which plastic deformation carried-out in Ti-06 HEA. Due to activation of multiple deformation twins and stacking faults and their complex interaction contribute to the appreciable plasticity, and increased sessile stair-rod dislocation results in enhanced strength in Ti-06 HEA. This pioneering work provides further insights into the significance of SFE effect on the deformation behavior and also sheds light on designing of high-performance HEAs.

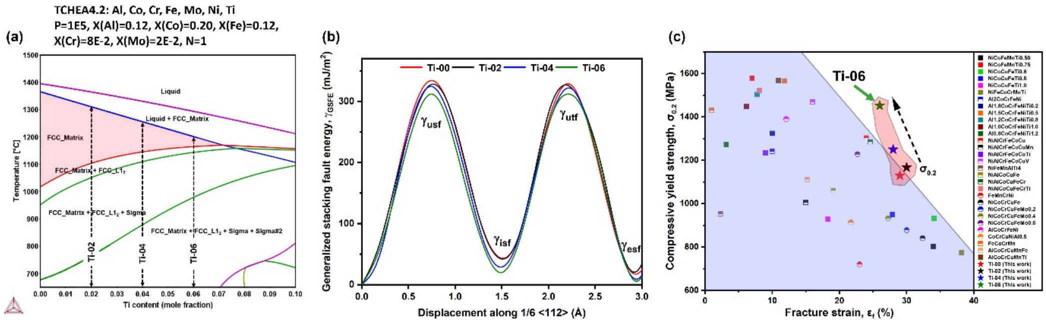


Fig. 1: (a) The pseudo binary phase diagram of the (NiCoAlCrFeMo)-Ti alloy system, (b) generalized-stacking fault energy of FCC {111} <112> slip of $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) HEAs and (c) comparison of the compressive properties of the present alloys with other HEAs

Keywords: High entropy alloy, Spark plasma sintering, Generalized stacking fault energy, Solid

# Evaluation of Mechanical Performance of Heat-Treated IN939 Fabricated by PBF-LB at its service temperature

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**Abstract**

This study evaluates the mechanical performance of IN939 superalloy, fabricated using Powder Bed Fusion-Laser Beam (PBF-LB) and subjected to post-process heat treatment, at its service temperature of 850°C. The primary focus is to understand how heat treatment affects the microstructural evolution and mechanical properties of IN939 for high-temperature aerospace and industrial applications. High-temperature tensile and compression tests at 850°C are conducted to gather data on yield strength, ultimate tensile strength, and ductility. Microstructural analysis using SEM and EBSD reveals significant modifications in grain structure and phase stability due to heat treatment, which are directly correlated with enhanced mechanical properties. The strain hardening behavior is assessed using the Hollomon and Ludwik equations, showing a decrease in the strain hardening exponent at 850°C, indicating increased susceptibility to localized deformation. The results demonstrate that heat-treated IN939 exhibits substantially improved mechanical performance at 850°C, with higher yield and tensile strength while maintaining adequate ductility. These improvements are attributed to refined microstructure and enhanced phase stability from heat treatment. This study underscores the importance of optimizing heat treatment parameters to ensure the alloy's reliability and effectiveness in high-stress, high-temperature environments.

**Keywords:** Powder bed fusion-laser beam (PBF-LB), High temperature mechanical performance, Heat treatment, Microstructural evolution

# A study of dry sliding wear performance of 304 stainless steel reinforced with $TiB_2$ particles

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**Abstract**

AISI 304 Stainless steels have been widely used as engineering materials in industries due to their excellent corrosion resistance, heat resistance, workability and biocompatibility. However, strength, hardness and wear performance of stainless steel are comparatively low, especially at high temperature, thus limit their usage in some extreme environment in industries effectively. One viable way to address these problems is Incorporation of hard ceramic particles, which can improve the mechanical and tribological properties of steel. Steel-Matrix Composites (SMCs) reinforced with $TiB_2$ particles offer great potential for a wide range of applications. In the current work, AISI 304 stain steel-based composites has been developed with 2-4 vol% $TiB_2$ reinforcement by powder metallurgy method. Pressure assisted hot-pressing was used to achieve uniform distribution of $TiB_2$ particles in steel matrix. The sliding wear performance of the composites was evaluated using pin-on-disc apparatus under different loads of 25, 30 and 35 N, and sliding speed of 0.08, 0.11 and 0.13 m/s. High chromium $100Cr_6$ ball with hardness of 62HRc was used as counterpart material. To determine the underlying wear mechanism, the worn-out surfaces were analysed using Field-Emission Scanning Electron Microscopy (FESEM) and Energy-Dispersive Spectroscopy (EDS). The results of the dry sliding tests revealed that, the presence of $TiB_2$ reinforcing particles significantly reduced the volume loss while simultaneously improving the wear performance of the steel matrix. The incorporation of $TiB_2$ particles was beneficial in improving the wear resistance over the entire range of load and sliding velocities used. Significant deformation traces in the form of micro ploughing, delamination and grooving was observed in the unreinforced steel indicating adhesive wear as the dominant wear mechanism. Upon adding $TiB_2$ to steel matrix, the adhesive wear mechanism changed to abrasive wear without any flake-like wear scars on the worn surface. However, deeper grooves and scratches were observed at higher load and sliding speed that lead to deterioration of wear resistance. A mixture of adhesive, delamination, and abrasive wear were observed as the predominant wear mechanism at higher load and sliding speed. The composites were able to sustain higher load compared to the unreinforced steel. Wear test results indicated that the $TiB_2$ content and wear test parameters were important factors influencing the specific wear rate.

**Keywords:** steel matrix, $TiB_2$ reinforcement, dry sliding wear, microstructure

# Characterization of Ti(100−X)MgX (X = 5, 10, 30 and 50) alloys synthesized by mechanical alloying

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**Abstract**

$Ti_{(100-X)}Mg_X$ (X = 5, 10, 30 and 50) alloys were prepared by mechano-chemical synthesis in a high energy planetary RETSCH PM400 planetary ball mill. The elemental powder blends of Ti and Mg (purity >99.9%) with appropriate amount were milled at a rotational speed of 300rpm in a WC coated vial with 10 mm diameter WC balls. Toluene was used to avoid agglomeration during milling. Gradual phase transformation during milling was studied by X-ray diffraction and high-resolution transmission electron microscopy. Powder blends of all the four compositions show the evolution of fcc powder alloy formation. Structural instability due to plastic strain, increasing lattice expansion and negative (from core to boundary) hydrostatic pressure is responsible for the above mentioned phase evolution. The lattice parameter of the fcc phase is a function of both the alloy composition as well as the milling duration.

Keywords: Mechanical alloying, X-ray diffraction, Transmission electron microscopy, Ti-Mg alloy

# Optimizing oxide dispersoid content towards enhancing mechanical properties of ODS Ni-based high entropy alloy

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**Abstract**

The oxide dispersion strengthened high entropy alloys (ODS HEAs) represent an advanced material that integrates the distinctive properties of high entropy alloys with the strengthening effect of oxide nanoparticles. The excellent high-temperature stability, strength, hardness, and corrosion resistance of the ODS HEAs thus offer new avenues for developing structural materials to meet high-temperature applications like aerospace, nuclear power plants, etc. The current research work provides a comprehensive approach for optimizing oxide dispersoids in oxide dispersion strengthened high entropy alloy (ODS HEA) to enhance the strength-ductility alliance, thereby widening its applicability. The study focuses on fabrication of ODS HEA featuring a composition of $Ni_{47}Al_6Co_{18}Cr_8Fe_{12}Ti_8W_1$ at. % via mechanical alloying (MA) and spark plasma sintering (SPS). The investigation encompasses variations in $Y_2O_3$ content, including 1 vol. %, 3 vol. % and 5 vol. %. The effect of $Y_2O_3$ addition on the microstructural evolution and mechanical properties of the sintered alloys was evaluated. Phase analysis reveals that presence of $Y_2O_3$ promotes the formation of $Y_2Ti_2O_7$ complex oxide precipitation in ODS HEAs. A significant enhancement in both hardness and strength is evident in the pristine HEA upon $Y_2O_3$ addition. However, a reduction in these properties is observed in the 5 vol.% $Y_2O_3$ ODS HEA due to agglomeration of $Y_2O_3$ nanoparticles. Notably, the ODS HEA containing 3 vol.% $Y_2O_3$ exhibits exceptional mechanical characteristics, achieving a compressive yield strength of 1517 MPa and a compressive strain of 27%, demonstrating a synergistic combination of strength and ductility. Enhancement of the mechanical properties in the ODS HEA is ascribed to both oxide dispersion strengthening resulting from addition of $Y_2O_3$ as well as presence of in-situ formed $Y_2Ti_2O_7$ complex oxide coupled with solid solution strengthening effect of the HEA matrix.

Keywords: High Entropy Alloy, Oxide dispersion strengthening, Mechanical alloying, Spark plasma sintering, Solid solution strengthening

# An Experimental Investigation on Surface Finish & Tribological Behaviour of Selective Laser Melted Titanium Alloy by Abrasive Flow Finishing Process

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**Abstract**

The manufacturing of a precise complex component is concerned with the most critical phase of final finishing operation. Most of the traditional finishing process has limitations, while addressing challenges with finishing inaccessible, intricate, complex shape components need to be addressed with non-traditional finishing methods. Abrasive flow finishing (AFF) is an extensively employed post-processing technique to finish additively manufactured parts. This process uses polymer rheological abrasive medium (abrasive medium) to finish internal and external surfaces.

The aim of this research paper is to study surface roughness of SLM printed Ti6Al4V alloy by using the Abrasive Flow Finishing process. Optimum process parameters are obtained by comparing the mechanical & tribological properties for a Ti6Al4V alloy samples printed using SLM technique by varying its process parameters like Laser Power, Scanning Speed, Hatch Distance, Layer Thickness, to attain the optimum SLM conditions. The outcomes of work have clearly facilitated in developing a better surface roughness of selective laser melting process Ti6Al4V. Further, an attempt is made to develop an economic AFF medium by using viscoelastic polymers i.e., soft styrene and soft silicone polymer. The experimental study showed that the nano surface finish could be achieved by varying the viscosity of the developed medium on the additive manufactured components.

**Key words:** Selective Laser Melting, TI-6Al-4V, Abrasive Flow Finishing Process, Tribological & Mechanical Properties.

# Development of novel high-strength high-conductivity Cu-Ni alloy through wire arc additive manufacturing and vacuum arc melting – Performance comparison on Mechanical and electrical properties analysis.

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## Abstract

Copper-based alloys possess numerous advantageous properties that make them suitable for a wide range of applications. These properties include high electrical conductivity, high thermal conductivity, good strength, excellent ductility, and good corrosion resistance. Additive manufacturing technology offers in-situ design freedom, which has the potential to reduce both cost and time. In this study, a Cu-2Ni alloy was fabricated using synchro feed pulse mode wire arc additive manufacturing technology (WAAM) and the vacuum arc melting process. Elemental mapping of the fabricated copper alloy from both processes showed that nickel was not segregated and was evenly distributed throughout the copper. The tensile strength of the copper alloy in the building direction was found to be twice that of pure copper, though there was a decrease in ductility. In the XRD graph, copper and nickel peaks merged together, forming a new phase. Additionally, the microhardness in the building direction was higher than in the scanning direction and vertical section.

Keywords: Additive manufacturing, copper-nickel alloy, mechanical properties, hardness, WAAM

# Evolution of amorphous phase in multicomponent γ brass during prolonged mechanical alloying

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## Abstract

The $Cu_5Zn_8$ γ-brass is complex intermetallics in the binary Cu-Zn system. Mukhopadhyay et al. [1] has discerned amorphization in such complex intermetallics during nanostructuring through mechanical milling due to accumulation of defects. Therefore, it is of utmost importance to understand the influence of milling intensity on the structural features. In the present work efforts were made to understand the structural transformation during mechanical alloying of the $(CoCuFeMnNi)_{25}Zn_{75}$ (at. %) multicomponent γ-brass. The BCC $Cu_5Zn_8$ - type multicomponent γ brass was formed after 20 h of milling. However, milling was extended until 60 h to understand the structural features. The TEM investigation confirmed the existence of amorphous phase. The phase fraction of amorphous phase and intermetallics in 60 h milled powder were found to be ~83% and ~17% respectively. The amorphous domain was ~1.69 nm and the size of intermetallics was in the range of 1.73 nm. Furthermore, the Miedema model confirmed the stability of amorphous phases with having size less than ~8 nm.

keywords : γ brass intermetallic, amorphous phase, mechanical alloying

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# Effect of Addition of CNTxGnPyhBNz Ternary Hybrid Nanofillers on Mechanical Performance of Al Nanocomposites: A Comparative Study

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**Abstract**

In the present study, the objective is focused on the synthesis of a unique combination of ternary hybrid nanofillers composed of one-dimensional (1D) carbon nanotube (CNT), one-dimensional (2D) graphite nanoplatelet (GnP) and hexagonal boron nitride (hBN) in different weight ratios, followed by the fabrication of Al-based hybrid nanocomposites reinforced with the various CNT-GnP-hBN ternary hybrid nanofillers. Leveraging the synergistic effects of these various nanofillers, the aim was to improve the mechanical and tribological properties of the Al-based hybrid nanocomposites. The Al matrix was reinforced with 1 wt.% of the various CNT-GnP-hBN ternary hybrid nanofillers, each comprising varying proportions in weight fractions of the individual nanofillers. Powder metallurgy (PM) technique was used to develop the Al-based hybrid nanocomposites by reinforcing the Al matrix with the various CNT-GnP-hBN ternary hybrid nanofillers. The fabrication process of the various nanocomposites was done using both the conventional sintering and spark plasma sintering (SPS) techniques. In order to assess the impact of the CNT-GnP-hBN ternary hybrid nanofiller on the characteristics of the Al-based hybrid nanocomposites, pure Al samples were also developed using similar technique. The incorporation of the CNT-GnP-hBN ternary hybrid nanofiller into the Al matrix revealed a significant enhancement in wear performance compared to the pure Al sample developed under similar conditions. However, it was observed that as the hBN content increased the nanocomposites exhibited a decrease in both relative density and hardness.

Keywords: Hybrid nanofillers, Powder metallurgy (PM), Spark plasma sintering (SPS), Hexagonal boron nitride (hBN), Wear

# In situ observation on recrystallization and grain growth in cast and selective laser melted SS316L using High-Temperature Confocal Scanning Laser Microscopy

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**Abstract**

In this study, the main focus is to investigate the recrystallization and grain growth phenomena of SS316L samples manufactured by conventional method and additive manufacturing techniques. Conventionally, samples were prepared by cast and wrought method, which were rolled to 50% thickness (referred as C&W), and compared with additively manufactured (AM) samples prepared by Selective laser melting (SLM) technique. Typically, AM samples have a non-equilibrium microstructure, due to the rapid heating and cooling, which occurs during AM process. It enforces us to understand the impact of temperature on microstructural variation and how it leads to recrystallization and grain growth. Hence, in this work, our prime concern is to study the evolution of the as-deposited (SLM) microstructure at various temperatures and compared with C&W samples. In addition, the effect of holding times at various temperatures is investigated in detail. All experiments have been performed for C&W and SLM samples by using a High Temperature-Confocal Scanning Laser Microscopy (HT-CSLM) technique focusing on recrystallization and grain growth. Initially, C&W and SLM samples were heated to 850°C, 1000°C, 1300°C, and 1400°C temperatures at 200°C/min rate and hold for 100 s, 100 s, 200 s, and 180 s, respectively. It was found that the grain structure for SLM samples being more stable than C&W samples. In C&W samples, the recrystallization phenomenon starts at ~850°C with fine grains becoming visible, while in SLM sample microstructure changes appears at ~1150°C. In C&W samples, twin boundaries start to form ~1350-1360°C, but not in SLM specimens. There is complete twin formation at 1400°C and thick grain boundaries in C&W, whereas SLM specimens lack twining while shows thick grain boundaries. For grain growth experiment samples were heated to 1000℃ at rate of 200°C/min and hold at 1000℃ for 1 hour. In another experiment, the samples were heated to 1100℃ at 200℃/min rate and hold for 15 min, then temperature was increased to 1150℃ and hold for 1 h. Finally, it has been observed that there is significant grain growth in C&W samples at 1000°C and 1100°C, while it remains unchanged in SLM samples. However, during hold at 1150°C, the grain size increases in SLM samples and this increase is more pronounced in C&W samples. Further, we explore the reasons underlying the stability of AM samples, in terms of stored dislocation density, and also segregation of alloying elements to various defects such as grain boundaries or cell walls.

Key words: SS316L; Selective Laser Melting; High Temperature Confocal Laser Scanning Microscope; Recrystallization; Grain growth.

# Development of Mo-based alloys by conventional and pressureless sintering

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**Abstract**

Mechanical alloying has emerged as a promising technique for the fabrication of Mo-Ni-based alloys, which are challenging to produce using conventional methods due to significant disparities in melting points and restricted mutual solubility. This study explores the synthesis of six unique alloy compositions through mechanical alloying: S1 ($Mo_{80}Ni_{10}Si_{10}$), S2 ($Mo_{80}Ni_{10}Co_{10}$), S3 ($Mo_{80}Ni_{10}Si_5Co_5$), S4 ($Mo_{79}Ni_{10}Si_{10}(Y_2O_3)_1$), S5 ($Mo_{79}Ni_{10}Co_{10}(Y_2O_3)_1$), and S6 ($Mo_{79}Ni_{10}Si_5Co_5(Y_2O_3)_1$) (composition in weight percent). The synthesized powders were consolidated at 1500 °C in hydrogen atmosphere for 1.5 hours. Adding Ni, Si, and Co to Mo facilitated liquid phase sintering, thereby enhancing densification, while $Y_2O_3$ addition played a crucial role in grain refinement and improving mechanical properties. The introduction of Ni and $Y_2O_3$ resulted in a bimodal grain size distribution. After 20 hours of milling, oxide particles were encapsulated within the Mo particles. Studies using high-resolution transmission electron microscopy (HRTEM) and selected area diffraction (SAD) reveal the formation of nanocrystallites in oxide dispersion-strengthened (ODS) Mo alloys after 20 hours of milling. Notably, alloys with $Y_2O_3$ exhibited the minimum particle size and a bimodal distribution. X-ray diffraction (XRD) analysis of the sintered samples revealed the formation of hard and brittle intermetallic phases, such as $Mo_3Si$ (cubic), $Ni_3Si$ (cubic), and MoNi (orthorhombic), across all compositions. Elemental mapping confirmed the presence of $Y_2O_3$ oxides within the Mo matrix for alloys S4 to S6. Among the compositions, sintered alloy S6 achieved the highest relative density at 89.74%. Alloys S2 and S3 recorded the highest hardness values at 9.08 GPa and 8.85 GPa, respectively, due to the extensive formation of intermetallic phases. Mo alloys incorporated with $Y_2O_3$ particles showcased enhanced wear resistance, attributed to oxide dispersion strengthening and the presence of intermetallic phases.

Key words : Mo alloys; mechanical alloying; sintering; hardness; wear

# Modelling microsegregation during laser-based additive manufacturing of SS 316L

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**Abstract**

SS 316L is a widely used alloy in automotive, marine and aerospace applications. Due to its suitable properties like high thermal conductivity and weldability, it is one of the most widely used materials for additive manufacturing processes like laser powder bed fusion and directed energy deposition. High solidification rates are experienced during these processes leading to non-equilibrium conditions. Due to this, there is segregation of the elements in dendritic and interdendritic solidified regions. Segregation of elements like Cr and Mo have been reported in literature. The aim of this study is to predict the microsegregation during laser powder-bed fusion of SS 316L considering the remelting during the multi-track and multi-layer laser passes. For this, the temperature history during the process is captured using a Finite Element Model. A multicomponent microsegregation model based on a model developed by Yao et.al. [1] , with extensions to include multicomponent interactions, is used to simulate the microsegregation during the process, considering the major elements. The thermal gradients and the cooling rates from the FEM model are used as inputs to the model. Different locations in the multiple layers in both transverse and longitudinal directions are identified for the same. The effect of rapid solidification and thermal history on the predicted segregation is analyzed in detail and the importance of including these effects is emphasized. The results are also compared with experimental data from literature [2] [3].

**Keywords:** microsegregation model, laser powder bed fusion, SS 316L, thermal history

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# Investigation of microstructure and corrosion behavior of Wire-Arc additive manufactured austenitic stainless steel

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**Abstract**

The current work investigates the microstructure and the corrosion behavior of wire-arc additive manufactured (WAAM) 316 L austenite stainless stee1. A 316 L wall with to-fro deposition strategy was fabricated using cold-metal transfer wire arc additive manufacturing technique, as this deposition strategy is efficient, minimizes material wastage, and free from deposition failure. The microstructure of the manufactured 316 L wall was characterized using advanced characterization techniques such as Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD). The microstructure composed of austenite matrix with fine fraction of delta ferrite. The carbides were expected to be present in the microstructure, which seems too small to be characterized using the employed characterization techniques. The corrosion behavior of the base material and the manufactured wall was assessed using Potentiodynamic Polarization (PDP) test. The corrosion behavior of manufactured wall was evaluated in as-fabricated and thermally aged conditions. It was assessed that the thermally aged sample showed a relatively poor corrosion resistance compared to the as-fabricated, owing to the sensitization.

key words : WAAM, stainless steel, 316 L, austenite

# X-ray diffraction line profile analysis of ball milled nanocrystalline iron: Application of Warren-Averbach and modified Warren-Averbach methods

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A comparison has been carried out between two different methods of X-ray diffraction line profile analysis for the determination of crystallite size and microstrain namely the traditional Williamson-Hall (W-H) method and the Warren-Averbach (W-A) method (based on the Fourier analysis of diffraction lines) . Theoretical background behind these two methods has been revisited and these methods have been applied to ball milled nanocrystalline Fe powder. Correction of instrumental broadening of diffraction lines has been performed based on the so-called Stoke's deconvolution. Traditional Williamson-Hall analysis indicates dislocation induced anisotropic microstrain broadening of diffraction peaks in the severely plastically deformed ball milled Fe. The evaluation of detailed dislocation microstructure in the severely plastically deformed ball milled Fe has been carried out by both the modified Williamson-Hall and the modified Warren-Averbach methods.

The results show that both the methods yield comparable values for the crystallite size, microstrain, dislocation density and dislocation character (fraction of screw/edge dislocations) in the ball milled Fe. Additionally, the modified Warren-Averbach method determines the precise values of the dislocation outer-cutoff radius and the dislocation arrangement parameter. Prolonged ball milling leads to strong asymmetry of the Fe diffraction peaks due to dislocation heterogeneity in the plastically deformed Fe which poses serious problem in the diffraction line broadening analysis.

**Keywords:** X-ray diffraction, Diffraction line broadening, Williamson-Hall, Warren-Averbach, modified Warren- Averbach, Ball milling, nanocrystalline Fe

# Phase evolution during mechanical alloying of Ti-Fe-Si ternary eutectic system

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**Abstract**
This work is focused on a comparative study of experimental observation of phase evolution during mechanical alloying (MA) of Ti-Fe-Si eutectic powder compositions ($Fe_{42}Ti_{14.5}Si_{43.5}$ ($E_1$), $Fe_{25}Ti_7Si_{68}$ ($E_2$), $Fe_{58}Ti_{8.5}Si_{33.5}$ ($E_3$) and $Fe_{29}Ti_{66}Si_5$ ($E_4$)) using hardened steel and tungsten carbide (WC) grinding media. Ti-Fe-Si based system is cheaper and amorphous alloy of this system could be a potential candidate for bio-implant materials. XRD analysis revealed evolution of various intermetallic phases during milling depending on the powder composition and the type of grinding media. Formation of partial amorphous phase was observed in $E_2$ and $E_4$ powders after 60 h of MA using hardened steel grinding media. However, with prolonged MA up to 100 h again different complex intermetallic phases appeared under the effect of various contaminations coming from the grinding media. When WC grinding media was used for $E_1$ and $E_4$ powder compositions, the wear of the grinding media increased, and higher level of contaminations got incorporated with the powder materials to form different intermetallic phases and there was no trace of amorphous phase formation.

**key words**: Mechanical alloy, Eutectic, Amorphous, Intermetallic.

# Microstructure and Microhardness Evolution in Wire Arc Additive Manufactured Al5356 alloy after High-Pressure Torsion Processing

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## ABSTRACT

The processing of Aluminium alloys using Wire Arc Additive Manufacturing (WAAM) has accumulated significant research interest following technological advancements in the manufacturing sector. WAAM is a material addition technology that enables the creation of large and complex objects through the layer-by-layer fusion of metallic wires via an electric arc. Al5356 alloy is particularly notable for its high shear strength and excellent corrosion resistance compared to other elements in the Aluminium series. WAAM has many challenges, such as porosity, inhomogeneity in grain size, etc. HPT can overcome these issues by applying high pressure and high torsion. High Pressure Torsion (HPT) is a Severe Plastic Deformation (SPD) technique that exerts high pressure and shear strain on the material, inducing significant microstructural changes. Recent studies have demonstrated that HPT can lead to notable alterations in the material properties, particularly at higher shear strains.

In the present work, Al5356 single brick block (Height = 135mm, Width = 200mm and Thickness = 25 mm) was prepared using WAAM and cut into disk-shaped samples having 10 mm diameter and 1 mm thick, along transverse and longitudinal sections to analyse microstructure in WAAM-manufactured wall. Later, the same-sized disks from the transverse and longitudinal direction of the WAAM specimen were used for HPT processing with one turn. The analysis was carried out from the centre to the edge region of HPT samples. The microstructure characterisation was performed using an Optical and Field Emission Scanning Electron Microscope. Electron Backscatter Diffraction (EBSD) was also used to study the crystallographic orientation of the grains before and after HPT processing. The Vickers microhardness tester was employed to measure the microhardness of the WAAM and HPT processed samples. For HPT samples, the microhardness measurement was carried out from the center to the periphery of the disk. The results showed that processing Al5356 by HPT significantly refines its grain size. After one turn of HPT, the microstructure became more homogeneous and equiaxed compared to the WAAM Al5356 samples without HPT processing. Additionally, hardness showed significant improvement after HPT processing. HPT processing resolved the issues associated with the WAAM sample and presented a promising approach for producing high-performance Al5356 alloy components with superior mechanical properties.

Keywords: Wire Arc Additive Manufacturing, Al5356 Aluminium alloy, High Pressure Torsion, Microstructure characterisation, Microhardness

# Effect of Mechanical Milling on Isothermal Oxidation Behaviour of Laser Surface alloyed CoNiCrAlY on Inconel 718 Substrate

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**Abstract**

Nano-crystallization has improved the chemical and physical properties of materials. One of the simplest approaches for nano-crystallization of material is mechanical milling. In the present study the effect of mechanical milling on isothermmal oxidation behaviour of Laser surface alloyed CoNiCrAlY has been investigated. A commercially available CoNiCrAlY powder (with the composition of 32 wt.%Ni, 21 wt.%Cr, 8 wt.%Al, 0.5 wt.%Y, balance: Co) of make PAC 9950AMF was milled for 10 and 25 hours at 300 RPM using stearic acid as a process control agent (PCA), in tungsten carbide (WC) balls and vials in a ball to powder ratio of 10:1. Then as received and milled powders were mixed with binder i.e 3% PVA solution to make a slurry. Then slurry was preplaced on Inconel 718 substrate with thickness of 500μm. After drying, preplaced CoNiCrAlY is melted by the laser beam having 1800W power and scan speed of 50mm/sec. The laser surface alloyed samples were subjected to detailed characterization by scanning electron microscopy (SEM) and X-ray diffraction technique (XRD). The microstructure of the alloyed region was found to be dendritic in nature and consisted of γ, γ', γ'', β, δ and η phases. Finally, the isothermal oxidation behaviour of the coupons was measured from 800°C to 1000°C for the maximum time period of 100hrs. The isothermal oxidation study showed the formation of predominantly alumina TGO layer in case of milled laser surface alloyed sample compared to un-milled sample. Mechanism of oxidation has been established through a post oxidation microstructure analysis of the oxide scale.

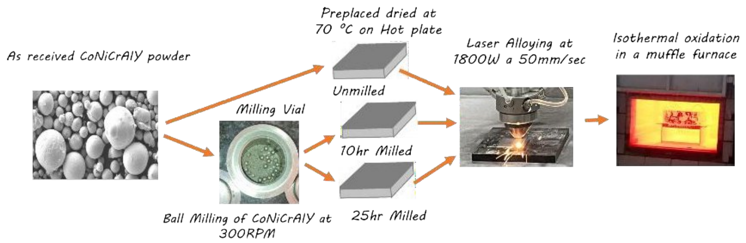


Fig.1: Experimental flow chart for isothermal oxidation of laser surface alloyed un-milled 10hr and 25hr milled CoNiCrAlY powder.

**Keywords:** CoNiCrAlY, Laser surface alloying, microstructure, high temperature isothermal oxidation.

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# Impact of Coating Thickness on Microstructure and Mechanical Behavior of HVAF-Sprayed Ni-Based Superalloys

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**Abstract**

High Velocity Air Fuel (HVAF) spraying demonstrates significant potential for surface coating and repair. This study evaluates the impact of varying thicknesses of Ni-based superalloy coatings, specifically IN625 and IN718, applied using HVAF. The microstructure and mechanical properties of these coatings were assessed using micro-hardness, coating cohesion, flexural, and coating-substrate adhesion tests. Results indicate that HVAF coatings maintain the original material phases from the powder. Cross-sectional analysis revealed robust bonding between the melted particles and the substrate, though porosity increased with coating thickness. Splat morphologies varied, including deformed, fully melted, partially melted, and unmelted particles. Thicker coatings (3 mm) displayed more undeformed splats with spherical bumps, which diminished in thinner coatings (1.5 mm and 0.5 mm). Pull-off adhesion tests indicated a decrease in adhesion strength with increasing thickness, attributed to higher porosity. The interface strength exceeded 65 MPa for defect-free coatings, while defective interfaces failed at lower stresses. Flexural strength decreased with thickness due to compressive residual stress and delamination, with coatings achieving up to 70% of the flexural strength of wrought material. Post-treatment with oxyacetylene flame spraying effectively reduced porosity, resulting in a denser of the coating. Moreover, IN718 coatings, in general, demonstrated superior performance compared to IN 625.

**Keywords:** HVAF coatings, Inconel superalloys, Adhesion strength, mechanical properties, flame spray.

# Enhancement of hot corrosion and hot oxidation resistance behaviors of selective laser melted Ti6Al4V by ultrasonic shot peening

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**Abstract:** Selective Laser Melting (SLM) is an emerging technology in manufacturing industries due to its numerous benefits such as minimum material wastage, design complexity and dimensional accuracy. In the present study, electrochemical corrosion, high temperature corrosion and ultrasonic shot penning (USSP) has been attempted for Ti alloy (Ti6Al4V) fabricated by SLM technique. The results shows the 20% improvement in micro hardness after USSP along with that improvement in electrochemical corrosion resistance in 3.5 wt. % NaCl solution and high temperature corrosion resistance in air, $Na_2SO_4$ + 25% NaCl, and $Na_2SO_4$ + 50% $V_2O_5$ environments at 750℃. The corrosion rate found to be minimum in USSP samples exposed under all environments. The samples exposed to $Na_2SO_4$ + 50% $V_2O_5$ environment was severely affected by the corrosion. Various techniques were used to characterize the hot corrosion products and the results confirmed the formation of $TiO_2$, $Al_2O_3$, $V_2O_3$, $V_2O_5$, $Na_2TiO_3$ oxides. Additionally, microstructural changes were observed compared to non-USSP sample. Both USSP and non-USSP samples showed flaky martensite with noticeable changes in flake length.

Keywords: Selective laser melting, ultrasonic shot penning, electrochemical corrosion, XRD

# Structural Analysis of RF Plasma Spheroidized Glass-Ceramic Powders Using Raman Spectroscopy

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## Abstract

This paper explores the suitability of glass ceramic powder synthesized using radio frequency plasma spheroidization process for additive manufacturing applications. Glass ceramic powders are crucial components in additive manufacturing, provided their unique properties, such as high strength, low thermal expansion and high resistance to thermal shock. Raman spectroscopy is a powerful analytical tool used to measure the unique vibrational fingerprint of the sample. From that information, the sample's chemical, structural and physical properties can be determined. This study employed Raman spectroscopy to analyze the glass ceramic powders synthesized using a radio frequency plasma spheroidization process. The Raman spectra of the glass ceramic powders revealed distinct peaks corresponding to the molecular vibrations of the glass ceramic components. The spectra were analysed to identify the powder's chemical composition and phase structure.

Keywords: Glass Ceramics, Spectroscopy, Polymorphy, Crystallinity

# OPTIMIZING THE HEAT TREATMENT PROCESSES FOR ADDITIVELY MANUFACTURED Ti-6Al-4V FOR ENHANCED DUCTILITY

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## ABSTRACT

Additive Manufacturing (AM), commonly known as 3D printing, has gained wide spread attention in recent years for its ability to produce complex and customized components with various materials. This abstract focuses on the application of additive manufacturing on Ti6Al-4V, a titanium alloy known for its excellent strength-to-weight ratio and corrosion resistance a highly versatile and widely used alloy in additive manufacturing, offering significant advantages in producing high-performance, customized, and complex parts for critical applications across various industries. Post-processing techniques play a crucial role in enhancing the mechanical properties and reliability of AM Ti-6Al-4Vcomponents.

Optimizing the heat treatment processes for additively manufactured (AM) Ti-6Al-4V is critical to enhance its ductility and overall mechanical performance. Ti-6Al-4V, a widely used titanium alloy, often exhibits anisotropic microstructures and residual stresses when produced through additive manufacturing, leading to suboptimal ductility and potential performance issues in critical applications. This study investigates the effects of various heat treatment protocols, including annealing, solution treatment, and multi-step heat treatment processes, on the microstructure and mechanical properties of AM Ti-6Al-4V. The objective is to identify an optimized heat treatment regimen that alleviates residual stresses, refines the microstructure, and improves ductility without compromising strength. Comprehensive microstructural analyses and mechanical testing were conducted to evaluate the influence of different heat treatment parameters. Results indicate that additively manufactured Ti-6Al-4V components should undergo heat treatment at 950°C for 4 hours or a multi-step heat treatment for over 8 hours at various temperature levels. These treatments enhance ductility to approximately 15% while retaining strength levels comparable to those of conventionally processed and heat-treated Ti6Al-4V. Therefore, a carefully controlled heat treatment process for additively manufactured Ti64 can significantly enhance the ductility of AM Ti-6Al-4V, making it more suitable for demanding applications in aerospace and biomedical industries.

Keywords: Additive Manufacturing , Ductility , Tensile properties, Heat Treatment.

# Study of the elastic properties and compressive behavior of porous copper fabricated using powder metallurgy route and having different porosities and pore morphologies

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**Abstract**

Porous copper having different porosities and pore morphologies has been fabricated via the space holder technique using the powder metallurgy route. $K_2CO_3$ and NaCl were employed as the space holders and five different mixture ratios of $K_2CO_3$:NaCl were used viz. 1:0, 2:1, 1:1, 1:2 and 0:1. The elastic property characterization of the porous copper samples was carried using the non-destructive ultrasound phase spectroscopy technique. The results showed that the samples were transverse isotropic in nature with lower elastic constants along the uni-axial green compaction direction, due to the pore flattening that occurred during green body fabrication. Moreover, the elastic constants were observed to be decreasing with increasing amount of porosity. The optimum elastic properties were observed in the porous copper samples having $K_2CO_3$:NaCl = 1:2. The compressive stress-strain behavior of the samples showed three different regions - the initial elastic region followed by the plateau region and finally the densification region. The yield stress decreased and the energy absorbed before densification increased, with an increase in porosity. While the stress-strain response was found to be similar for both monomodal and bimodal porous copper samples at lower porosity levels, after a critical porosity of ~50%, the strength of the bimodal porous copper samples was considerably higher. The effect of the uni-axial green compaction pressure on the elastic anisotropy of the porous copper samples having $K_2CO_3$:NaCl = 1:2 was investigated by varying the pressure systematically from 120 to 180 MPa. The results showed that while the average elastic anisotropy increased when the pressure was increased from 120 to 160 MPa, at 180 MPa applied pressure, the anisotropy decreased due to the presence of lower melting point NaCl particles, which facilitated the sintering of the Cu particles, thereby leading to enhanced densification. The yield strength and Young's modulus of porous copper samples are plotted in the Ashby material property map and it is observed that the samples having dual pore morphologies are potentially attractive for lightweight elastic hinges.

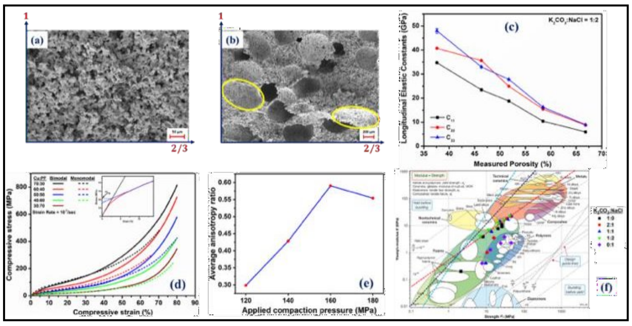

Figure 1: SEM micrographs of (a) monomodal, (b) bimodal porous copper, (c) variation of longitudinal elastic constants of porous copper, (d) compressive stress-strain behavior of porous copper, (e) variation of average anisotropy ratio with applied compaction pressure and (f) Young's modulus and yield strength of porous copper samples in Ashby material property map

Keywords: Porous copper, Elastic properties, Ultrasound phase spectroscopy, Compressive

behavior, Anisotropy

# Single-Crystalline CMSX-4 Superalloy builds with Laser-Directed Energy Deposition (L-DED) using Multi-Scale Models and Experiments

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**Abstract**

Additive manufacturing (AM) is rapidly becoming a viable alternative for producing complex geometries, making it a potential choice for manufacturing aerospace components. The high-pressure turbine blades in a jet engine not only have complex geometry but also require stringent microstructural specifications such as single-crystallinity. The combination of complexities in the topology and microstructure makes it challenging to identify the right process parameters for additive manufacturing of these blades.

This work describes a novel workflow for identifying these parameters, involving physics-based modeling at the melt pool length scale, and microstructure modeling at the grain and dendritic length scales. We introduce a diffuse-interface-inspired model to simulate the melt-pool shape during multi-layer deposition. The thermal histories obtained from this model are used in a Potts-based grain-structure model to determine the approximate texture during solidification. By combining the process and grain-structure model, we determine the parameter space for single-crystalline builds. Experimental analysis confirms that the identified parameters produce single-crystalline microstructures.

Furthermore, the thermal histories are utilized in phase-field simulations to determine the primary dendrite arm spacing (PDAS) for the CMSX-4 alloy. Comparison of these PDAS with experimental measurements serves as validation of the solidification conditions derived from the process model. Thus, the complementary utilization of experiments and modeling provides insights that not only allow the identification of appropriate additive parameters for epitaxial growth but also aid in designing strategies for building complex shapes.

Keywords: L-DED; Single-crystal; CMSX-4; Epitaxial; Additive manufacturing

# Solid state Layer Deposition Using Friction based Advanced Manufacturing Technique

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## Abstract

This study highlights the potential of friction-based AM techniques in successive deposition of aluminium alloy. Friction Surfacing, a solid-state progressive technique, is an advancement of traditional friction stir welding process. The process involves the rotation of a tool at high speed, generating sufficient heat to soften and plastically deform the material, which is then deposited onto a substrate in successive layers. The deposition rate which is influenced by the tool rotational speed and feed rate, along with the dwell time it plays a critical role in achieving the desired layer thickness. The ability to precisely control the microstructure and mechanical properties makes these techniques ideal for applications requiring high reliability and performance. AA2219 alloy is widely used in aerospace and automotive industries due to its favorable mechanical properties. In this work, AA2219 consumable tool was prepared and deposited over the steel substrate with rotation speed of 1200rpm and feed rate of 10mm/min. The microstructural quality of the deposited layer was studied through an optical microscope and scanning electron microscope (SEM). The layer-wise deposition in this method allows for controlled build-up of material ensures a high degree of accuracy and repeatability, making it ideal for additive manufacturing of metals especially AA2219 alloy.

Key words: Additive Manufacturing, Friction stir Surfacing, Aluminium alloy; Layer deposition.

# Phase-Separated Bulk Cu70Fe30 (at%) Alloys with Bimodal Grain Size Distribution for Enhanced Strength and Ductility

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**Abstract**

Cu-Fe alloys can be used in a wide range of applications, including automotive components, aerospace components, structural applications, high performance bearings, electrical contacts and connectors. However, synthesizing homogeneous Cu-Fe alloys is challenging, as Cu and Fe are insoluble in each other due to their high positive enthalpy of mixing, which is 13 kJ/mol. In this study, a metastable $Cu_{70}Fe_{30}$ (at%) single-phase face centered cubic (FCC) solid solution $\gamma^S$ was produced from the elemental powders of Cu and Fe through mechanical alloying for 20 h. Consequently, the alloyed powder was consolidated by SPS at $0.6T_m$ (622°C) and $0.7T_m$ (772°C) temperatures, where $T_m$ represents the linear-interpolated melting point of $Cu_{70}Fe_{30}$ alloy (1219 °C). Scanning electron microscopy (SEM), X-ray diffraction (XRD), electron backscatter diffraction (EBSD) and differential scanning calorimetry (DSC) analyses were conducted on the MA powders and the consolidated SPS bulk samples. Compression and hardness tests were conducted on the SPS samples to evaluate the mechanical properties. The $0.7T_m$ SPS sample exhibited an excellent ultimate compressive strength of 1056 MPa, and a ductility of 23% due to the bimodal grain size distribution in the microstructure as shown in Fig. 1, which includes an ultrafine-grained γ and α phase mixture, large discontinuous γ clusters formed from the phase separation of $\gamma^S$ during SPS, and a small amount of $Fe_3C$ phase. This $Fe_3C$ phase was observed due to carbon contamination from the milling media. During compressive deformation, the bimodal grain size distribution contributes to high strength through the fine grains (γ+α phase mixture) and enhances ductility through the larger grains (γ clusters).

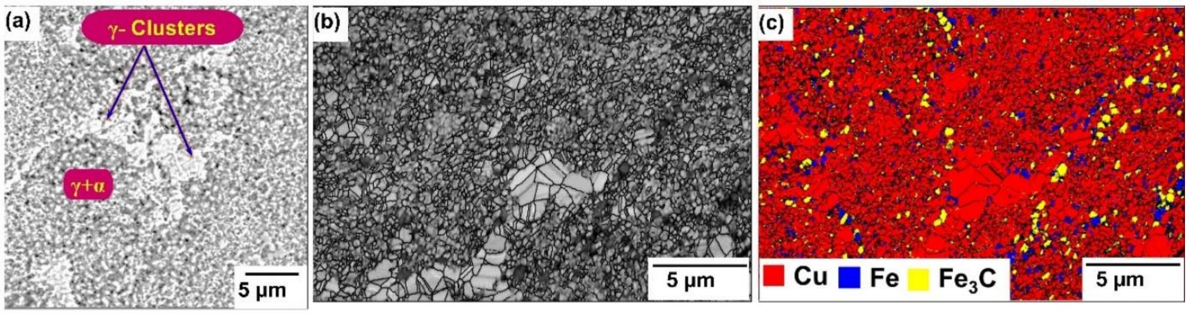


Fig. 1. (a) SEM image of $0.7T_m$ SPS sample, (b) EBSD band contrast and grain orientation image and (c) EBSD phase map

**Keywords:** Cu-Fe insoluble alloys, Mechanical alloying, Spark plasma sintering, Phase separation, Bimodal grain size distribution.

# Single-crystalline CMSX-4 superalloy builds manufactured through directional solidification and laser-directed energy deposition (L-DED) routes

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**Abstract**

Single crystalline Ni-based superalloys are preferred in the hottest parts of the aero-engine due to absence of the grain boundaries which improves high temperature creep strength. Conventionally, Directional solidification processing (DS) is used to produce columnar and single crystalline (SX) microstructures in Ni based superalloys. However, traditional manufacturing involves multiple complicated steps and requires long-term homogenization heat treatments before the component can be used in the final application. Additive manufacturing (AM) has revolutionized the manufacturing sector because of its ability to produce near-net-shaped components in a single step using a computer-aided design (CAD) model of the part. In addition to that, high thermal gradients and solidification rates associated with the AM processing favour epitaxial growth and results in microstructural refinement compared to the conventional processing.

The objective of this study is to understand and compare the microstructure, segregation behaviour and mechanical properties of the CMSX-4 superalloy single crystals manufactured through DS and laser based directed energy deposition (DED) AM routes. In-house developed vertical Bridgman furnace is used to generate the superalloy single crystals through seeding technique as a function of thermal gradient and solidification velocities. Laser based DED machine is used to manufacture superalloy single crystals of [001] orientation by epitaxial growth from the substrate using raster scan strategy as a function of the laser power, scanning speed, powder flow rate and layer height.

Microstructural analysis of DS and AM processed single crystals revealed a dendritic microstructure with a larger dendrite arm spacing in the former case. Compositional analysis of DS single crystals revealed severe segregation of Re and W to the dendritic regions; Ta, Al and Ti to the inter-dendritic regions compared to AM builds. Mechanical properties are also evaluated and compared in the as printed and heat-treated conditions.

**Keywords**: Single crystal; Directional solidification; Laser based additive manufacturing; epitaxial growth; mechanical properties.

# Study of the microstructural and mechanical properties of 316L stainless steel fabricated using ultrasonic vibration-assisted CMT wire arc additive manufacturing

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## Abstract

Wire Arc Additive Manufacturing (WAAM) is an advanced technique used to produce medium to large metallic components. Despite its advantages, one significant limitation is the formation of coarse columnar grains within the manufactured parts, which negatively impacts their mechanical properties. This drawback restricts the broader application of WAAM in various engineering fields. Ultrasonic vibration can be used to refine grains and improve their mechanical properties of SS 316L. In the current investigation, an ultrasonic generator was used to produce ultrasonic frequencies, and a sonotrode was employed to vibrate the substrate at different frequencies. X-ray diffraction was conducted to determine if any phase changes occurred after the application of ultrasonic vibration. The microstructure before and after using ultrasonic vibration was analyzed using both an optical microscope and a scanning electron microscope. Mechanical properties, including hardness, tensile strength, and fretting wear resistance, were also evaluated. The results demonstrated that after applying ultrasonic vibration, the grains became more refined, resulting in increased hardness, as hardness and grain size are inversely proportional. The tensile strength and fretting wear resistance increases post using ultrasonic vibration. The findings also indicated that as the frequency increases, the grain size initially decreases and then increases. This insight is valuable for fabricating parts with desired grain sizes in ultrasonic vibration-assisted WAAM. Thus, employing ultrasonic vibration significantly impacts the properties of the deposited structure.

**Keywords:** Wire arc additive manufacturing, Ultrasonic vibration, SS 316L, Fretting Wear

# Microstructural characterization and mechanical properties of heterogeneous bimodal copper

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**Abstract**

Owing to high thermal and electrical conductivity, good corrosion resistance and high melting point, copper (Cu) is widely used in thermal, automobile, aerospace, and electronic applications. However, the low mechanical properties of pure Cu limit its engineering applications. The mechanical properties of Cu can be enhanced through various strengthening mechanisms, including the addition of alloying elements in solid solution, particle dispersion, precipitation strengthening, severe plastic deformation, and grain refinement. However, these strengthening mechanisms resulted in a sharp decline in ductility, exhibiting the long-standing dilemma of strength–ductility trade-off in Cu. Recently, a heterogeneous bimodal microstructure design consisting of fine-grained (FG) regions and coarse-grained (CG) regions has been proposed as an effective strategy to overcome the strength–ductility trade-off. In this study, the heterogeneous bimodal Cu is developed by powder metallurgy route with a coarse-to-fine powder ratio of 50:50 (vol%.). The coarse and fine powders are mixed by magnetic stirrer, in which the coarse powders serve as a source for CG regions, while the fine powders act as a source for FG regions. The XRD patterns of the Cu powders and sintered samples reveal peaks of the pure Cu phase without any Cu oxide peaks. The SEM micrographs demonstrate a heterogeneous bimodal grain microstructure containing two distinct regions, one of which is fine-grained and the other is coarse-grained. Furthermore, the EBSD analysis also confirms the fine and coarse grain regions in the microstructure. The compression test is performed by the universal testing machine. The results show that the bimodal Cu sample exhibits a better balance of strength and ductility compared to pure Cu and milled Cu.

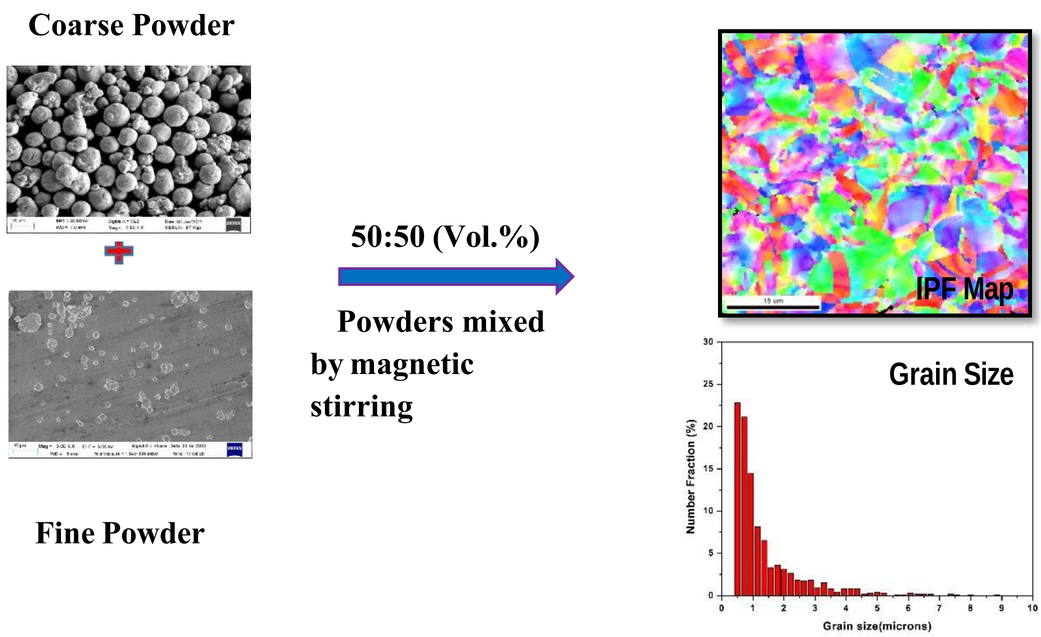


Fig. 1: Heterogeneous bimodal microstructures

keywords: Copper, Hardness, CG and FG regions, X-ray diffraction, EBSD analysis.

# Structural and Thermo-electric Behaviour of High Entropy BiSbTeSeSn Alloy Synthesised by Mechanical Alloying and Spark plasma Sintering

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**Abstract**

High entropy alloys (HEAs), are now being explored as possible candidates for numerous engineering applications, including structural and energy ones. Their advantages over traditional engineering alloys are the reason for this. The synthesis and consolidation of BiSbTeSeSn high entropy alloy for thermo-electric applications is investigated in this work. With the aid of high energy ball milling under optimum processing conditions (milling speed, ball-to-powder ratio, process control agent, environment, etc.), the equi-atomic composition of BiSbTeSeSn alloy doped with sodium (Na) was synthesised. To comprehend the high entropy solid solution, nanostructure, etc., structural characterisation was carried out using techniques including X-ray diffraction (XRD) and electron microscopy. The thermal stability of the produced alloys was investigated using differential thermal analysis (DTA). Subsequently, the powders that were ball milled were consolidated using spark plasma sintering. Studies on the sintered alloy's seebeck coefficient, electrical conductivity, and thermal conductivity were conducted. It was used to calculate the power factor and figure of merit. The high entropy solid solution of the nanocrystalline BiSbTeSeSn alloy is confirmed by the XRD measurements. Additionally, the good thermal stability of the nano-crystalline BiSbTeSeSn alloy is displayed in the sintered alloy. However, because the BiSbTeSeSn HEA alloy is more metallic in composition, its thermo-electric properties are reduced.

Keywords: High Entropy Alloy, BiSbTeSeSn, Mechanical Alloying, Spark Plasma Sintering,

# High-Temperature Mechanical properties of Haynes 282® Nickel base superalloy processed through Laser Powder Bed Fusion Additive Manufacturing Process

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**Abstract:**

In order to increase an efficiency and reduce the emission of greenhouse gases, there is an urge to increase the operating temperature of advanced ultra-supercritical (AUSC) power plants. Currently, Ferritic/martensitic dual-phase steels are the material of choice for such applications. However, the dual phase steel has temperature limitations, and so in order to further increase the operating temperature of AUSC, the development of alternative materials with high-temperature capabilities is critical. Nickel base superalloys are possible alloy classes that can be used in an A-USC power plant. Among available nickel-based superalloys, Haynes 282® is an ideal candidate for the A-USC application. Haynes 282® is a precipitate-strengthened nickel-base superalloy (combination of L12-ordered coherent γ′ precipitates and carbides) and exhibits better creep and oxidation resistance along with good processability (Thermo-mechanical processing and welding). At present, this alloy is processed through conventional casting followed by thermo-mechanical heat treatment. Some parts in A-USC have intricate shapes and require precision dimensional clearance, which is difficult to achieve through conventional processes. In this study, we explored the Laser powder bed fusion additive manufacturing (LPBF-AM) of Haynes 282® nickel-base superalloy. The process parameters were optimized based on the distribution of defects and microstructural evolution. The heat treatment parameters were optimized based on the distribution of precipitates in the matrix and the mechanical properties. The creep behavior for the optimized heat treatment cycle was further explored in the temperature range of 560-760°C and stress values of 300,400 and 500 MPa. The active deformation mechanisms during the creep were discussed based on the obtained Norton's creep exponent (n) and activation energy (Q) values and are correlated with the crept microstructure. The detailed microstructural analysis was carried out using a correlative EBSD-TEM and APT analysis. Further, the effect of varying load, speed and distance on wear behavior at elevated temperatures was studied and a detailed comparison with conventional Haynes 282® nickel superalloy is made.

**Keywords:** Nickel base superalloys, Creep, Additive Manufacturing, correlative microscopy techniques.

# Grain size effects on interdiffusion in multicomponent alloys

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## Abstract

Interdiffusion between metals and alloys is frequently encountered in engineering components and devices, which is often an assembly of different types of materials, for e.g., in flip-chip technology, bond coating, production of $Nb_3Sn$ superconductors, nanotubes and laminate structures. The development of the interdiffusion zone (IDZ) is expected to be altered with the change in grain size of one or both end members, which can affect the interface properties in relevant applications.

The present study focuses on investigating the phase growth during interdiffusion by employing a novel sandwich couple approach comprising of CG-M/Sn/UFG-M materials (where CG denotes coarse-grained (~250 µm), UFG denotes ultrafine-grained (~200 nm), and M represents CoNi and CoFeNi). The interdiffusion experiments have been conducted in the temperature range of 175- 215 $^0$C. The CG-M and UFG-M samples have been fabricated using arc melting and spark plasma sintering (SPS) techniques, respectively. The composition of phases formed has been confirmed through electron probe microanalysis (EPMA) and micro-x-ray diffraction (XRD) measurements.

It has been demonstrated that the phase transformation in IDZ is controlled by both thermodynamics and kinetic factors. For e.g., in CoNi diffusion couples at 175 $^0$C, only the $CoNiSn_3$ intermetallic phase is observed at the CG interface, while the UFG CoNi/Sn interface displayed the formation of the $CoNiSn_2$ phase. At 200$^0$C, the formation of the $CoNiSn_2$ phase treatment for over 8 hours at various temperature levels. These treatments enhance ductility to approximately 15% while retaining strength levels comparable to those of conventionally processed and heat-treated Ti6Al-4V. Therefore, a carefully controlled heat treatment process for additively manufactured Ti64 can significantly enhance the ductility of AM Ti-6Al-4V, making it more suitable for demanding applications in aerospace and biomedical industries.

Keywords: Additive Manufacturing , Ductility , Tensile properties, Heat Treatme

# Effect of Ti modification and T6 heat treatment on the mechanical properties of the additively manufactured Al 2024 alloy.

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**Abstract**

The current study investigates the impact of annealing temperature on mechanical properties such as strength, hardness, and microstructural evolution of laser powder bed fabricated, Ti modified Al 2024 alloy. Al 2024 is a precipitation hardened Cu, and Mg based aluminum alloy that finds widespread applications in various industries. The titanium acts as a grain refining agent for the aluminum alloys and reduces the solidification cracking in aluminum alloys. The addition of titanium in additively manufactured Al 2024 alloy can lead to the formation of ultrafine grained (UFG) structure with average grain size of 0.4 μm. The formation of UFG structure also improves the mechanical properties of the Al 2024 alloy. The Al 2024 alloy has Al2Cu, and Al2CuMg as its main strengthening precipitates. These precipitates are evolved during heat treatment process and are responsible for the high strength observed in the Al 2024 alloy. Hence, optimal evolution of these precipitate is very essential for producing high strength, additively manufactured Al 2024 alloy. The mechanical properties were evaluated using compression, and hardness test. The microstructural behavior and phase evolution were analyzed using a variety of techniques such as x- ray diffraction, scanning electron microscopy, and transmission electron microscopy.

key words : Additive manufacturing, structure property correlation, Fracture toughness, Laser powder bed fusion.

# Laser powder bed fusion of AISI 4140 high strength low alloy steel: optimization of process parameters

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Laser powder bed fusion, often referred to as selective laser melting, is the predominant technique in metallic additive manufacturing. It enables the production of intricate components with complex shapes by depositing metallic powders layer by layer, resulting in a nearly net-shaped final product. Experiments on single tracks were conducted to investigate the impacts of scan speed and laser power on the behavior of the tracks during laser powder bed fusion. For the high strength low alloy steel AISI 4140, bead mode, the melt pool dimension, and the track stability were investigated. The laser power for the tracks were varied between 150 W and 400 W, while the laser scan speed ranged from 300 mm/s to 1400 mm/s. The bulk specimens were built using identical parameters as those employed in the single-track testing. High porosity was seen at both high and low energy input densities. This was attributed to the presence of un-melted particles and keyhole pores, respectively. An increase in laser scanning speed results in the observation of discontinuities in the tracks. As the laser intensity increases, the depth of penetration of the bead also increases, indicating a shift in the bead morphology from conduction mode to transition mode or keyhole mode. This would lead to an increase in the occurrence of porosity flaws. The occurrence of balling can be elucidated by considering the Marangoni convection and the Rayleigh instability in relation to the flow of the molten material. The contact angle is a direct measure of the wettability of the bead. The experimental investigation revealed that the tracks became unstable when the droplets solidified prior to spreading out over the substrate, resulting in a contact angle exceeding 90°. Through the analysis of the track and bead morphology, a refined set of parameters was derived that can be utilized for printing specimens. The examination of the bulk specimens revealed the presence of martensite formation in the microstructure. Vickers hardness testing was performed in the vertical direction, starting from the bottom and moving towards the top. The hardness exhibited minimal variance, indicating a high degree of homogeneity.

Keywords : LPBF, HSLA steel, single-tracks

# Role of process parameters on microstructure and mechanical property variations in an additively manufactured 316L Stainless steel

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## Abstract

Additive Manufacturing (AM) is a cutting-edge technique for producing components on demand, enabling the creation of complex geometries while simplifying the production process. Our current research focuses on understanding how various process parameters impact the formation of specific microstructural features and the resulting changes in hardness and modulus. We characterized the 316L stainless steel samples deposited under different conditions of selective laser melting technique using Electron Backscatter Diffraction (EBSD) and nanoindentation. Both the average value and spread in the hardness and modulus distributions varied between top and bottom regions along the build direction. For samples deposited at 700 m/s scanning speed, in spite of similar variations in laser power, the hardness and modulus values remain almost similar between the top and bottom regions. While at 800 m/s scanning speed, increasing the laser power increases the difference in modulus values between the top and bottom regions. A direct correlation between the difference in hardness values and Kernal Average Misorientations could be observed. Here, the differences in local orientation gradients (i.e. KAM) are related to the geometrically necessary dislocations, and a higher KAM value correlates well with a high hardness value. Similarly increase in hatch distance, while maintaining constant scan speed and laser power, results in a corresponding rise in dislocation density and a subsequent increase in hardness value.

Keywords: 316L stainless steel; selective laser melting; EBSD; GND; nanoindentation

# Surface Mechanical Attrition Treatment of Spark Plasma Sintered Titanium Aluminide: Microstructural and Mechanical Behaviour Analysis

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## Abstract

Titanium Aluminide (TiAl) alloys are promising materials for high-temperature and aerospace applications due to their excellent strength-to-weight ratio and oxidation resistance. However, their inherent brittleness and surface properties require enhancement for broader applications. In this study, Spark Plasma Sintering (SPS) was utilized to fabricate TiAl specimens, followed by surface modification through Surface Mechanical Attrition Treatment (SMAT). The modified surfaces were extensively characterized using Electron Backscatter Diffraction (EBSD), Scanning Electron Microscopy (SEM), and 3D profilometry to evaluate the microstructural changes. Mechanical properties, including hardness and surface roughness, were assessed to understand the impact of SMAT on the treated surfaces. Furthermore, the corrosion resistance of the SMAT-treated TiAl samples was evaluated, providing insights into the effectiveness of the surface modification process. The results indicated significant improvements in both the mechanical and microstructural properties of the TiAl alloy, with enhanced corrosion resistance, highlighting the potential of SMAT as a viable technique for improving the performance of TiAl components in demanding environments.

# The role of inter-layer rotation in minimising mechanical anisotropy during laser powder bed fusion additive manufacturing of an IN718 alloy

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## Abstract

Laser Powder Bed Fusion (LPBF) is an additive manufacturing technique that utilises a laser as the heat source and metal powder as the feedstock. Several critical parameters, including laser power, scan speed, step over distance (hatch spacing), and interlayer rotation significantly influence the mechanical properties of the printed components in the LPBF process. This study investigates the impact of two distinct deposition strategies (0 and 67 interlayer rotation) on the microstructural and room temperature tensile properties of Inconel 718 samples in parallel and perpendicular to the build direction. The contributions to strengthening from grain boundaries, texture, and dislocation-dislocation interactions were quantified using the Hall-Petch, Taylor, and Bailey-Hirsch models using Electron Back Scattering Diffraction (EBSD) data and correlated with the experimental investigations.

It was found that the interlayer rotation during depositions significantly influenced the grain size, aspect ratio, dendritic arm spacing, crystallographic orientations, and the overall mechanical behaviour. The 0 º interlayer rotation results in a strong texture, characterised by the presence of columnar grains with orientation parallel to the build direction. In the perpendicular to the build direction, bimodal structure was found to be stabilised which led to higher yield and ultimate tensile strength perpendicular to building direction and higher elongation in parallel to building direction. On the contrary, the 67 ˚ interlayer rotation reduces both grain sizes and the texture intensity, respectively. This led to nearly similar strength and elongation in parallel and perpendicular to building direction for a 67 ˚ interlayer rotation.

# Optimal Reinforcement Distribution for Multi-scale Segregated Structures to Boost Aluminium Metal Matrix Composite Performance

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## Abstract

Recently, there has been interest in the unique design opportunities that arise from the controlled distribution of reinforcements at an intermediate or mesoscopic scale. With their distinctive discontinuous segregated microstructure arrangements, multi-scale segregated microstructure composites are a relatively new class of composites that combine metallic properties like excellent thermal conductivities, toughness, formability, hardness and strength with ceramic properties like modulus, low thermal expansion, high-temperature durability, improved hardness and strength. In the current work, high-energy ball milling and rotor mixing are used to generate conventional aluminium (Al) matrix composites (with homogenous reinforcement distribution) and discontinuous segregated aluminium matrix composites with 10% weight percentage of aluminium nitride (AlN) as reinforcement. The development of these composites involve 10 hours of high-energy ball milling followed by 30 minutes of rotor mixing. Further microstructure modifications are done based on the percentage distribution of composite region and matrix region in suitable ratios. The importance of segregated microstructure formation is demonstrated by structural, mechanical, and thermal characterisations, which also highlight how more customisation of the composite and matrix distribution broadens the range of useful applications for a given system.

keywords: Aluminium metal matrix composites, segregated microstructure, thermal conductivity

# Mechanical alloying in Cu-Ru immiscible binary system: X-ray diffraction investigation

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Cu and Ru are completely immiscible at equilibrium even at very high temperature (> 1059ºC) due to their positive enthalpy of mixing ($\Delta H_{mix}$ ~ 7 kJ/mole). Mechanical alloying is a well-known non-equilibrium synthesis method for alloy creation between immiscible elements. Nevertheless, reports on mechanical alloying between Cu and Ru are rare in the literature [1]. The present investigation is an attempt to create metastable Cu-3wt%Ru single phase alloy by high energy ball milling of Cu and Ru powder (purity ~ 99.9% for both) for different milling durations (~ 20h to 170h). Alloy formation and defect microstructure have been studied by X-ray diffraction (XRD), differential scanning calorimetry (DSC), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Surprisingly, even after 170h milling of Cu-3wt%Ru powder, XRD results show presence of prominent diffraction peaks from both Cu and Ru phases indicating no significant solid solubility between Cu and Ru. However, notable changes in the lattice parameters of Cu and Ru have been observed along with significant lattice parameter anisotropy for Cu phase. Furthermore, large broadening of Cu and Ru peaks are observed and detailed XRD line broadening study for Cu phase indicates generation of dislocations and planar faults in the Cu matrix along with severe reduction in the average crystallite size of Cu. Currently, formation of such nanostructure, defects creation and segregation of Ru in Cu grain boundaries are being investigated in detail by SEM and TEM along with spectroscopic techniques. Additionally, DSC results of Cu-3wt%Ru powder ball milled for various durations are being studied in order to understand the underlying thermodynamics of alloy formation and micro/nanostructural changes in the Cu-Ru system.

**Reference:** C. Suryanarayana, Mechanical alloying: A critical review, MATER. RES. LETT, 10 (2022) 619 - 647; https://doi.org/10.1080/21663831.2022.2075243

**Keywords:** Mechanical Alloying, Cu-Ru, Immiscible, ball milling, XRD, DSC, SEM, TEM

# Influence of Nitrogen on the printability & microstructure of CoCrMoFe alloy produced by Laser- Powder bed fusion(L-PBF)

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A careful selection of materials with desirable biocompatible qualities is necessary for the design of prostheses for maxillo-facial restoration of patients having a large wound from trauma. Medical grade ASTM F75 Co-Cr-Mo alloys are the hardest known biocompatible materials commonly used in medical implants, partial denture frameworks, and crown & bridge substructure restorations in dentistry.

Co-Cr-Mo alloys are preferred for dental applications owing to their excellent tribological and mechanical properties. However, the toxicity and the cost due to the high concentration of cobalt is a major concern. In this study, an attempt is made to develop a novel, low-cost CoCrMoFe alloy composition by the reduction in the Cobalt concentration by the addition of Iron (Fe) that can be printed using a laser powder bed fusion-based additive manufacturing process. The designed alloy is envisaged to possess reduced toxicity potential and excellent mechanical, biocorrosion and tribological properties compared to commercially used expensive CoCrMo alloys.

The alloy composition is developed using the Calphad approach, and a grid search method is employed to develop a robust set of process parameters for producing parts with minimal defects. Poor printability of CoCrMoFe alloy has posed a difficult challenge to achieve a crack-free specimen. In order to improve the printability, the infusion of Nitrogen gas into the powder was achieved by Hydrogen gas annealing at 1200°C for 10 hrs. Nitrogen being a strong FCC stabilizer helps in suppressing BCC phase formation and As-printed specimen displays single phase FCC crystal structure owing to the rapid solidification phenomenon experienced in L-PBF.

This novel method of improving the printability of complex alloy compositions by the virtue of nitrogen infusion has shown its potential of mitigating solidification cracking in LPBF process.

Keywords: Hydrogen gas annealing, Laser-Powder bed fusion, Biomaterials, Co-Cr-Mo alloy

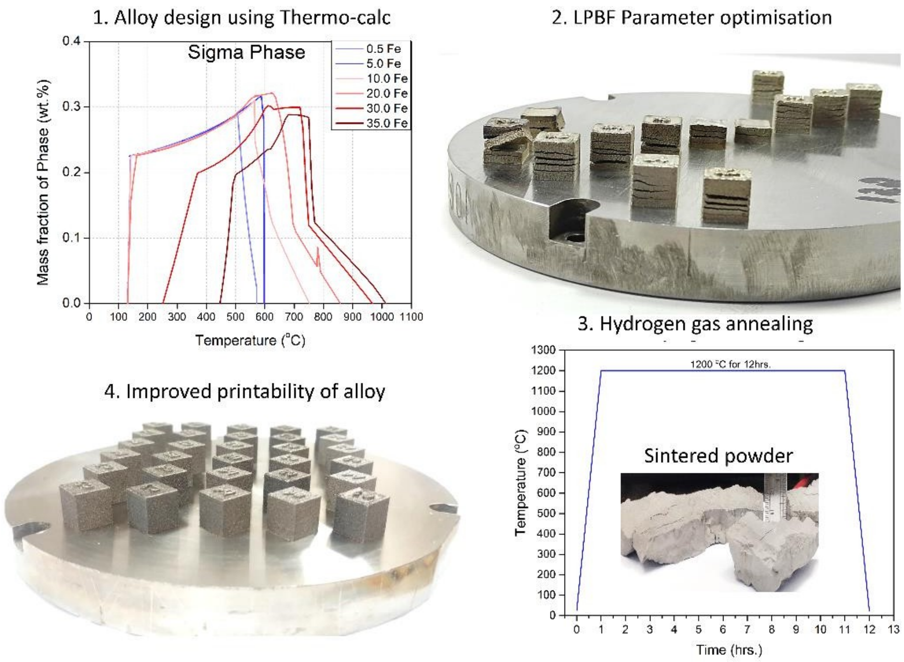


**Figure 1 Graphical Abstract**

# Characterization of Additively Manufactured Cu-1Cr-0.1Zr for Liquid Rocket Engines

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**Abstract**

Cu-1Cr-0.1Zr alloy possesses balanced thermal conductivity and strength at elevated temperatures for rocketry. Through additive manufacturing(AM), flexibility in design coupled with manufacturing intricate parts with reduced number of joints results in enhanced buy-to-fly ratio. Present work provides detailed characterization of Cu-1Cr-0.1Zr copper alloy manufactured through LPBF (Laser Powder Bed Fusion) for liquid rocket engines.

Test coupons of Cu-1Cr-0.1Zr were manufactured with optimized LPBF process parameters. Chemical and gas analysis were performed on specimens. Solution treatments on as-printed coupons were performed between 900-1030°C to ensure complete dissolution of the melt pools and re-crystallization of microstructure, where 980°C solution treatment was identified to be the most suitable. Differential Scanning Calorimetry analysis was carried out to identify the ageing temperature range and experiments were performed between 400 – 600°C with different holding time periods. Tensile properties were evaluated for temperatures ranging from RT to 650°C in both solution treated and solution treated + aged condition. Microstructural analysis provided insights into the grain structure and defects like voids and lack of fusion, while fractography offered valuable data on fracture behaviour. Thermal conductivity, coefficient of thermal expansion, and specific heat capacity were measured upto 800°C for comparison with other copper alloys used in liquid rocket engines. Further, studies on the effect of simulated brazing and post brazing heat treatment on AM Cu-1Cr-0.1Zr was carried out. These findings contribute to the understanding of the usability of Cu-1Cr-0.1Zr in the thrust chambers of liquid rocket engines operating at high temperatures.

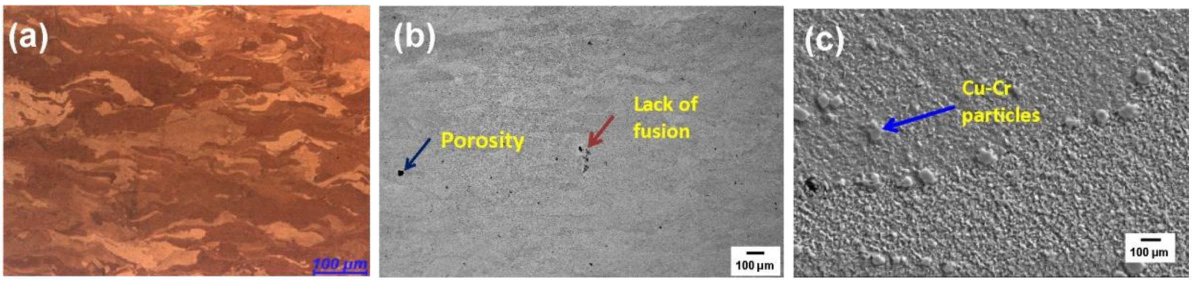


Fig. 1: a) Optical micrograph, b) SEM micrograph of Cu-1Cr-0.1Zr, c) SEM micrograph showing Cu-Cr particles

key words: Cu-1Cr-0.1Zr, Laser Powder Bed Fusion, ageing, brazing, physical properties

# Stress relaxation behaviour of laser powder bed fusion additive manufactured AlSi10Mg at elevated temperatures (30 – 250°C)

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**Abstract**

AlSi10Mg is a widely used cast alloy in the automotive and aerospace sectors for its high specific strength and stable microstructure up to 225°C. The hard Si phase dispersed in a soft aluminium matrix bears the load resembling that of a metal matrix composite. Recently, this alloy has been processed extensively via laser powder bed fusion additive manufacturing technique due to its excellent weldability. The high cooling rates involved in the LPBF-AM result in a fine interconnected eutectic that provides superior mechanical properties compared to conventional cast counterparts. The time-dependent deformation behaviour of LPBF AlSi10Mg under different prestress (repeated stress relaxation) and restrain (single stress relaxation) conditions at operating temperatures (i.e., 100 – 250 °C) has not been understood well. To investigate this, as-printed LPBF AlSi10Mg specimens were subjected to monotonic and repeated stress relaxation tests in tensile mode, with an initial strain rate of $10^{-4}$ $s^{-1}$, over a temperature range of 30– 250 °C. The activation energy of the as-printed LPBF AlSi10Mg was found to be influenced by both the eutectic network and temperature. The Si phase contributes to back stress, increasing resistance to deformation, but at 250 °C, this resistance diminishes due to changes in the microstructure. Further, the Caillard and Martin logarithmic model was applied to understand the relaxation behaviour, and the experimental results were consistent with the model's predictions across the tested range.

# Wettability and bond strength of $TiO_2$ doped SAC305 lead-free solder nanocomposites

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**Abstract**

The use of lead-based solders in the microelectronic industry is now restricted due to their toxicity. This has initiated the development of lead-free solders. Unlike lead-based solders, lead-free solders have poor wettability and result in weak solder joints. One of the most promising alternatives for lead-based solders is SAC solders. Of the SAC solders, SAC305 has relatively good solderability and mechanical properties. The introduction of ceramic nanoparticles to the solder alloy improves the reliability and performance of solders.

In the present work, the effect of the addition of $TiO_2$ nanoparticles on wetting, microstructure, and bond strength of SAC305 was investigated. The SAC305 solder alloy was doped with 0.1 and 0.4wt% $TiO_2$ nanoparticles to prepare nanocomposites using mechanical stirring. The nanocomposite solder droplets were deposited on 12.5mm diameter and 8mm thickness copper substrates with a mean surface roughness ($R_a$) of 0.05 ± 0.02 μm. Figure 1 shows the experimental methodology and the results obtained. Nanocomposite solders showed an improvement in wetting as well as bond strength compared to that of the bare solder alloy (Fig.1). Adding $TiO_2$ nanoparticles at a smaller weight percentage produced a more reliable solder joint than the bare solder alloy.

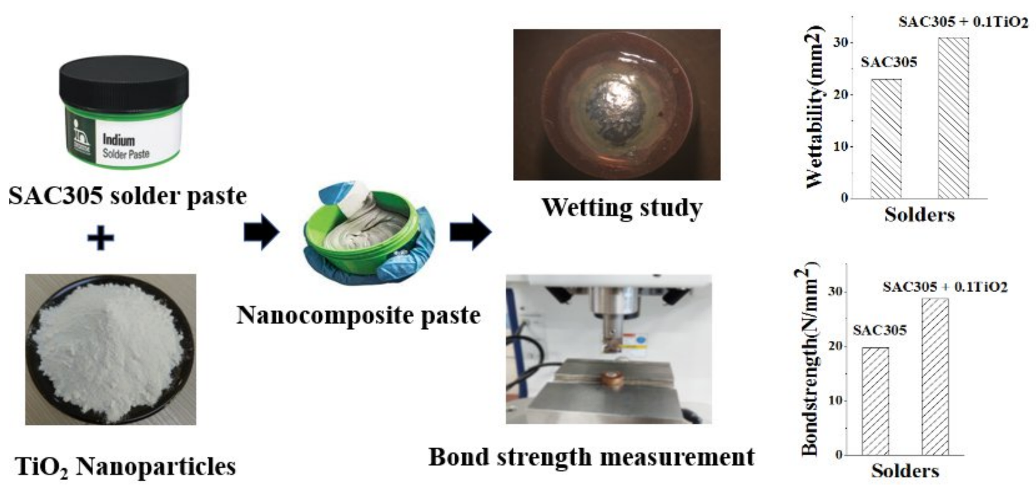


Fig.1 Experimental Methodology

Key words: $TiO_2$ nanoparticles; SAC 305 solder nanocomposite; wettability; bond strength; intermetallic compound (IMC)

# Effect of post heat treatment by Gleeble® 3800 on RSW weld nugget.

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## Abstract

Resistance Spot Welding (RSW) is the most prominent joining process used to join the thin sheets of dual phase (DP) steels in the automotive industry. Very high cooling rates during RSW lead to the formation of hard martensitic structures in the weld nugget, which results in loss of ductility. This paper aims to join the DP980 steel sheets and study the secondary heating effect at the weld nugget. The purpose of post-heat treatment at weld nuggets is to get the desired microstructure, defect-free weld and to improve the material property. About 1.5mm thick DP980 steel sheet was used supplied by JSW for this study. The industrially accepted (4√t, where ‘‘t’’ is the sheet thickness) welding parameters were optimized for nugget diameter. The observed nugget diameter is ~7.20mm. Based on the inter critical temperature during DP steel manufacturing process, three thermal cycles (750ºC, 800ºC & 850ºC) were chosen and used for post heat treatment purposes. Used Thermo-Mechanical Physical simulator Gleeble® 3800 as controlled & precise heat treatment on weld nuggets. The dual thermal cycle experienced by the nugget and surrounding zone affects the phase fractions and distribution. Detailed microstructural characterization and mechanical properties were conducted for welded components. The microstructure shows an equal distribution of Ferrite and Martensite phases at the weld zone. The moderate hardness at the weld region is attributed to secondary heating as tempering.

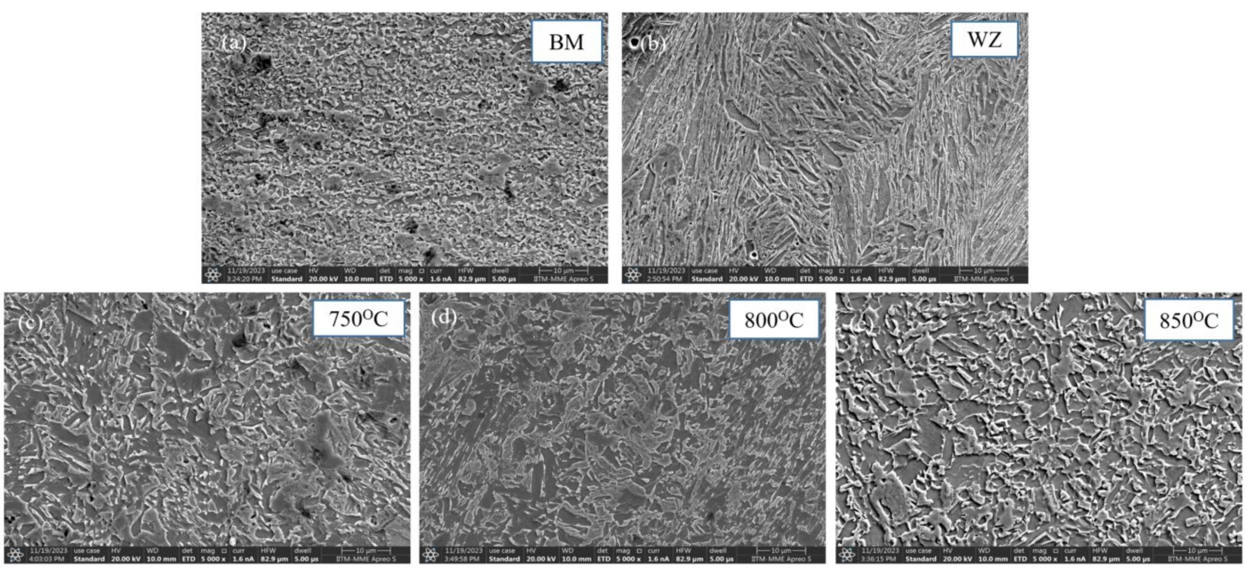


Fig. 1: SEM micrographs of DP980 steel, RSW weld nugget and post heat treatment by Gleeble® 3800 of weld nuggets. (a) Base metal having equiaxed fine grains consists of martensite and ferrite phases, (b) RSW Weld zone having large columnar grains, (c) 750°C, (d) 800°C and (e) 850°C temperature conditions. (c,d,e) micrographs taken at welded zone, having equiaxed fine grains.

**Keywords:** DP980, Resistance spot welding, Gleeble® 3800.

# Characterization Studies on Wire Arc Additive Manufactured Functionally Graded Material (SS316L / Hastelloy C-276)

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## Abstract

Hastelloy C-276, a nickel base superalloy is the most popular material due to its excellent corrosive resistance and good strength at high temperatures. These properties make it suitable material for harsh and high temperature corrosive environments in industries like chemical processing, nuclear power plants, offshore oil and gas production. However, the high cost of raw material and fabrication using traditional methods makes it difficult for widespread applications. With the concept of Functionally Graded Material (FGMs) and advanced manufacturing processes like Wire Arc Additive Manufacturing (WAAM), the above-mentioned limitations can be reduced. In the present work, Gas Metal Arc Welding based WAAM process was adopted to fabricate FGM of Hastelloy C-276 on SS316L. WAAM process parameters were optimized for obtaining the FGM with defect free interface. Further microstructural analysis and mechanical properties evaluation were carried out. The micrograph revealed the defect free interface composed of predominantly columnar dendrites along the build direction. The hardness test revealed the interface region with intermediate hardness compared to SS316L and Hastelloy C-276 ensuring optimal elemental distribution at the interface in correlation with SEM-EDS analysis.

Key words: FGM, GMAW, Wire Arc Additive Manufacturing, Hastelloy C-276.

# Experimental Determination of Interdiffusion Coefficients Fe-Ni-Co Ternary System Utilizing Body Diagonal Diffusion Couple Approach

C. Raviteja &Dr. Kaustubh Kulkarni

## Abstract

Fe-Ni-Co alloys are well-known due to their low thermal expansion. They are used in vacuum and borosilicate glass connections, electronic packaging, aerospace applications, and electric vehicles. However, they gained prominent interest in thermomagnetic motors used for clean energy production. The magnets play an essential role in the advancement of this technology. The magnetic properties vary in the Fe-Ni-Co system by changing the Ni and Co and many of the processing technologies in permanent magnets are based on the interdiffusion process. Hence it is crucial to find the interdiffusion coefficients of these components, which help to understand the atomic interaction between these individual elements and makes it easy to control the microstructure. We must conduct a diffusion couple experiment using the body diagonal method to find interdiffusion coefficients at the desired compositions. The diffusion couples were annealed at 1273k and then quenched to retain high-temperature microstructure and composition. These couples were further analyzed using an electron probe micro analyzer _(EPMA) for experimental composition profile the composition profiles were analyzed for interdiffusion fluxes using the MultiDiFlux program. The interdiffusion coefficients were evaluated at selected composition using Kirkaldy's approach of couples with intersecting diffusion paths.

# Identification of optimized spot welding parameters for Advanced Automotive steels using SYSWELD simulation

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**Abstract**

Due to increasing demand of reducing weight to strength ratio in automotive industries Advanced High Strength Steel (AHSS) materials demand increases. However, there was welding problem associated with these materials. Therefore in this study commonly used automotive steel grades: IF 270, TRIP 690, DP 780, and TRIP 980 materials selected and there welding study was done. Experimentation of welding is time and resource consuming therefore a simulation method were developed. In this study a model was developed using SYSWELD software consist of thermo mechanical and metallurgical phenomenon to simulate the resistance spot welding. This study provides critical welding current values mapping for various phenomena during resistance spot welding. It was observed that with increase in welding current weld diameter and failure load increases before expulsion. The developed model's predictions of nugget size and the heat-affected zone (HAZ) closely matched the experimental results. It was observed that current range for the selected grades was 9–10 kA, cautioning against welding beyond these values, especially for DP780 and IF grade steel.

**Key words** : Advanced High Strength Steel (AHSS), SYSWELD, RSW, HAZ

# Development of Manufacturing Process for Zircaloy Annular Cobalt Capsule

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## Abstract

Cobalt-60 is in high demand for industrial and medical applications due to its radioactivity with high energy gamma rays. Currently, Co-60 is generated in 220MWe PHWRs where Co-59 is used as absorber material in control rods. To further augment generation of Co-60, Zircaloy annular Cobalt Capsules are manufactured for the first time by Nuclear Fuel Complex (NFC), Hyderabad for irradiation in Research reactor.

In annular Cobalt Capsule, Co-59 pellets are encapsulated in an annular region between Zircaloy-4 components. Cobalt pellets are nickel coated small cylindrical bids and are filled in annular gap with stringent weight control. NFC Hyderabad improvised design of cobalt capsule which reduced nos. of components and associated welds, resulting in improved weld quality and simplified manufacturing process. Advanced welding processes such as Electron Beam Welding and Orbital TIG welding were optimized and used for capsule welding.

This paper explains the development of manufacturing process for Zircaloy annular Cobalt capsules for research reactor including design improvement, optimization of weld parameters, and stage-wise inspection.

**Keywords:** Cobalt, Zircaloy, Electron Beam Welding, Orbital TIG Welding

# Effect Of Multi pass FSP on Friction Stir Welded Joint of Dissimilar Aluminium Alloys Aa5052-H32

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## Abstract

Friction stir processing was used on a friction stir welded joint of dissimilar alloys AA5052-H32 and AA6082-T6 in order to investigate the effect of multi pass FSP (MFSP) on the metallurgical and mechanical properties of the joints. Friction stir welding and processing of AA5052 and AA6082 are done with optimal settings such 80mm/min travel speed, 900 rpm Tool rotational speed, and 2° tilt angle. Both procedures were carried out using a cylindrical tool profile made of EN8. Evaluation of metallurgical and mechanical properties using Tension, microhardness, macro examination, micro examination, and bend tests were performed on the welded and processed samples. These results are investigated and compared. The mechanical properties are co-related using microstructure evaluation. SEM analysis and EDAS mapping were also used to investigate the fracture area of the multi pass FSP.

key words : FSP, Friction Stir Weld, Microhardness, Tension, Fracture

# Welding characteristics of Fe30Mn5Al1C3Mo (wt. %) lightweight austenitic steel: Microstructure and Mechanical properties

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## Abstract

Lightweight austenitic steels exhibit high specific properties at room temperature, which are essential to improve fuel efficiency and reduce $CO_2$ emissions in automobiles. Welding characteristics of such steels need investigation to successfully use them in structural applications. The present investigation involves understanding the room temperature deformation behaviour of gas tungsten arc welded (GTAW) wrought Fe30Mn5Al1C3Mo (wt. %) lightweight austenitic steel. The base metal is prepared by vacuum induction melting followed by hot-deformation and cold-rolling, subsequently annealed at 1100 °C to obtain a single phase, recrystallized alloy with equiaxed grains of ~ 80 ± 5 µm. The as-welded microstructure showed equiaxed dendrites with the formation of molybdenum-enriched carbides in the fusion zone confirmed using SEM-EDS. The observation was in line with the Scheil solidification curve. The fine interdendritic spacing with carbides increased the micro-Vickers hardness from 218 (± 4) HV in base metal to 250 (± 6) HV in the fusion zone. Further, the YS and UTS of the as-welded alloy increased by 36 % and 12.5 % respectively, while the fracture strain dropped by 26 % in comparison to the base metal. The underlying mechanism behind the observed differences in mechanical properties is correlated with the post-deformed microstructures.

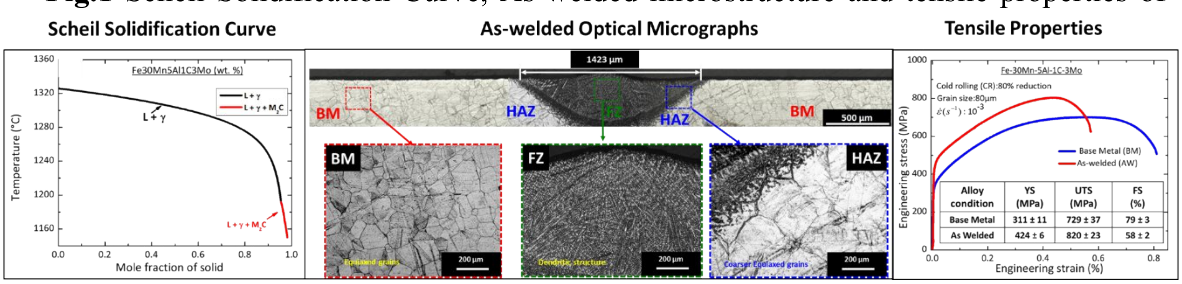


**Fig.1** Scheil Solidification Curve, As-welded microstructure and tensile properties of GTAW Fe30Mn5Al1C3Mo (wt. %) Light Weight Austenitic Steel.

**Key words:** Lightweight austenitic steels, Gas Tungsten Arc Welding, Microstructure, Mechanical properties.

# Integrity of Propeller Shaft : a case study for MIG vis-à-vis Friction Welding

Omkar Nath Mohanty and Susant Kumar Sahoo

## Abstract

Apart from basic strength, ductility, and torsional characteristics, a propeller shaft requires adequate fatigue strength, which is often evaluated using full-length assembly. A hardness profile on the welded joint of the shaft can however be taken as a preliminary, but good indicator of the fatigue behaviour. A drop, i.e. softening, in the hardness-traverse, particularly in the HAZ area, would correlate well with a lowering in the fatigue resistance.

Solid state friction welding of automotive propeller shaft, based on medium carbon – manganese steel, for achieving superior fatigue properties is commonly adopted by several industries. However, it is worthwhile looking into the more conventional and less expensive MIG welding for a comparison. A case is described, where a controlled MIG welding with $CO_2$ was carried out, and a hardness profile on the joint was investigated along with characterization of the microstructure in each zone. Full scale fatigue life tests were also undertaken. Overall, it was observed that acceptable mechanical properties, even comparable to the friction-welded situation, can be achieved through MIG welding.

**Keywords**

Propeller Shaft, Friction Welding of Fork and Tube, MIG welding using $CO_2$, Hardness Profile, Requirement of Torque, Fatigue Properties

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# Enhancing the working life of Industrial components by Laser Cladding Technology

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**Abstract**

To improve the service life of engineered components by application of advanced Robotic Laser Cladding by minimal dilution and strong metallurgical bonding without porosity and defect free cladding layers by fusion process of base material and cladded material with rapid solidification obtaining finer grain structure with consistent hardness values and low distortion with cladding of single layer and multiple layers can be deposited on the components. In present paper application of cobalt based powder through Direct Energy Deposition(DED) method on the base material of martensitic steel which are used in steam turbine components in harsh and erosive environments.

Laser cladding of Cobalt based material improves the superior hardness and corrosion resistant to the above base material with working temperature at elevated temperature up to 1000°C. Transverse hardness achieved is average of 42 HRC and there are many process parameters which plays a prominent role in cladding of metallurgical bonding between the base material applied cladding material. We have successfully cladded the cobalt based and other various material as per the industrial applications such as Angle rings, Diffusers, Dampers, Turbine blades, Wedges & Valves. Microstructure observed was austenitic dendritic structure, with minimal dilution and low heat affected zone (HAZ). Hardness compared with the base material there is a colossal improvement in the working life of component by 39 to 45 %.

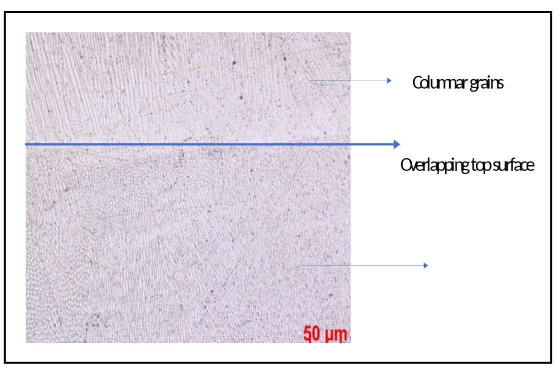


Fig. 1: Microscopic image of Laser cladding and Base material and grain structures

key words : Laser cladding, Dilution, Heat affected zone, Erosion, Corrosion

# Iron extraction from lean iron ores through a hydrometallurgical process followed by electro-winning

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## Abstract

The declining quality of iron ore is increasingly concerning for the future sustainability of the steel industry. Iron leaching from iron waste and subsequent electrolysis represent environmentally and economically viable approaches for recycling iron-rich materials. The extraction of metallic iron from lean iron ores, mill scale, iron ore tailings, and pickled liquor from rolling mills generates a substantial amount of tailings during iron ore beneficiation. The lean iron ores mainly contain 35-70% Fe, 18-36% silica, and 10-15% alumina. The process involves the leaching of iron from the aforementioned iron-bearing materials. For the leaching of 1 kg of iron-bearing waste in 5 litres of 6 normality sulphuric acid, ferric sulphate is produced. This ferric sulphate can be converted to ferrous sulphate by treating it with steel scrap or DRI. The generated ferrous sulphate is suitable for electro-winning iron in an electrolytic cell. Metallic iron with 99% Fe is produced, and the process evolves oxygen at the anode to the tune of 20,000 litres per kilogram of iron, contributing to environmental greening. The hydroelectric-metallurgical process developed avoids high-temperature processes for iron making, thereby mitigating $CO_2$ emissions.

**Keywords** **:** The hydroelectric-metallurgical process, electro-winning

# Soda ash roasting of iron ore slime to produce value added product

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## Abstract

Iron ore slime is a by-product of all iron ore mines. It is produced in huge quantity near the mines waste. It contains major part of iron along with more than 4% alumina and silica each. Due to large quantity of gangue associated with ore it is not suitable for use in the hot metal production. In the present investigation an attempt has been made to remove these gangues by chemical treatment with sodium carbonate. Soda ash roasting of iron ore slime at near 850ºC produces alumina and silica to their sodium salt. Thus produced sodium aluminate and sodium silicate is soluble in hot water. After leaching of roasted product alumina and silica is removed from the iron ore. Therefore, the grade of iron ore is enriched up to a level of direct hot metal production. The process is simple and cost effective in terms of high value iron ore produced. The raw material, roasted product and leached residue of iron ore is characterised through X-ray diffraction, Scanning Electron Microscope and Thermal Analysis to know the product quality and mode of conversion during product formation.

**Keywords** Iron ore slime, Soda roasting, Sodium aluminate, Sodium silicate

# Chemical Beneficiation of Complex Minerals and Industrial Waste Using Alkali-based Reduction Reaction Engineering for Reclamation of Mineral Values

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## Abstract

In industrial processing of natural ores such as the bauxite and chromite, the extraction of valuable constituents, namely alumina and chromium oxide, respectively, is dependent on the chemical breakdown of crystalline mineral lattice with alkali, which then produces water-soluble and water-insoluble phases for subsequent hydrometallurgical separation and phase enrichment. Today, the alkali reaction in oxidizing condition has been widely adopted for tonnage production of alumina and sodium chromate. The oxidative reaction-based process engineering and mineral beneficiation has left a legacy of toxic red mud and hazardous chromite ore process residue (COPR) generation, respectively, from bauxite refining and chromite ore processing. The COPR also contains $Cr^{6+}$-ions which are locked into the pores of processed chromite and are released into the environment. The $Cr^{6+}$ ion is classed as mutagen and clastogen and, therefore, not only damage healthy living cells but also cause genetic defects which might have a profound effect on exposure to environment, general public health, soil, water and quality of air when airborne.

At Leeds, we focussed on targeting such significant "industrial wastes" as resources for recovering valuable oxides by adopting a novel process chemistry and engineering approaches which not only helps in maximizing the recovery of valuable constituents but also aims to reduce the long-term dependency on depositing waste on land. The process engineering approach developed aligns well with the installed plant infrastructure for integration for deriving valuable coproducts by promoting chemical and physical phase separation via "a combination of in situ or ex situ phase separation".

In this presentation, two case studies will be discussed on the processing of red mud for the recovery of non-extractable alumina, iron oxide as high-C steel, either synthetic rutile $TiO_2$ (95% pure) or high-grade ilmenite ($FeO.TiO_2$) for pigment and Ti-alloy production. High-grade ilmenite can be used for making ferro-titanium alloy during pyrometallurgical beneficiation. Any alkali present is also recycled with carbon dioxide for reuse in the process, demonstrating in-process $CO_2$ sequestration and energy use.

The second example is on COPR and chromite ore processing from which we have demonstrated the extraction of $Cr_2O_3$, FeCr alloy, alumina, and magnesia for refractory application. The approach is also applicable for processing the Indian chromite overburdens which often have less than 1wt% nickel and up to 0.1wt% cobalt. The alkali-based reduction reaction yields high to medium alloy steel containing nickel, cobalt, vanadium, and chromium. Alkali may be possible to recover for reuse in the process. Implementation of such approaches will save land, improve the quality of air and water, and above all aid Climate Repair which is urgently needed.

key words: Bauxitic waste, red mud, chromite, $Cr^{6+}$-ions, reclamation, COPR

# Impact of annealing hood on sinter quality and productivity

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**Abstract**

To improve the sintering process at IISCO Steel Plant (ISP) has extended the existing annealing hood over the sinter machines. The significance of the annealing hood in iron ore sintering can be sintering control, heat recovery, slow cooling of top layer as well as combustion. In existing system, ignition burners were provided above wind-box no.1. Thereafter an annealing hood was present above wind box no 2 which was extended to half parts of wind box no 3. To improve the sintering process, a modified annealing hood has been worked out of similar design and were put over wind-box no 3-4 adjacent to existing annealing hood. After commissioning of extended annealing hood a comparative study was carried out for studying the effects of annealing hood. Study showed hot air from sinter cooler passing through annealing hood provides extra heat to top layer sinter and eliminate quenching of top layer by cold air. Also, there is less fines generation from top 100 mm of bed. This paper discusses about the actual benefits from extended annealing hood and reduction in return sinter. The study showed that there was a reduction in coke rate after installation of extended annealing hood. Also, reduction in -5 mm % sinter generation from top 100 mm layers of sinter bed was observed. Improvement in productivity as well as TI has been observed in line with increased waste utilization.

Fig. 1: New fabricated post-ignition annealing hood

Fig 2. Hot air for new hood drawn from tapping in main hot air line

Keywords: Annealing hood, return fines, sintering, productivity

# Characterisation of sinter based on horizontal and vertical segregation on strand

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## Abstract

SFCA phases are considered to be having a direct influence on sinter properties including mechanical strength. A lower FFS provide more reaction time and hence more melt will be formed which results in improved sinter strength. The total sintering time in top layer was shorter due to higher FFS, which generally increases gradually to pallet bottom, with exception in the zone just before Burn Raise Point along the moving bed industrial sinter plant.

Loaded pallets was collected from industrial sinter plant. Afterwards, pallets were allowed to cool to one day and subsequently dissected into 12 layers i.e. 4 vertical layer X 3 horizontal layers along the pallet width. Around 60 kg of sinter samples were collected from each of the 12 layers and stabilized by four vertical drops of 2 m on steel plate. Then those sinter samples were characterised for granulometry and phases analysis.

Granulometry analysis of sinter reveals that, average 24% of top layer from both the sides of sinter machine is having size less than 5 mm. Middle portion is also comparable, at 22% of minus 5 mm. Percentage of minus 5 mm reduces gradually in next layer (average at 17%), and 11% in middle layer. Bottom layer generated minimum return sinter, value recorded as 8-9%. Bottom most layer generated 15-23% plus 40 mm, which gradually decreased with moving upwards in pallet, recording 14-16% in middle layer, 9-13% in top two layers.

Dissected pallet sample shows that, with bed height down, glass phases reduced gradually from 16% in top layer to 13% in next layer, to 12% in middle layer to ultimately 9% in bottom layer (test 1). From top layer to gradually downwards, the quantity of the dominant bonding phase, SFCA, increased from 18% to 20% (next layer) to 20% (middle layer) to 22% in bottom layer.

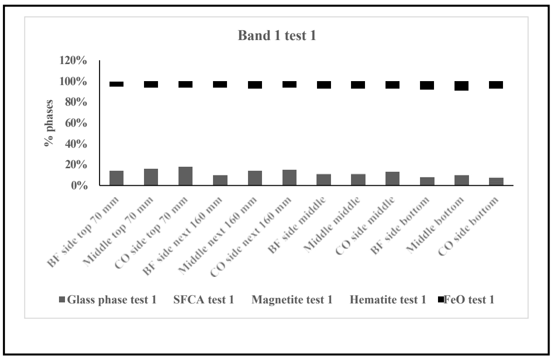


Fig. 1: Phase analysis of sinter collected from different layers

**Key words** : Phase analysis, characterisation, SFCA

# 3D Screen Panel: Increase Recovery of Iron Ore Fines at Wet Plant Noamundi

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## Abstract

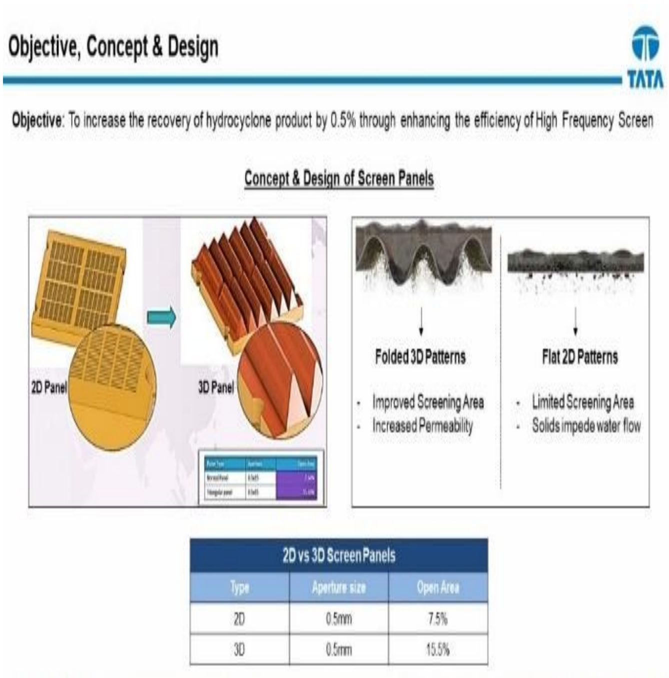
Iron Ore Processing Plant at Noamundi produces two products Calibrated Lump Ore (+10mm & - 40mm) & Fines Ore (- 10mm) and the demand for fines iron ore is increasing continuously from customers recently. In the process of generation of fines, slurry is produced that is fed into the Hydrocyclone circuit wherein we can recover more iron ore in form of ultra fines from the slurry.

To increase surface area & open area another dimension for screen panel can be thought of. This extra dimension provides additional surface and open area where screening can be carried out. More open area on the 3D screen panel and more residence time for particles enabled capture of particles in sizes between 50 & 100 microns, thus leading to increase in the recovery of fines ore.

After the commissioning of Iron Ore Processing Plant fines ore recovery was about 5% and it was subsequently increased to 6% over the years. This innovation increased the recovery of fines ore from high frequency screen equipment by about 1% to 7% from existing level of 6%. This increase amounts to nearly 70,000 metric tons per annum. Considering the market price of 5,000 INR per ton of iron ore fines, this project has a potential savings of about 35 crores in a year. The Innovation will provide benefits worth 140000 metric tons of iron ore fines in the next two years valued at 70 crores INR (Considering iron ore fine market price at 5000 INR per ton). This innovation will reduce the burden of purchasing iron ore raw materials from market.

Fig. 1: Concept and design of 3D

Fig 2.Graphical representation for the benefits received by 3D






# Improvement in High-Rate Thickener underflow pulp density (g/cc) through optimization of its process parameters

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## Abstract

High-Rate Thickener (HRT) is a dewatering device in mineral processing field, and performance of dewatering is defined by pulp density or solids% in thickener underflow. In Tata Steel, at iron ore wash plant the purpose of HRT is to recover process water from hydrocyclone overflow slurry and discharge (slime) underflow pulp density in the range of 1.55-1.60 g/cc. The recovered process water is thereafter recirculated to the wash plant. The important process parameters of HRT are Rake Arm Torque, Bed Mass, Flocculant dosage, Underflow discharge rate and Underflow pulp density. At present, the HRT underflow pulp density in the range of 1.25-1.45 g/cc (target of 1.55-1.60 g/cc). In view of this, a slurry density meter was installed in the HRT underflow which will help to improve and optimize the HRT performance in real time. Further, the effect of change in HRT process parameters i.e., Rake Arm Torque (%), Bed Mass (%), and Underflow discharge flow rate (m3/hr) on the HRT performance i.e., underflow pulp density was also studied (Refer Fig. 1 & Fig. 2), and it was observed that Rake torque(%) and Bed Mass(%) play a vital role in maintaining desired underflow pulp density and subsequently a suitable process regime was identified to operate the HRT underflow pulp density in the target range.

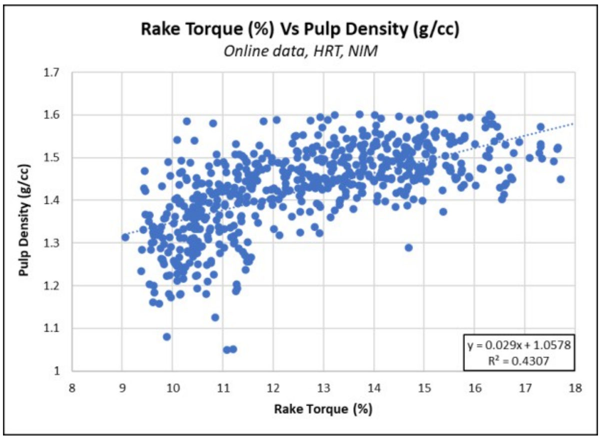


**Figure 1: Effect of Rake Torque (%) and Pulp density (g/cc) for HRT**

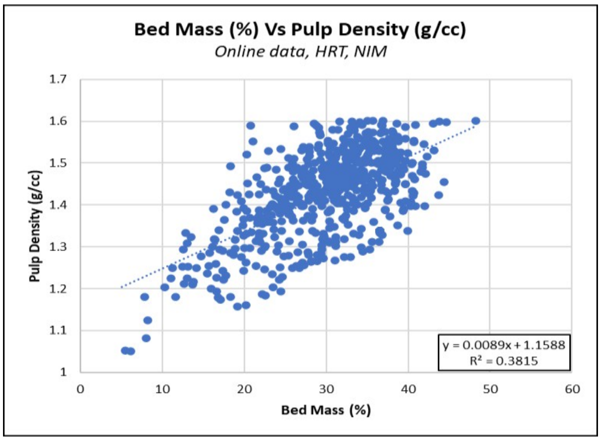


**Figure 2: Effect on Bed Mass (%) and Pulp density (g/cc) for HRT**

**Key words** : Thickener, Pulp Density, Bed Mass, Rake Torque

# Study of Oxidation behaviour of low grade ilmenite ore

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## Abstract

The raw material for producing titanium sponge and white pigment, which is typically extracted from ilmenite and rutile. For the production of titanium metal, titanium sponge is the essential material. A wide range of industries, including the aerospace, marine, chemical, and biomedical sectors, utilize heavily the titanium metal and alloys. White pigment widely used in paints, coatings, cosmetics, food, plastics, and paper. The titanium industry is continuously growing, while the reserves of rutile ($TiO_2$) is diminishing day by day. This led to more and more utilization of ilmenite. Ilmenite invariably contains iron oxide forming complex compound ($FeTiO_3$) with titania. To obtain a valuable titanium product, iron must be removed. The primary objective is to break the bond between the oxides of iron and titanium using an oxidation process. The oxidation process to prepare pseudobrookite phase from low grade ilmenite ore was investigated with 700°C to 1000°C temperature range under air atmosphere. Based on different holding hours (2 hr., 6 hr., 8hr) and temperature, the XRD investigation showed an expected phase evolution sequence with temperature. And observed, Hematite ($Fe_2O_3$), Rutile ($TiO_2$), Pseudobrookite ($Fe_2TiO_5$) of ilmenite powder. $Fe_2Ti_3O_9$ is an intermediate phase formed from above 800°C. And above 900°C pseudobrookite phase formed. The maximum percentage of mass gain, indicating the highest oxidation level, is observed at 900°C for a holding time of 6 hours is shown in below figure. The oxidation mechanism and rate constant calculation are also explained by the CBG model.

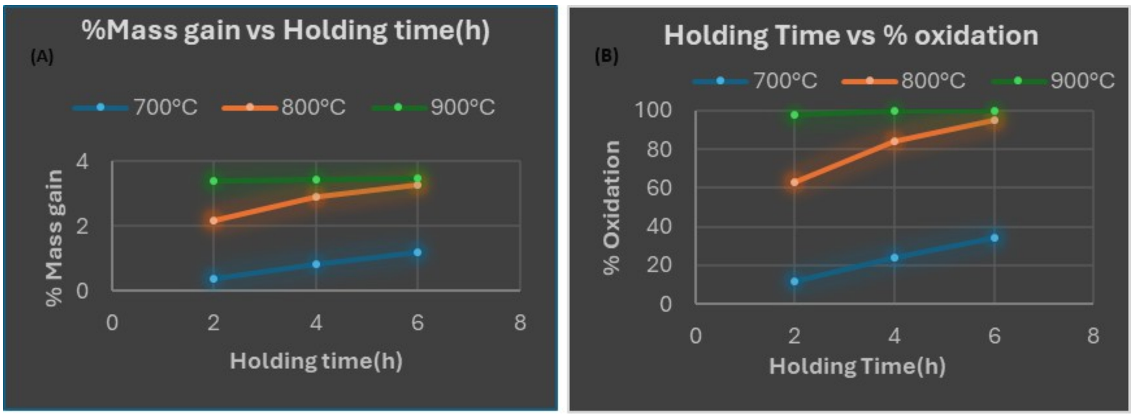


Figure: (A) Shows the graph percentage of mass gain vs holding time, (B) Showing the % of oxidation vs holding time, of ilmenite during oxidation.

key words : Oxidation, ilmenite, pseudobrookite, temperature & time

# IMPROVEMENTS IN IRON ORE PROCESSING AND SLURRY PIPELINE TRANSPORTATION THROUGH BETTER CLASSIFICATION IN GRINDING CIRCUITS

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## Abstract:

Growing global demand for metals, coupled with decreasing ore grades and a focus on sustainability, has led to the adoption of more efficient mining and processing techniques. Comminution circuits, being one of the most energy-intensive processes in the mine-to-metal value chain, need to be made more efficient. Grinding circuits in iron ore processing are characterized by inefficient classification and high recirculating loads, resulting in capacity constraints, wide product size distribution, and high specific energy consumption due to the limitations of cyclone classification efficiency. Replacing hydrocyclones with Derrick Screens results in improved grinding circuit performance, due to classification efficiency improvements from 50-60% with cyclones to 85-95% with Derrick Screens. The paper discusses the plant data from a iron ore processing plant and evaluates the improvements in the circuit due to improved classification efficiency through simulation. It demonstrates the narrower product size distribution consequently benefiting slurry pipeline transportation, palletization, and metal recovery along with the grinding circuit capacity improvement by 20 – 35%. The benefits justify the CAPEX investment of Derrick fine screens with a payback period of 4 -8 months.

**Keywords:** Classification Efficiency; Capacity improvement; Simulation; Fine Screening; Energy Savings; Steel Making; Slurry Transportation

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# CHARACTERIZATION OF PHYSICAL STRENGTH AND METALLURGICAL PROPERTIES OF IRON ORE PELLET BASED ON PORE DISTRIBUTION IN IT

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Iron ore pellets, essential in contemporary steelmaking, are produced through pelletizing of ore fines. These pellets must possess adequate porosity for heat transfer and gas flow in reduction furnaces, along with sufficient mechanical strength for the smelting process. An optimal pore structure, featuring open pores for high reducibility and low porosity for strength, is crucial. This study aims to establish the relationship between the heating cycle and the physical and metallurgical properties of heat-hardened pellets.

Industrial pellets were characterized using 3D non-destructive microstructure analysis via an X-ray CT system. Laboratory-scale pellets were prepared at various induration temperatures to simulate industrial conditions. Comparative analysis of industrial and laboratory-scale pellets focused on closed pore size distribution and sphericity.

Results indicate that closed pore size distribution and sphericity significantly influence pellet strength. For low basicity pellets (e.g., BSP) with higher silica content, achieving a cold compressive strength (CCS) value of >160 kg/pellet necessitates that ~65% of total closed pores be <100 microns, with >75% of these being sub-rounded to rounded. High basicity pellets (e.g., ISP) require >80% of closed pores to be sub-rounded to rounded to achieve a CCS value of >170 kg/pellet.

Experimental data supports these findings, showing that low basicity pellets achieve >160 kg/pellet CCS at induration temperatures >1200°C, with ~75% of pores <100 microns and >75% sub-rounded to rounded. Similarly, high basicity pellets attain the desired CCS at induration temperatures >1100°C. This study elucidates the critical relationship between closed pore characteristics and pellet strength, providing a foundation for optimizing pelletizing processes.

Keywords: Pellet, Porosity, CCS, Sphericity

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# Utilisation of Jhama coal in sintering process at DSP

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**Abstract**

Around 80% of the heat required in sintering is supplied by the combustion of solid fuel. The solid fuels used in sintering are primarily coke breeze and, in some cases, anthracite, with each having different thermal effects depending on the chemistry (carbon content) and the combustion efficiency. The main combustible constituent of coke breeze, used as a solid fuel in sintering, is carbon. As coke accounts for only 4–5 wt.% of the sinter mix, a small change in its properties (reactivity, size, and ash content) can have a large effect on the combustion behavior, heat generation, and sintering performance. The combustion behaviour of solid fuel in the sintering bed along with the velocity of the descending gas (through the bed) determines the temperature, width, and speed of the transverse flame front, which in turn influences the quality of sinter, its yield, and productivity.

Coal affected by igneous intrusion is a common phenomenon and the heat altered coals are commonly known as Jhama coal in Indian context. Jhama coal is available in plenty, in SAIL Ramnagore colliery. However, there is no process for the gainful utilization of this natural resource in any steel plant.

Jhama coal collected from Duburdih face of Ramnagore Colliery, SAIL and detailed characterization studies conducted. Volatile matter was 6-7% while ash was 22-24% and fixed carbon was 68-70%.

10% replacement (wt. basis) of coke breeze with Jhama coal has been tried in industrial sinter plants of SAIL Durgapur Steel Plant. 15-20 deg C increase in Burn Through Point (BTP) temperature and 5-8 deg C increase in flue gas temperature was reported. Sinter strength improved, which was evident in average 1% (absolute value) reduction in minus 5 mm sinter generated. 8-10% increase in sinter mean size was also reported, with 1.5% increase in specific productivity.

This indigenous resource has been proven as an effective substitution of costlier coke breeze in sintering.

key words : Jhama coal, sinter

DRAFT

# Study on removal of phosphorus from industry waste B.F. Flue dust and sludge, B.O.F. sludge by froth flotation

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## Abstract

Industrial wastes produced from the steel plant presents many challenges due to the high economic and environmental impacts involved with their disposal. Dumping solid waste in open space and excavated land creates environmental pollution in the form of soil pollution apart from huge financial liability. Today's demand is utilisation of those wastes back into the process for better economy or salvation of the precious metals from it.

Industrial wastes, such as Blast Furnace (B.F.) flue dust, Blast Furnace sludge and Basic Oxygen Furnace (B.O.F.) sludge is considered in this project. Briquette prepared from this material in specific proportion will be used for desulphurisation of steel as it contains free lime to 25%. This waste material was first processed by froth flotation to remove the phosphorus contained in it. Sulphur increases the brittleness of steel and decreases the weldability.

In this study, the raw material to be used for desulphurisation of steel contains Phosphorus to the extent of 0.081%. This contamination of phosphorus would further decrease the ductility and impact to toughness. Hence, this project was taken to remove the P from BF Flue Dust, BF Sludge and BOF Sludge by froth flotation. Flotation process was carried out using Denver D-12 M having a capacity of holding 10 L water. The flotation process was carried out by using Kerosene as frothers and Sodium Oleate as collector. In the first set of experiment, the amount of BF Flue Dust was varied from 100g, 120g, 150g to 200g taking the amount of water as 8 L with a constant pH of 9 and flotation time fixed at 15 min. The Yield of concentrate was between 70% to 80% for all the cases. With 200g of flue dust and varying pH 7 and pH 9, the yield was 83% for the pH 9. It was also found that the optimum recovery was obtained with 15 min flotation time. The flotation was carried out in two stages, initially at roughing cell followed by secondary flotation. The amount of frother and collector used in secondary flotation is half of that used in roughing cell. The percentage of phosphorus in the concentrate decreased to 0.05, Yield of the concentrate has less phosphorus compared to tailing, so the concentrate can be used for process. Similarly, the experiment has been carried out for BOF sludge and BF Sludge, where the phosphorus in concentrate decreased from 0.081% to 0.017% and 0.082% to 0.015% respectively. The experiment result was validated by chemical analysis of the samples and phase analysis by XRD.
This paper deals with the experimental procedure and discussion of the result for Phosphorus removal from BF Flue dust, BF Sludge and BOF Sludge. Thus, this industrial waste material or byproducts can be readily used for iron making process.

**Key words**: Desulphurisation, Dephosphorisation, Froth flotation, Industrial waste, Kerosene, Sodium Oleate.

# Recovery of metallic copper values from the discarded copper slags of Indian origin

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## Abstract

Copper plays a crucial role in humans' daily requirements, from household electrical appliances to major industrial machinery, making it an indispensable metal for the global market. The increasing demand for copper and the depletion of primary resources have urged researchers and industrialists to explore secondary resources, copper slag being one of them. Copper slags are a by-product generated from copper extraction. Usually, the production of 1 ton of Cu is associated with the generation of around 2.2 tonnes of slag. The global production of copper slag from the smelters is about 21.1 Million Tonnes (MT), the copper content of which lies in the range of 0.5-2%. Rich in iron oxide, silica, calcium oxide, and alumina, copper slags are mostly stockpiled or used in landfill applications. These slags consist of a substantial amount of valuable metals in an entrained metallic, sulphide, or dissolved oxidized form, copper being one of them. The loss of such metallic values and the disposal issues of the enormous quantum of discarded slags have urged reprocessing. Therefore, recovering copper from these slags would be a prudent approach to promote environmental protection and a circular economy.


Gravity concentration, froth flotation, roasting, leaching, and electroplating are the primary routes reported in the literature for recovering copper values from the discarded Cu-slag. Amongst all the methods, flotation has gained the attention of most researchers because of its cost economics. In the present investigation, attempts were made to characterize, beneficiate, and extract the Cu values from the slags of Indian origin. The collected granulated Cu-slag samples assayed a Cu content of 3.35%. The mineralogical studies indicated the presence of fayalite, covellite, and chalcopyrite as the major mineral phases. Froth flotation studies were conducted on the granulated Cu-slag samples ground to a particle size finer than 75µm by varying the reagent dosages and pH of the slurry. Under optimized conditions, the flotation studies of the granulated slag indicated enrichment in the Cu content to about 27.78% with a recovery of 88.48%. The beneficiated concentrate was further subjected to roast-leaching studies, wherein about 76% of Cu values were recovered. Subsequently, the leach liquor was subjected to electroplating using a three-electrode cell configuration. The electrochemical studies confirmed the deposition of high-purity copper values from the leachate solution. Based on the laboratory-scale investigations, a process flowsheet was developed for the recovery of metallic Cu-values from the slags of Indian origin. The investigation results indicate that the beneficiation, and extraction of the Indian Cu-bearing slags can recover the metallic Cu values having a purity of 99.99% from a feed of 3.35% Cu.

Fig. 1: Copper metal balance in various stages of copper-making

**Keywords:** Copper slag, Recovery, Froth-flotation, Roasting, Electroplating

# CFD-DEM modelling for the controlled reduction of Hematite iron-ore to Magnetite

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## Abstract

Steel production has proven its importance as the major backbone of several economies. The low-grade iron ores and rejected slimes/tailing are the remaining but valuable resources for some countries. The enrichment of these resources by conventional route of mineral beneficiation is difficult in certain geographical regions due to their mineralogical characteristics, especially the presence of clay minerals. The partial reduction of iron ores to magnetite significantly enhances the magnetic properties and helps conveniently enrich the resources. Further, the process also decreases the hardness of the feed material, which helps save the cost of the grinding process. The modelling of the direct reduced iron (DRI) process has been reported in the literature. In the present work, the process for such gas-based partial and controlled reduction has been optimized with the help of reaction modeling coupled with CFD-DEM simulations with an objective of maximizing the production of magnetite while minimizing the over-reduction in the form of Wustite and metal iron. The CFD-DEM simulations are often limited by their capability to handle a limited number of particles. The effect of coarse-graining in CFD-DEM coupling is discussed in detail as the process is expected to also target low-grade iron ore fines such as slimes and tailings. It is concluded that coarse-graining significantly reduces the computational cost while minimally affecting the predictions on the extent of reduction. Further, the solid or gaseous reductant for the reduction process is often obtained from the fossil, which leads to the greenhouse emissions.

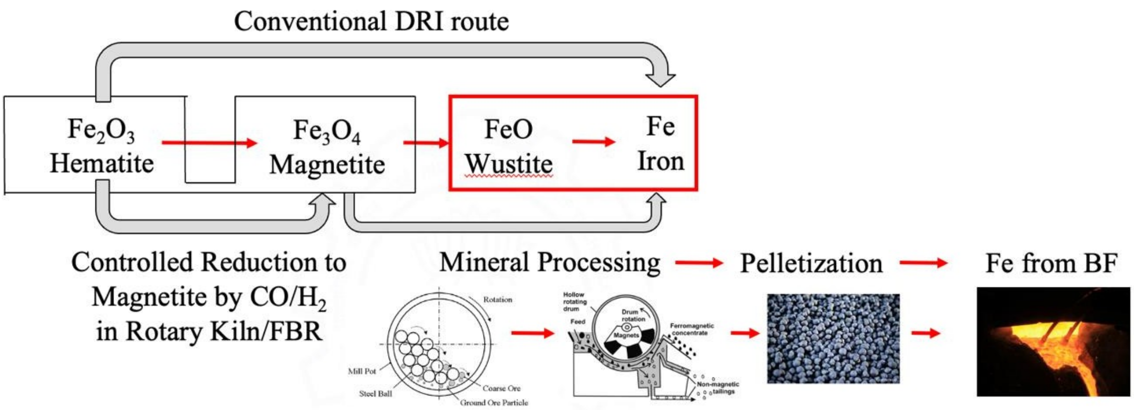


Fig. 1: Graphical representation of the controlled reduction of iron-ore to magnetite.

**Keywords:** Reduction-roasting; use of low-grade iron ore; fluidized bed reactor; enrichment to magnetite; reduction reaction modeling

# Development of a techno-economic flowsheet for lean grade chrome resource utilization through beneficiation perspective

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## Abstract

Chrome being an essential component of the stainless-steel chemistry as a corrosion resistant ingredient, is required to lead India's stainless steel growth aspirations for the future. Chrome comes from the captive chromite mines in the form of high, medium, and low-grade ores. These ores depending on the grades and Cr/Fe ratio, gets utilized in ferrochrome (FeCr) production. Most of the high/medium grade ores gets utilized for ferrochrome/charge chrome production whereas low grade resource goes unutilized. These lean grade ores however carry Cr values but due to the excessive impurity constituents, creates difficulty in processing and increased operation expenditure on per ton basis. The ore being studied here is a lean grade chromite ore with Cr varying between 10-20%, Fe, Al, Si, and Mg. The base rock in this material is a Mg rich olivine and serpentine. Chrome is present in spinel form along with Fe whereas Mg is associated with silica as silicates. Chrome is finely disseminated within the olivine and serpentine matrix. The density difference is also below the concentration criterion, making the separation difficult for chrome from the impurities. The objective of the present study is to develop a techno-economic flowsheet to utilize the low-grade resource through beneficiation route (dry/wet) to obtain a usable grade for ferrochrome/charge-chrome production, value addition, and direct selling in the market.

Keywords: Chrome sustenance, Stainless steel aspirations, ferrochrome, mineral processing, sustainability

# Fusion mixture of Sodium peroxide replacement by Borax mixture without affecting testing accuracy at TATA STEEL Gamharia

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## Abstract

The present method of testing of Alumina based refractory is time taken experiment, expensive a lot, delayed in reporting time and taking approx. 7-8 hours for completion of the analysis. We did lot of brainstorming session and multiple heat & trial experiments to find out the wage & means for alternative method which is less time (half of earlier practice) consuming, best nomenclature and cost effective as well.

Failure Mode and Effect analysis, Control plan, Process parameters, Product quality, Flow diagram, Critical parameters. We did lot of brainstorming sessions and multiple trial & error experiments to find out the wage & means for alternative method which should be less time consuming and cost effective. Concluded a method through research and experiments. In this method we are using Sodium Carbonate and Borax as a fusion mixture. Taking 0.5 gm of refractory sample is mixed with 10 gm Borax and 1 gm of Sodium Carbonate in Nickel crucible and ignited in muffle furnace at about 950 degree C for one hour. Cool the crucible and extract it in 500 ml beaker, add about 150 ml of distilled water and boil for about half an hour. Collect the extract in water and add 100 ml of conc HCl and again boiling for complete dissolution. Alumina is determined by Zinc Acetate method and results are coming close to the original certified value with less time (3-4 hours) as compared to the old method (7-8 hours).

Keywords: Innovation, Cost & Time saving

# Bead fluxer development for Ferro Alloys At TATA STEEL,Gamharia

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## Abstract

This practice nowhere yet be succeeded, On initial stage also we could not be able to do the Glass bead for ferro alloys samples as the required recipes and the

technique behind it was critical in nature, it was not successful to make bead sample in entire process during cooling cycle time sample getting broken repeatedly. While we did multiple brain storming session and getting exposure

from literature and industrial practices we started carry out multiple experiment on research outcomes then on multiple trial & error experiments carried out to determine the wage & means for alternative method which could be less time consuming and cost effective. Finally concluded a method through research and experiments. In this method we introduce zirconium crucible in place of platinum (which is too costly compared with zirconium)

Fusion is a technique used to prepare inorganic samples, with a view to analyse them by x-ray fluorescence (XRF), inductively coupled plasma (ICP) atomic absorption (AA) or any traditional wet chemistry method. Typical samples include cements, ores, slag, sediments, soils, rocks, ceramics, pigments, glasses, and metals. A fusion can produce either a small, homogenous solid glass disk (or "bead") for XRF, or an acid solution for other analytical methods. The process of fusion as a sample preparation method

exhibits many advantages over other methods, as it does not produce mineralogy, grain size or orientation effects and the result is perfectly homogenous. In sample preparation by fusion, the sample never actually melts. It is merely dissolved into a

solvent. This solvent generally a lithium tetra borate/Mata borate flux is type of solid at room temperature and must be molten to dissolve anything at certain

temperature(1100 – 1200 deg.C) inside the furnace.

Keywords: Innovation.

# Unlocking the Potential of Utilizing Biomass for Magnetizing Roasting of Low-Grade Iron Ores

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**Abstract**

One of the major concerns for the iron and steel industries is the gradual reduction of high-grade iron ores. Therefore, beneficiation of low-grade iron ores to generate high-grade concentrate has become necessary. Advanced beneficiation techniques, such as magnetization roasting followed by magnetic separation, come to the rescue when conventional beneficiation fails for some difficult-to-treat ore. However, the traditional magnetization roasting method generates a significant amount of $CO_2$ emission and pollutes the environment due to the usage of large quantities of fossil fuels as reductants. The primary objective of this work is to reduce greenhouse gas emissions and focus on carbon neutrality by utilizing agricultural and industrial biomass residues as alternative reductants. Rice straw is an abundant agricultural waste in India, often burnt in open fields in the northern parts of the country without being utilized. The present study aims to investigate the use of rice straw as a biomass-based reductant in the magnetization roasting of low-grade iron ore.

A low-grade Indian iron ore with a Fe content of about 51% was used in the present study. Characterization analysis of the as-received iron ore shows that it mostly contains hematite and goethite as iron-bearing minerals, along with quartz and clay as the primary gangue minerals. The process of magnetization roasting was studied by optimizing different parameters such as temperature, time, and reductant content. An iron ore concentrate with 65.2% Fe at a weight recovery of 77.4% was achieved at a temperature of 800°C with a roasting period of 45 min and a biomass content of 17.5%. Experiments conducted under ideal conditions revealed that the predominant phase in the magnetic fractions obtained was magnetite, with small amounts of hematite. However, further studies showed that roasting at higher temperatures and higher biomass content leads to the formation of weakly magnetic phases like wustite, fayalite, and complex iron aluminosilicates, resulting in poor iron recovery.

Keywords: Low-grade Iron Ore, Goethite, Magnetization Roasting, Biomass, Rice Straw, Kinetics

# Opportunities and challenges with use of domestic coking coals in coke making & JSW Steels approach towards this initiative

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## Abstract

The utilization of domestic coking coals in coke making presents both significant opportunities and challenges. This paper examines the potential benefits, including cost reduction, economic development, enhanced supply chain security, and improved sustainability. On the other hand, it addresses challenges such as quality variability particularly high ash content infrastructure limitations, technological adaptation requirements like coal washery setup, and environmental and social impacts, including tailing disposal. JSW Steel's approach serves as a case study of how a leading steel manufacturer navigates these complexities. The company's strategy involves investing in Research and Development to establish pilot-scale coal washery units, forming partnerships with domestic coal producers, enhancing logistics and infrastructure, and adhering to stringent environmental policies. Through a comprehensive and adaptive approach, JSW Steel aims to effectively leverage domestic coking coals while mitigating associated challenges, thereby promoting operational efficiency and sustainability in steel production.

**Keywords:** Cost Reduction, Economic Development, Supply Chain Security, Sustainability, Quality Variability, Coal Washery

# TAT Reduction at Hirakud Aluminium to enhance Productivity

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## Abstract

Hirakud Smelter (HKD), a unit of Hindalco Industries Limited is a part of Aditya Birla Group (ABG). Hirakud Aluminium is an integrated aluminium smelting complex which uses GAMI Technology and one of the oldest Smelter in India established in the year-1959. Half of the potline converted from Soderberg to prebake in the year-2009 has its own inherent challenges in terms of technology and retrofitting the old pots into prebake.

Aluminium production is a continuous process and productivity depends upon the no.of operating Pots. To maintain the normal life cycle of 6 years, pot line team has to do approximate 10 - 12 pots/month as a proactive approach towards avoiding any sudden pot failure. To execute this we have to achieve Pot turnaround time (TAT) below 8 days. As pot replacement activity was carried out in operational zone in pot line, therefore many different types of challenges surfaced during the pot lining activity to maintain the pot turnaround time within target time.

After lots of brainstorming and analysis, various initiatives were applied during day to day operation & maintenance practices which helped to sustain as well as maximize the production volume by reducing pot idle time.

Pot TAT trend for Year on Year is as follows:

FY-21:12.7 days, FY-22: 11.8 days, FY-23:10.0 days, FY-24:7.8 days.

FY-25 (till July'24):7.4 days

Through continuous improvements in procedures and co-ordination among the teams, Hirakud has achieved the best average TAT of 7.19 days in FY 25, against the target of 9.0 days.

Keywords: Idle Time, Relining, Dead Pot, Pot change over, Productivity

# A Sustainable Reduction Roasting Technology to enrich the Low Grade Ferrous Resources

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## Abstract

India's iron ore production, a vital cornerstone of steel manufacturing, encompasses both low- and high-grade ores, with the nation holding vast reserves of the former. In FY23-24, India achieved an unprecedented milestone, producing approximately 280 million tons of iron ore - a remarkable 10% y-o-y increase driven by soaring steel demand. Concurrently, it is essential to curb the export of such low-grade deposits, preserving these resources for domestic use. These iron ore deposits, shaped by geological processes over millions of years, are found in banded formations such as banded hematite quartzite (BHQ) and banded hematite jasper (BHJ), where hematite and silica-rich layers alternate in intricate patterns. Additionally, tailings and crushed fines, by-products of mining due to the softness of ores at certain depths present potential sources of iron but also contribute to environmental challenges like erosion, deforestation, and pollution.

Addressing these issues, the study explored the reduction roasting of these resources to maximize iron recovery. Representative samples of crushed fines, beneficiation plant tailings, BHJ, and BHQ were treated under controlled conditions (Temperature: 900°C; Residence time: 75 minutes; 25% coal as reductant) and subjected to a three-stage magnetic separation process using a magnetic separator with variable field intensity. The results revealed that crushed fines had the highest reducibility with a 91% recovery of Fe values, while beneficiation plant tailings responded less favourably with a 61% recovery. BHJ and BHQ samples showed moderate responses, highlighting their potential. The roasted ore with magnetite phase is suitable for use in pelletization.

**Key words** : Reduction roasting, Banded iron ores, SEM, XRD

# Advancements in the Agglomeration of Mining and Metallurgical Waste

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## Abstract

Significant volumes of fines to ultra-fine sized particles get generated across "Mine to Metal Value chain". Mining and mineral processing operations generate fine fractions of different size and grade during mining, sizing, beneficiation processes whereas, GCP sludge, dust, mill scale, oxides, metal fines etc., are the by-products of metallurgical operations. Due to its typical characteristics (fine size, moisture, inhomogeneous quality) such materials pose numerous challenges (storage, handling, environment, disposal etc.,) for its techno economic reutilisation. Further, there is no tailor-made process available to convert such materials into a usable product. Carbon and iron bearing fines generated in metallurgical operations are generally used by sintering process, though it's not a full proof solution. However, sintering has a limitation of accepting ultra-fines materials. In addition, sintering is responsible for almost half of all harmful emissions from steel production. Pelletization process has gained wide popularity for utilization of ore fines and most preferred agglomeration process. The technology, like sintering, requires high-temperature firing of raw materials. Traditional briquetting is most popular in ferro alloys area as a feed stock to submerged arc furnaces (SAF) along with lumpy ores. However, the traditional agglomeration process has limitations in terms of dust generation, strength of briquettes, productivity, costs, binders and difficulties in handling of wet metal oxide bearing materials. Pre-processing methods for these materials such as drying, etc., adds to process cost and create difficulties in handling of fine wet materials leading to dust environment. With the stringent environmental norm, across the mine to metal value chain, present focus of industries is on development of processes / techniques which can make use of industrial waste and mine fines to produce composite materials suitable for furnaces and are techno economically viable.

In the recent past, new agglomeration methods have been developed that are free from the above-mentioned disadvantages of the traditional technologies listed. This article, based on a review of the latest achievements in the agglomeration of natural and man-made raw materials of ferrous metallurgy in the light of the transition to decarbonization, provides convincing examples of the effectiveness of cold briquetting as the only technology not accompanied by harmful emissions and $CO_2$ emissions. The results presented in the article reflect the personal contribution of the authors to the development of this important technology.

Key words: Fines, Sludge, Agglomeration, Composite agglomerates, Stiff vacuum extrusion,

# Proposed Bath Cleaning facility at Bath Treatment Plant for value addition in any Aluminium Smelters operation

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## Abstract:

The Aluminium Smelters standard operation practice to supply bath to rod shop through a storage facility after cooling. The recovered bath from different sources within smelter comes to bath treatment plant to deliver to each pot room for reutilization as covering material during electrolysis. The transportation of bath from pot room to pallet storage area by road, then from pallet storage area to rod shop, from rod shop to bath treatment plant and then finally to pot rooms can be minimized by locating bath cleaning stations at Bath Treatment Plant (BTP). Same time the bath treatment plant location can be kept close to pot room to minimize the length of travel of bath. An overhead chain conveyor can be installed to collect spent anodes, bath bins, and crucibles at end of pot rooms. The overhead chain conveyor will deliver direct to BTP. The bath treatment plant will be equipped with bath cleaning station in place of Rod Shop in present layout. The hot bath will be processed at bath treatment plant. The capital cost of large pallet storage area, number of anode transport vehicles and their movement, the bath transport vehicle number and their movement can be reduced. It can benefit green and brown field Aluminium Smelter projects.

The paper proposes to provide hot bath handling and hot bath cleaning machine at bath treatment plant so that the conveyance of bath to the rod shop can be eliminated and the environment within smelter can be improved. The bath treatment plant will be closer to the reduction compared to present practice of installing as a unit of the carbon area. This will improve the safety, health and environment (HSE) of the smelter operation by eliminating transport distances of hot bath in open pallets. The lean manufacturing methods and safety by design principle is used along with Pugh Selection Matrix for evaluation.

**Key words:** Bath Treatment Plant, hot bath, Overhead Chain Conveyor, Bath Cleaning station, Spent Rodded Anodes, HSE, Pugh Selection Matrix.

# Enhancing alumina concentration in Lateritic Bauxite through silica reduction technique: A case study of Chhattisgarh and Gujarat deposits

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## Abstract

India's extensive lateritic bauxite resources, derived from diverse geological formations such as Deccan trap basalt, Khondalite, and Granite gneiss, present significant challenges for efficient utilization, particularly due to their siliceous and ferruginous nature. These bauxite deposits, characterized by high levels of silica ($SiO_2$: 10-20%), iron oxide ($Fe_2O_3$: 10-25%) and quite low alumina content ($Al_2O_3$: 35-45%), largely unsuitable for metallurgical and non-metallurgical applications without significant beneficiation. In particular, the high silica content, predominantly in the form of kaolinite, causes a major problem, as alumina production required a silica content below 7%. This paper presents the findings of a study that involved the collection and detailed technical evaluation of lateritic bauxite samples from different geological origins, particularly highlighting the Chhattisgarh and Gujarat deposits. Samples from these regions were collected and subjected to detailed technological evaluation. This study focuses on addressing these challenges through a comprehensive investigation into the chemical, mineralogical, and petrological characterization. The characterization studies showed that silica is primarily present as kaolinite, while iron oxide is found as goethite and hematite. These minerals are often interlocked, complicating the beneficiation process.

Physical beneficiation techniques, including scrubbing tests and crushing to a specific size followed by screening to remove fines, were investigated to evaluate the potential for separating silica-bearing minerals, especially kaolinite, from the bauxite. Scrubbing tests were conducted under various conditions, including different grain sizes, scrubbing times, rotational speeds, and solid slurry percentages. The results demonstrated a substantial reduction in silica content ($SiO_2$ reduction by 30-50%) and a corresponding increase in alumina concentration ($Al_2O_3$ increase by 10-20%). However, the reduction of iron oxide was not significant ($Fe_2O_3$ reduction by 5%). It is found that scrubbing techniques are more effective in removing the silica coating from marginal grade bauxite. The findings highlight the importance of geological and chemico-mineralogical factors in the beneficiation process and underscore the potential of scrubbing techniques in improving the quality of Indian lateritic bauxite. This research contributes to a deeper understanding of the unique challenges associated with Indian bauxite deposits and offers valuable insights for the future utilization of this vital resource.

keywords: Bauxite, physical separation, scrubbing, silica reduction, alumina enrichment

# Magnetizing roasting of iron ore fines in a hybrid two-stage reactor

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## Abstract

Low grade iron ore, consisting of complex phases such as goethite, limonite, laterite etc., and iron ore fines are abundantly available, and are not being effectively utilized as they require different treatment techniques to unlock and liberate the iron bearing mineral. Therefore, in the present work, a novel hybrid two-stage reactor has been designed to roast low-grade iron ore fines using thermal-grade coal. The first stage employs a packed bed of coal particles of composition 4.48 % moisture , 38.8 % volatile matter, 26.5 % fixed carbon and 30.22% ash with a median size of 5 mm are used, which on incomplete combustion, produces reducing gas. In the second stage, iron ore fines which consist of 61 % hematite and 39 % goethite with a median particle size of 10 µm are charged and reduced in a fluidized condition. The iron ore fines has a true density about 4.85 g/cm$^3$.The reactor temperature was varied from 650 °C – 800 °C. Reduction temperature was fixed for 5 to 10 minutes, and the airflow rate was kept at 20- 25 LPM for the reduction of iron ore. Reduced iron ore fines were allowed to cool in the presence of nitrogen gas and separated by wet magnetic separation with a magnetic field strength of 700 gauss. The samples were further characterized by the X-ray diffraction (XRD) and inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) methods to quantify the phases. The effect of reduction time, air flow rate, and temperature has been studied on the fraction and rate of reduction. Effect of reduction temperature and on iron recovery and magnetite conversion is shown in figure 1. Based on this study, it is found that the optimum reduction temperature is 750 °C, the air flow rate is 20 lpm, and reduction time is 10 min. Under these conditions, magnetite concentrate is found to be 68.6 % and iron recovery of is 97.50 % after low-intensity magnetic separation.

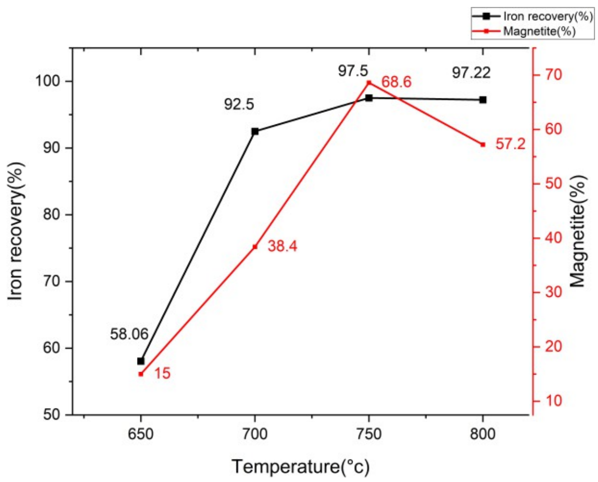


Figure 1. Iron recovery and Magnetite conversion as a function of temperature

**Keywords**: two-stage rector, magnetite, reduction roasting, wet magnetic separation

# Beneficiation and Purification of Silica Sand for Enhanced SiO2 Content of 99.9% Purity

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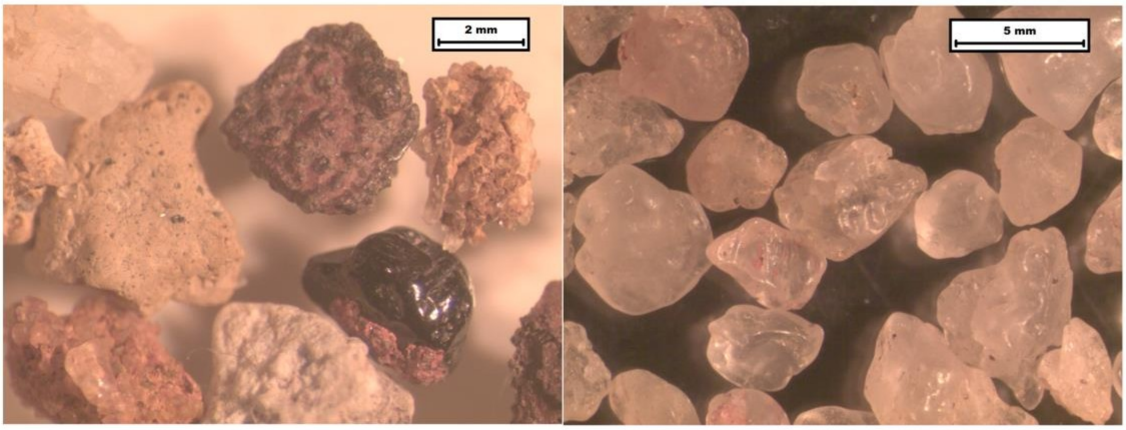
## Abstract

Silica sand, sourced from the overburden of a lignite mine in Gujarat and referred to as Stack-1, was collected and thoroughly mixed using the coning and quartering method to obtain representative samples for experimentation. Chemical composition analysis of these samples revealed that Stack-1 contains approximately 96.24% $SiO_2$. Size classification studies indicated that particles smaller than 45 µm were rich in iron oxides (~11-13%) and alumina (~26-27%). The presence of tungsten as an oxide was also detected; ICP-OES analysis showed that the $WO_3$ content in the Stack-1 sample was 0.037%. To enhance the $SiO_2$ content, the bulk representative sample underwent a series of beneficiation processes, including physical (scrubbing, grinding), physico-chemical (flotation), and chemical (leaching) methods. The final product from these processes achieved a $SiO_2$ purity of 99.9% for the Stack-1 sample.




| Sample | Size Fractions | Sample Taken (g) | Sink (g) | Float (g) | Total | Sink Weight, % | Float Weight, % |
|---|---|---|---|---|---|---|---|
| Stack 1 | -212 µm + 100 µm | 200 | 4.6 | 195.3 | 199.9 | 2.3 | 97.7 |

**Keywords:** Silica sand, overburden of a lignite mine, beneficiation, purification,

# Micro-Computed tomography studies of a lean iron ore

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## Abstract

Iron and steel industry is increasingly facing the prospect of leaner and leaner quality of ores. Conventional BF-BOF route of iron production is challenged, albeit needs to be challenged with a prospective greener route of steel production. Hydrogen use in the BF blast furnace is deemed to be the most promising short-term technology. In this regard, a novel non-destructive technique of X-ray micro-computed tomography along with a lab-scale, inhouse built thermogravimetry set up was used to understand the fundamental reduction behaviour of iron ore forms. The iron ore characteristics of importance such as porosity, permeability etc have been non-destructively examined and related to the standard, conventional metrics of the ore.

# Oily Bubble Flotation of Coal

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## Abstract

Flotation is a physicochemical process that separates particles based on differences in their surface chemistry, selectively floating hydrophobic particles. Coal, being naturally hydrophobic, exhibits an affinity for attaching to air bubbles, forming a froth phase. To enhance the efficiency of this separation process, hydrocarbon oil-based collectors are used. These collectors adsorb on the coal particles, modifying their surface chemistry to increase the contact angle between the coal and air bubbles. This increased hydrophobic nature promotes the attachment of coal particles to the air bubbles, resulting in improved recovery of fine clean coal. Though flotation process is widely used and is an effective separation technique for beneficiating fine coal, a persistent gap exists between the theoretical and the actual yield of fine clean coal. This gap signifies opportunities for process optimization or improvement. However, increasing the recovery without introducing complex measurement and process control systems to the flotation process or necessitating a complete redesign of the flotation cells, which would incur substantial capital expenditure, presents a significant challenge. The bubble-particle attachment is a controlling step in a flotation process. The current research focused on enhancing the affinity of air bubbles to attach to coal particles without altering the inherent hydrophobicity of the coal particles. By modifying the surface properties of the air bubbles through the application of a thin collector coating, the energy barrier that impedes the formation of a three-phase contact line between the coal particle, water, and air bubble was reduced. This presence of collector over air bubbles promotes more efficient particle-bubble attachment, leading to an increase in the recovery of fine clean coal and thereby bridging the gap between the theoretical and actual yield of the flotation process. This novel approach, termed oily bubble flotation, involves the creation of a flotation carrier composed of an air bubble covered by a thin layer of collector, designed to facilitate the bubble-particle attachment process. In this study, an oily bubble flotation set up was designed based on the concept of vaporizing the collector using a nozzle assisted heating process and injecting a homogeneous mixture of vapor and air into the coal slurry. The process of coating air bubbles was comprehensively explained and compared to conventional flotation. A decrease in induction time and an increase in the value of wrap angle for oily bubble flotation confirmed enhanced collecting power of the collector-coated air bubbles. The performance gap between conventional and oily bubble flotation for sub-bituminous coking coal was analyzed and reported. Results showed higher combustible matter recovery with lower ash content in the concentrate for oily bubble flotation compared to conventional flotation.

Key words: Oily bubble flotation, Bubble-particle attachment, Three-phase contact line, Hydrophobicity, Induction time.

# Utilization Of Iron Bearing Solid Wastes for Enhancing The Quality And Sustainability Of Iron Ore Pellets

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## Abstract

The utilization of iron bearing solid wastes, such as mill scale, sludge fines, Electrostatic Precipitator (ESP) fines, and oxide fines, offers a sustainable approach to improve the pelletization process in the iron ore industry. These waste materials, typically generated during various stages of iron and steel production, represent a significant resource that can be effectively reused in the iron ore pelletization process, thereby reducing environmental impact and contributing to a circular economy. Mill scale, a byproduct of hot rolling processes, has been proven to increase the cold compressive strength of iron ore pellets when added to the pellet mix. Experimental results show that adding mill scale raises CCS from 232 kg/ pellet to 268 kg/pellet. Furthermore, the incorporation of mill scale improves the tumble index, indicating improved mechanical stability and lower the abrasion resistance of the pellets. This study shows that the addition of ESP fines does not negatively affect the pellet's quality attributes, such as strength and reducibility, making them a viable component for palletisation. The neutral impact of ESP fines on pellet quality allows for their use without compromising the structural integrity or metallurgical properties of the final product. Oxide fines, which are frequently regarded as a low-value waste product, have the ability to significantly increase the iron content of pellets. Their inclusion in the pellet feed mixture raises the overall iron content, boosting the efficiency of the pellet production process. Higher iron concentration improves reduction kinetics in the blast furnace, resulting in more efficient steel manufacturing. The integration of these solid wastes into the palletisation process offers numerous benefits. It not only helps to reduce waste disposal costs and environmental impact, but it also enhances the mechanical and metallurgical qualities of iron ore pellets. The use of mill scale, sludge fines, ESP fines, and oxide fines helps to produce higher-quality pellets that match the rigorous standards of modern steel-making processes by improving cold compressive strength and iron content. Overall, this approach enhances resource efficiency and aligns with the industry's goals of lowering carbon footprints and implementing sustainable practices. This study highlights the possibility of utilizing iron bearing solid wastes as useful raw materials in iron ore palletisation, paving the door for more environmentally friendly and cost-effective iron and steel production.

Keywords: Pelletisation , Mill scale, ESP and carbon footprint.

# A novel approach for upgrading iron ore slime through magnetization roasting using sugarcane bagasse.

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## Abstract

This study addresses the pressing challenges posed by environmental regulations and carbon taxation on traditional reductants like coal and coke by exploring the utilization of sugarcane bagasse as a sustainable alternative in iron ore slime processing. With a focus on both environmental concerns and economic viability, the research employs a dual approach involving microwave-assisted magnetizing roasting and conventional roasting techniques. The primary objective is to enhance the iron ore slime's Fe content by transforming hematite into magnetite, thereby facilitating its efficient separation in a low-intensity magnetic field. This process enables the isolation of diamagnetic gangues, primarily quartz, through low-intensity magnetic separation.

Experimental results reveal promising advancements in the case of microwave magnetizing roasting, showcasing a substantial improvement in Fe content from an initial iron ore slime of Fe content of 44.53% to 61% with 68.8% recovery under the hybrid microwave power of 6 kW, a temperature of 700$^0$C, with a particle size of 105 µm, and a 5-minute exposure time, utilizing a specific reductant ratio of 50 wt.% sugarcane bagasse. However, conventional heating at 800$^0$C with 30 wt.% sugarcane bagasse and a 90-minute exposure yielded a 66.5% recovery rate and 55.7% Fe content improvement.

The study utilized Taguchi methods to optimize parameters, including temperature, particle size, microwave exposure duration, and reductant ratio. Additionally, X-ray diffraction analyses confirmed the successful conversion of hematite to magnetite in the low-intensity magnetic fraction, affirming the effectiveness of the chosen methodologies. Overall, these findings highlight the potential of microwave magnetizing roasting with biomass reductants as a viable, cost-effective, and environmentally friendly approach. This advances sustainable ore beneficiation methodologies and opens avenues for the direct conversion of low-grade ore into blast furnace feed, thus enhancing efficiency and sustainability within the metallurgical industry.

Keywords: Iron ore slime, Sugarcane, Biomass, Magnetisation Roasting, Magnet

# Studies on Characterization of High Phosphorous Iron Ore

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**Abstract**

The current study focusses on determining the distribution and association of phosphorus within the ore body of high-P iron ore collected from the eastern part of India. Detailed characterization study is carried out with the help suitable characterization technique which involves X-ray fluorescence spectrometry (XRF), Optical microscopy, X-Ray diffraction (XRD), Scanning electron microscopy (SEM), Energy dispersive spectroscopy (EDS), and Fourier Transform Infrared spectroscopy (FTIR), Thermogravimetric Analyzer (TGA) and Differential Scanning Calorimetry (DSC) analysis. Chemical analysis of the iron ore indicates that Fe (55.41%), $Al_2O_3$% (7.65), $SiO_2$% (0.81) and phosphorous P% (0.56%). Characterization result showed that the presence of phosphorous within iron ore was found to be principally associated with gangue minerals (Alumina, $Al_2O_3$). The real presence of phosphorous is determined by XRD analysis as a berlinite phase ($AlPO_4$) which shows the phosphorous containing crystalline phase. Fourier Transform Infrared Spectroscopy (FTIR) analysis shows that the peak around 1100 $cm^{-1}$ shows the phosphate association, and 593 $cm^{-1}$ represents the hematite. These types of lower grade iron ore with high phosphorous content need specially designed beneficiation approach for phosphorous removal. Ultrafine grinding is required in stages for better liberation of iron and phosphorous minerals which leads to reduction of phosphorous (P) in the final concentrate with significant recovery of iron.

key words: Goethite, High Phosphorous, Iron ore, Impurities, Berlinite

# Iron values recovery from red mud by reduction roasting using different reductants

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## Abstract

Red mud is a byproduct generated during the extraction of alumina from bauxite. Being environmentally hazardous due to its high alkaline content, it can be reused based on its contributory properties. As India aims to produce 300 MT of crude steel by 2030, this red mud can be a potential raw material. Red mud, which has considerable amounts of iron, is often regarded as a secondary resource for iron. Nevertheless, it holds potential as an alternative source for iron extraction and should be investigated to reduce its environmental constraints and value addition towards waste utilization. Red mud has a high iron content in the form of goethite (FeOOH) and hematite ($Fe_2O_3$), making them suitable for iron extraction through various processing methods. Reduction roasting combined with Low-Intensity Magnetic Separation (LIMS) of red mud can offer a promising and environmentally friendly approach to iron extraction. Further, biochar, produced from biomass such as sawdust, is a sustainable reductant, offering an advantage over traditional fossil fuels. This study concentrated on performing reduction roasting of a red mud sample with 35.03% Fe in a muffle furnace at a varying temperature from 700 to 900˚C and residence time from 15 to 60 minutes. Samples were prepared using biochar and non-coking coal as reductants, with red mud-to-reductant ratios of 10:1 and 10:2, respectively. The study found that the sample using biochar as a reductant produced an output of 60.2% Fe, whereas the non-coking coal produced an output of 54.18% Fe at 850˚C and 30 minutes. These results suggest that reduction roasting of red mud with biochar as a reductant provides superior outcomes to non-coking coal and can become a suitable feed material for ironmaking.

Key words : Red mud, biochar, reduction roasting

# Mineralogical and Chemical Changes after Reduction Roasting of Siliceous Iron Ore from Bonai-Keonjhar (BK) Belt

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## Abstract

The Bonai-Keonjhar (BK) belt in eastern India is rich in Precambrian iron formations, a vital part of the Odisha Iron Ore Super Group. As the steel demand intensifies, attention turns to beneficiating low-grade iron formations, particularly siliceous iron ore. The most prominent silicious ore of the BK belt is Banded Hematite Jasper (BHJ), which has alternating hematite and jasper layers that pose challenges in geometallurgical characteristics, requiring high grinding energy for the liberation of required and gangue minerals. This is crucial for developing a viable process route for BHJ processing. A preliminary characterization study of the feed sample indicated the presence of prismatic, specularite, and microplaty hematite grains embedded in the fine-grained siliceous matrix and vice versa. Reduction roasting of the BHJ feed sample contained 42.84% Fe(T), which yielded a product with 64.56% total iron content and significant iron recovery at 800°C. The effectiveness of reduction roasting in enhancing BHJ beneficiation was explored through a detailed analysis of the mineralogical phase transformations and the accompanying chemical and textural changes. Techniques such as X-ray diffraction (XRD), stereo zoom and optical microscopy, and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) were employed to study the roasted products in detail. The findings from this study not only provide insights into optimizing energy consumption during BHJ processing but also highlight the potential for improved resource utilization by using mine overburden. This research contributes to the sustainable exploitation of siliceous iron ore resources, with significant implications for ensuring the future security of the iron and steel industries.

**Keywords:** Mineralogical, Banded Hematite Jasper, Liberation, Reduction Roasting.

# Influence of fluoride ion on $Fe^{2+}$ oxidation kinetics by Leptospirillum ferriphilum dominated chemostat culture

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## Abstract

Bioleaching is a commercially applied method for the processing of secondary copper sulphide ores such as chalcopyrite and chalcocite as well as uranium ores, facilitating high extraction rates at a relatively rapid leaching kinetics. Fluoride interacts with the process chemistry in the form of impurity in the minerals. The toxic level for bioleaching process has been determined as 0.05 $gL^{-1}$ or lower in the literature for bio-heap leaching of copper sulphides where the operation failed due to the toxic effect of fluorides on microbes. This work investigated the toxic effects of fluoride on $Fe^{2+}$ oxidation by Leptospirillum ferriphilum dominated chemostat culture. Therefore, two different concentrations of 0.030 and 0.045 $gL^{-1}$ fluoride (as KF) were added to 9K (mineral salt medium with 9 $gL^{-1}$ $Fe^{2+}$) growth medium and compared with 0 $gL^{-1}$ fluoride (9K medium) for their influence on $Fe^{2+}$oxidation kinetics in a chemostat. The chemostat study for 0.030 $gL^{-1}$ and 0.045 $gL^{-1}$ fluoride was operated at three dilution rates (D) of 0.024 $h^{-1}$, 0.054 $h^{-1}$, 0.072 $h^{-1}$ and 0.029 $h^{-1}$, 0.045 $h^{-1}$, 0.079 $h^{-1}$ respectively. The critical dilution rate ($D_c$) approached at 0.072 $h^{-1}$ and 0.080 $h^{-1}$ for 0.030 and 0.045 $gL^{-1}$ fluoride, respectively. For all three experiments with 0 $gL^{-1}$, 0.030 $gL^{-1}$ and 0.045 $gL^{-1}$ fluoride, the measurable parameters used for modelling were flow rate (F), working volume (V), biomass concentration (X), feed substrate concentration ($S_0$) and residual substrate concentration (S). The classical approach for modelling chemostat data was used to determine maximum specific growth rate ($\mu_{max}$) and substrate coefficient ($K_s$) linearizing Monod equation by Lineweaver- Burk method, Eadie-Hofstee method and Langmuir method, while the best fit based on regression value was considered. The observed biomass yield ($Y_{obs}$) was determined as $Y_{obs} = X/(S_0-S)$, whereas the true biomass yield for growth ($Y_{true}$) and maintenance coefficient ($m_s$) was calculated from the Pirt equation. Other kinetic values of reactor biomass productivity ($P_X$), reactor ferric productivity ($P_S$) and specific ferrous utilization rate ($q_{Fe}2+$ ) were determined by linearizing both Monod and Pirt equation. The kinetics study showed 2 times and 2.3 times higher $K_s$ values for 0.030 and 0.045 $gL^{-1}$ fluoride compared to 0 $gL^{-1}$ fluoride. However, the $\mu_{max}$ value was similar for 0 $gL^{-1}$ and 0.030 $gL^{-1}$ fluoride but was 1.3 times higher for 0.045 $gL^{-1}$ fluoride. The $m_s$ decreased by 1.6 times and 1.4 times for 0.030 $gL^{-1}$ and 0.045 $gL^{-1}$ fluoride, whereas the $Y_{true}$ value increased by 1.2 times for 0.030 $gL^{-1}$ fluoride and decreased by 8.4 times for 0.045 $gL^{-1}$ fluoride compared to 0 $gL^{-1}$ fluoride. The $Y_{obs}$ showed an increasing trend for 0.030 $gL^{-1}$ fluoride and decreasing trend for 0.045 $gL^{-1}$ fluoride compared to 0 $gL^{-1}$ fluoride. The finding suggests that Leptospirillum ferriphilum dominated chemostat culture thrived well at 0.030 $gL^{-1}$ fluoride but 0.045 $gL^{-1}$ fluoride was determined to be toxic, possibly due to the formation of HF at low pH of 1-2. Therefore, the iron oxidising microbes may not work efficiently in biomining process if the concentration of fluoride exceeds
0.045 $gL^{-1}$.

Keywords: Leptospirilllum, fluoride, $Fe^{2+}$ oxidation kinetics.

# Hydrometallurgical process for high-pure EMD preparation from Low-grade Mn ores and Secondaries for LIB application

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## Abstract

Resource recycling and eco-sensitive processing are the key to utilization of minerals in the future. Global demand for EVs is projected to grow manifolds and the energy metals required for EVs especially Mn, Co, Ni are often found to occur leaner grade ores in India. Electrolytic manganese dioxide (EMD) is one of the cost-effective cathode materials used in Li ion batteries of EVs due to its excellent discharge capacity. Existing carbothermic reduction and leaching process for Mn recovery from its oxide ores is not viable to treat lower grade Mn ores due to high iron content, lower product purity besides high GHG emissions. To address this, a hydrometallurgical reductive leaching process using lean $SO_2$, which is readily available from sulphur burners and smelters, has been developed and applied to low-grade Mn ores and silico-manganese slag. The ambient temperature leaching in spent electrolyte with lean $SO_2$ as reductant offers high selectivity for Mn dissolution and substantially decreases the chemical requirement during iron purification. The resultant high pure $MnSO_4$ solution was then used to prepare electrolytic manganese dioxide using graphite as cathode and titanium as anode. The EMD hence obtained was found to be high pure $\gamma$-$MnO_2$ with a discharge capacity of 230 mAh/g, containing >90% $MnO_2$ and less than 200 ppm Fe, surpassing the best dry cell grade of BIS (IS11153:1996). This high efficiency process producing high pure EMD product can ably substitute the existing carbothermic reduction- leaching based process for a greener, cleaner approach to producing energy material and utilization of secondaries.

Keywords: Electrolytic Manganese dioxide; Mn ore; secondaries; $SO_2$; energy material;

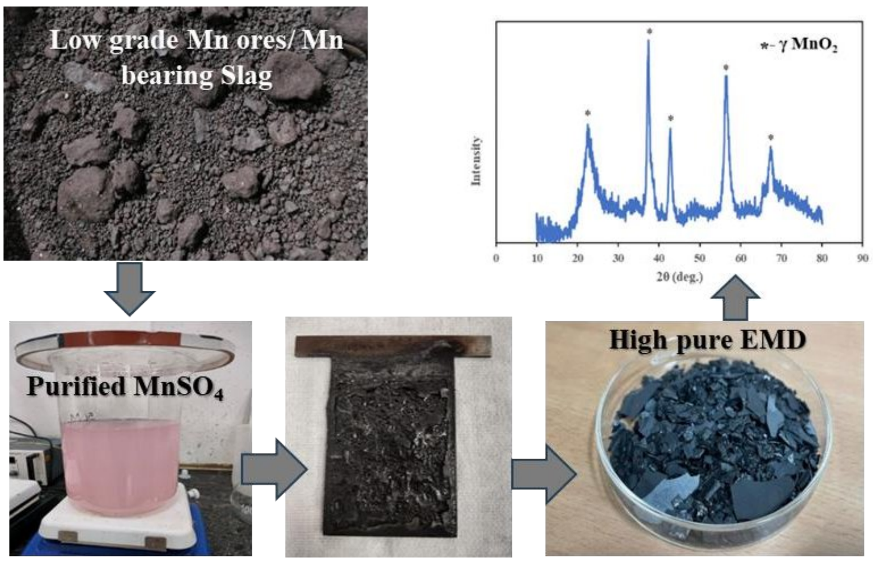


**Figure.1**: EMD preparation from low-grade ores or secondaries.

# Novel polymeric resin for selective recovery of rare earth metals and mercury from end-of- life compact florescent lamps (CFLs) – Urban Mining

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## Abstract

Rare earth metals have unique physicochemical properties which are reflected in most of their applications in advance technologies, for example, green energy production, magnetic materials, phosphors, catalysis, medical diagnosis and treatments, etc. During the last few decades the demand of rare earth metals have increased exponentially and therefore to bridge the gap between demand and supply it has become necessary to exploit the secondary resources, especially, end-of-life products such as compact florescent lamps (CFLs). Further, it is of utmost importance to recover hazardous mercury for CFLs to keep it away from environmental matrix.

To this end novel separation process has been developed based on in-house designed metal selective polymeric resins using structure activity relationship. The process ensured highly selective and quantitative recovery of mercury and highly valuable rare earth metals from leach liquor of CFLs with very high selectivity of Thioglycolamide (TGA) resin for mercury and very high selectivity of BiPyridylDiamide (BiPyDA) resin for rare earth metals over other metals.

Leach liquor obtained on leaching of CFL in HCl medium
Uptake behavior of TGA resin at 3.0 M HCl
Uptake behavior of BiPyDA resin at pH=2, raffinate obtained after Hg removal

| S. No. | Constituent | Concentration (mg/L) in CFL leach liquor |
|---|---|---|
| 1 | $H^+$ | 3.0 M |
| 2 | Hg | 140 |
| 3 | Y | 3198 |
| 4 | Eu | 275 |
| 5 | Tb | 5 |
| 6 | Al | 95 |
| 7 | Ca | 475 |
| 8 | Ba | 26 |
| 9 | Mg | 50 |
| 10 | Mn | 11.5 |
| 11 | Ni | <1 |
| 12 | Sn | <1 |

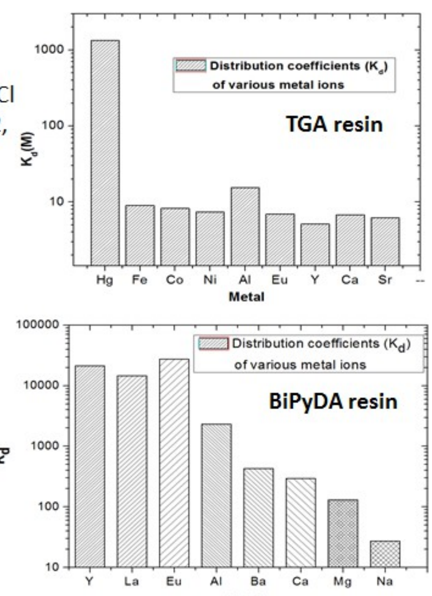


Figure 1. Composition of CFL leach liquor and distribution behavior of mercury, rare earth and other base metals on TGA and BiPyDA resin

Keyword: CFL, rare earth metals, mercury, resin, leach liquor.

# Welding of Laser Powder Bed Fusion Manufactured Haynes 282 alloy: Microstructure and Mechanical Properties.

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## Abstract

Laser Powder Bed Fusion (LPBF) stands out as the most prevalent Additive manufacturing (AM) process for creating complex shaped parts, but it comes with inherent limitations like constraints on part size, high porosity levels, and inefficiencies in producing simple geometries in bulk quantities. As a strategic solution to address these constraints, the feasibility of producing complex-shaped parts by the LPBF process followed by welding with other additively manufactured or wrought parts to form the final component, is the topic of this study. This hybrid type of manufacturing technology has recently grown in significance within the domain of new-generation power plants, especially Ultra Supercritical (USC) power plants for accommodating intricate geometries such as compact-type heat exchanger cores. Investigation on microstructure evolution and mechanical properties of Keyhole TIG (KTIG) welded additively manufactured nickel-based superalloy Haynes 282 in as-built and heat- treated conditions has been done and noticed that weldability between additively manufactured and wrought Haynes 282 plates is well acceptable. Also, mechanical property deterioration in heat-affected zones (HAZ) is less in the LPBF-manufactured plate side compared to the wrought plate side. These findings will expedite the adoption of additively manufactured intricate shapes in USC power plants.

Keywords: Keyhole TIG, Laser Powder Bed Fusion, Haynes

# Characterization Studies on Wire Arc Additive Manufactured Functionally Graded Material (SS316L / Hastelloy C-276)

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## Abstract

Hastelloy C-276, a nickel base superalloy is the most popular material due to its excellent corrosive resistance and good strength at high temperatures. These properties make it suitable material for harsh and high temperature corrosive environments in industries like chemical processing, nuclear power plants, offshore oil and gas production. However, the high cost of raw material and fabrication using traditional methods makes it difficult for widespread applications. With the concept of Functionally Graded Material (FGMs) and advanced manufacturing processes like Wire Arc Additive Manufacturing (WAAM), the above- mentioned limitations can be reduced. In the present work, Gas Metal Arc Welding based WAAM process was adopted to fabricate FGM of Hastelloy C-276 on SS316L. WAAM process parameters were optimized for obtaining the FGM with defect free interface. Further microstructural analysis and mechanical properties evaluation were carried out. The micrograph revealed the defect free interface composed of predominantly columnar dendrites along the build direction. The hardness test revealed the interface region with intermediate hardness compared to SS316L and Hastelloy C-276 ensuring optimal elemental distribution at the interface in correlation with SEM-EDS analysis.

Key words: FGM, GMAW, Wire Arc Additive Manufacturing, Hastelloy C-276.

# Experimentally validated and empirically compared machine learning approach for predicting yield strength of additively manufactured multi-principal element alloys

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## Abstracts

Traditionally, yield strength prediction relies on detailed and resource-intensive microstructural characterization combined with empirical equations. However, quantifying microstructural feature length scales for novel processes like additive manufacturing, which involves inhomogeneous hierarchical features, poses a challenge. The lack of accurate material constants for broader composition ranges further limits empirical predictions. This study proposes an alternative machine learning (ML) approach for predicting the yield strength of additively manufactured (AM) multi-principal element alloys (MPEAs) from the Co-Cr-Fe-Mn-Ni system by correlating composition, printing parameters, and testing conditions. The best-performing ML model achieved an accuracy comparable to that achieved using microstructural detail- driven empirical strengthening contributions. Printing and testing of multiple compositions (including novel ones) was carried out, and the validity of the ML approach was established. Stacking fault energy and lattice friction changes on varying the composition affected the yield strengths and the post-yielding deformation mechanisms. This data-driven approach directly relates yield strength to initial printing parameters, highlighting their significance and individual effects, such as scan velocity's direct impact and laser power's inverse impact on yield strength. This demonstrates ML's potential to guide AM processes, reducing the need for iterative experiments and enabling rapid exploration of compositional and printing spaces to achieve desired properties.
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# Design and operational parameters of a 16.5 mva submerged electric arc furnace (saf) for ferro silicon production

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## Abstract

Most of the Ferro-alloys are produced in Submerged Electric Arc furnace any where in the world due to its economical and qualitative aspects of the production. Proper design and operational technics play a key role in achieving better yield and moderate specific power of the Ferro-alloy products. Ferro-Alloys are mostly extracted from its oxide ores. Localized temperature is the most important factor for better reduction of oxides ores. A good electrode diameter with compactible pitch circle diameter is the main source for achieve high temperature. However not only these two parameters but also there are several electrical, mechanical and metallurgical parameters involved in to successful operation of Submerged Electric Arc Furnace. In this paper we discussed various mechanical, electrical and operational characteristics of Submerged Electric Arc Furnace. The designing of mechanical and electrical parameters in sub merged electric arc furnace are highly influences the operational parameters in Ferro-alloys production.

There are so many operational difficulties rises due to improper design parameters of the furnace. Among all of these the major problem is operational load is always not reachable to the theoretical load. That means the maximum load attaing is not achievable. Load factor mainly depends on resistance of the charge material. Resistance is mainly depending on current density. A proper design of electrode diameter provides adequate current density. Design of furnace diameter and depth depends on electrode diameter. Hence furnace design parameters are all interlinked with each other. If any parameter designed wrong its impact appears on the operational and process parameters. Proper design of the furnace reflects the good Power Factor (Cos Ø), optimum specific power, there by we can get good yield of the alloy.

Designing of submerged electric arc furnace is mainly based on the following requirements.

1. Total production required per day in tons (Tp).
2. Type of the product to be produced (Si-Mn, Fe-Mn, Fe-Cr, Fe-Si).
3. Average specific power of the product in kWh (Sp).
4. Power Factor of the process (CosØ).
5. Furnace availability for process in a year (fa).

These are the indispensable parameters to be considered at the time of submerged electric arc furnace design for Silico-Manganese Product. There is a little bit of changes in the design of Fe-Mn, Fe-Cr, and Fe-Si Products. The temperature attains for reduction of Ferro-alloys are shown as:

ΔH for Fe- Si >Si- Mn > Fe-Cr >Fe-Mn

So that the reduction temperatures are vary for product to product. Hence the arc voltage, diameter of the electrode, pitch circle diameter, bath depth and diameter will be varying to product to product. Therefore, there is no common design parameter for all the products.

In this paper we discussed submerged Electric Arc Furnace design and operational parameters to produce Ferro-Silicon 75grade.

# A comparative study of additively manufactured vs wrought maraging 250 for various ageing parameters

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## Abstract

Maraging steels are low carbon Fe-Ni-Co-Mo based steels that exhibit combination of high strength and good toughness through the formation of intermetallics such as $Ni_3Mo$, $Ni_3Ti$ in tough bcc martensite matrix. They find wide applications in aerospace and defence sectors due to its unique combination of strength and toughness.

Additive manufacturing is widely gaining importance in which a CAD file is processed layer by layer to manufacture a 3D object. This technology facilitates the fabrication of customizable parts which can be tailored to suit the needs of shape or composition or shape and composition. Powder ba

The present work is aimed to understand the structure and properties of additive manufactured maraging steel 250. 10mmx10mm cylinders of maraging 250 were deposited using powder bed fusion technique. The microstructure shows lath martensite which is typical of maraging steels. Maraging steel gains its strength and toughness by ageing heat treatment. In the present work, additively manufactured maraging 250 was subjected to various ageing treatments by varying temperature (400 to 600°C) and time (2hrs-6hrs). Hardness was found to increase with increasing ageing temperature upto 500°C. Beyond 550°C reverted austenite formation was observed in the martensite matrix which decreases the hardness. The microstructural features of samples were evaluated using optical and SEM. A comparative study was also carried out w.r.t the microstructural features of additively manufactured maraging 250 with that of the wrought material.

Key words: Maraging 250, Additive manufacturing, ageing, reverted austenite

# High-performance triboelectric nanogenerator with ionic liquid processed polyvinylidene fluoride for energy harvesting application through an additive manufacturing technique

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## Abstract

In recent years, the growing demand for sustainable power solutions for flexible electronics, the Internet of Things, cloud computing, and artificial intelligence has become increasingly prominent. Additive manufacturing offers a means to create energy-harvesting devices with the necessary characteristics to meet these demands. This study focuses on fabricating flexible and transparent triboelectric nanogenerator (TENG) devices for energy harvesting by using ionic liquid-processed polyvinylidene fluoride (PVDF) and polyamide 6 through material extrusion. The research investigates the effects of varying ionic liquid concentrations (5%, 10%, 15%, 20%) on the formation of the electroactive β-phase in PVDF, as well as its impact on the dielectric properties and energy output of TENG devices. The results indicate that PVDF processed with 15% ionic liquid produces the highest triboelectric performance, with a peak output voltage of 180.5 V, a short-circuit current of 16.5 µA, and a power density of 3.42 W/m². The incorporation of ionic liquid into PVDF enhances the polar β-phase, increases the dielectric constant, modifies surface potential, and acts as a conductive medium for electrons from the surface to the bulk material, thereby boosting triboelectric charge density and improving TENG device performance. Additionally, the additive manufacturing process contributes to better surface contact between the two tribolayers by increasing surface roughness and ensuring uniform layer printing, which further enhances charge transfer and energy output. This study demonstrates the potential of fabricating flexible TENG devices using ionic liquid-processed PVDF through additive manufacturing, with promising applications in energy harvesting.

# Development of Gas-atomized Fe-Based Amorphous Alloy Powders and its 3-D Printed Products

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## Abstract

The iron (Fe) based amorphous alloys have high research importance owing to its high elasticity and strength, good wear and corrosion resistance superior functional properties. The main drawback of these alloys is the difficulty of its bulk production, which is related to the necessity of rapid cooling rate for generating amorphous structure. It is conventionally overcome by the rapid solidification planar flow casting, generating thin (micron range) ribbons confined to specific magnetic core applications. Alternatively, with the advancement of material processing technology, the gas atomization technique has been adopted to process amorphous alloy ingots as spherical shaped powders, which are utilized for making bigger size (order of cm range) components by 3-D printing technique. In present research, the pre-alloyed FeCrMoBSiCP alloy ingots are processed as spherical powders (0-300 µm size range) by gas atomization technique. The powders are sieved by mechanical vibratory sieve shaker, sorting the powders of 25-93 µm size range for further characterization and discarding remaining powders. The developed gas- atomized powders possess smooth surface, high sphericity, and good flowability. The powders of below 63µm size range are completely amorphous in nature, while that of above 63 µm size range show crystallinity in amorphous matrix. The thermal parameters of supercooled liquid region ($\Delta T_x$), reduced glass transition temperature ($T_{rg}$) and [redacted], are derived as 50, 0.60 and 0.40, respectively, indicating high glass forming ability (GFA) of developed gas-atomized powders. Due to high GFA, the powders (53-80µm size ranges) are utilized for manufacturing the sample products ($25 \times 25 \times 9$ mm$^3$) by 3-D printing of direct energy deposition (DED) technique under different laser parameters. All DED printed samples are found with 65-75% amorphous structure along with major crystalline phases of $(Fe,Mo)_{23}B_6$ and α-(Fe, Mo) and minor phases of $Fe,Mo)_3P$, $(Fe,Mo)_3B$ and $(Fe,Mo)_3C$. The high magnification scanning electron microscopy (SEM) reveal crystalline phases in amorphous matrix, attributed to their compositional elements of EDS analysis. The amorphous matrix is also signified by its high microhardness values (813- 932 $HV_{0.1}$) and the generation of cracks near indent point due to its brittleness.

# Effect of scanning strategy in laser-powder bed fusion of crack susceptible AISI M2 high speed steel

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**Abstract**

High-speed steel (HSS) contains high carbon (C) along with tungsten (W), molybdenum (Mo), vanadium (V), and chromium (Cr) as major alloying elements. AISI M2 is a W-Mo-based HSS known for its high hardness (700-800 HV) and wear resistance, even at elevated temperatures (500–600 °C). These properties are attributed to the presence of complex carbides and hard martensite. However, processing AISI M2, which has a high carbon equivalent, using laser powder bed fusion (L-PBF) is extremely challenging. Rapid solidification, martensite formation, and the presence of complex carbides during the L-PBF process generate significant residual stresses, leading to severe cracking and delamination of the printed part from the base plate. This work aims to study the effect of scanning strategies on residual stress development and its impact on the printability of crack-susceptible AISI M2 HSS. The study analyzes the effect of scanning strategies by varying the laser scan vector length, direction, and scanning sequence. The printed parts are then characterized by their microstructure and mechanical properties.

key words: AISI M2 high speed steel, laser powder bed fusion, path planning, residual stresses, tool steels

# Ferromagnetism in Bismuth Ferrite Nanoparticles via Jet Milling

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## Abstract

We report the magnetic behavior of multiferroic bismuth ferrites synthesized using milling-annealing processes. The antiferromagnetic behavior is tailored through the crystallite reduction of the nanoparticles. X-ray diffraction and Rietveld analysis were used to evaluate the crystallite size and microstrain of the crystal structure. Morphology was studied by scanning electron microscopy, and magnetic behavior was evaluated using vibrating sample magnetometry. The powders were obtained from crystal size reduction by milling process areundergone a heat treatment at 650°C. Relationships between microstructural transformationand oxidation-reduction reactions, as well as antiferromagnetic-ferromagnetic changes, are discussed. The changes in antiferromagnetic properties found by milling-pressure.

Keywords: Bismuth ferrite; Jet milling; Nanoparticles; Size effect; Ferromagnetism; Anti ferromagnetism.

# Synthesis of 1D and 2D material and its application as a SERS Substrate

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**Abstract**

Surface-enhanced Raman spectroscopy (SERS) is an analytical detection technique which significantly increases the weak but structurally rich signal of Raman scattering. Two mechanisms, i.e., electromagnetic enhancement mechanism (EM) and chemical enhancement mechanism (CM), are used to describe the effect. EM mechanism counts for the dipole iteration between the analyte and metal surface, whereas CM mechanism counts for some special functional groups containing SERS substrate that can change its polarisation.

1D Materials like Silver nanoparticles (AgNP), Gold nanoparticles (AuNP) and 2D materials like Transition metal dichalcogenides (TMDC) have grabbed the attention of the researcher for their unusual properties, which make them suitable for SERS substrates. In the study, silver and gold nanoparticles were synthesised as 1D materials ideal for the SERS substrate, and MoS2 was studied as 2D material for the SERS substrate. Methylene Blue dye is used to study the SERS activity of the substrate. TEM, UV-Vis spectroscopy and SEM are performed to characterise its nanostructure. Raman spectroscopy is used to study the substrate's SERS activity. The mechanism behind the signal enhancement is discussed, and it is found that these substrates can serve as a biosensor.

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# Effect of Ti addition on strengthening and deformation mechanism of Ni-rich high entropy alloy synthesized via spark plasma sintering: An experimental and atomistic approach

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## Abstract

Due to the immense alloy designing compositional space, high entropy alloys (HEAs) exhibit unique single phase microstructure with outstanding mechanical properties such as superior strength and ductility synergy, excellent toughness and higher hardness. For the design of high performance HEAs, understanding the strengthening mechanisms and deformation behavior is crucial, which remain less explored till date. In the present study, effect of Ti microalloying on phase evolution, microstructural development, mechanical behaviors and deformation mechanism of novel $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) high entropy alloys (HEAs) synthesized via mechanical alloying and spark plasma sintering (SPS) were systematically investigated. The equilibrium phase formation by varying Ti content was predicted using Thermo-Calc software (TCHEA-4.2 database), indicates that the proposed HEAs exhibit single-phase solid solution at the sintering temperature of 1150 °C without presence of any brittle intermetallic phases, shown in Fig. 1(a). Phase analysis of the sintered HEAs envisaged the formation of face centred cubic (FCC) structured solid solution with minor amount of brittle Cr-rich and Mo-rich sigma (σ) phases along with essential $L1_2$ phase in the FCC matrix. Phase fraction of the σ phases deceases continuously with raise in Ti amount. Increasing in Ti content promotes continuous increase in number average twin boundary per grain i.e., ~2 per grain for 6 at. % Ti HEA (Ti- 06) compared to other HEAs, ascribed to decrease in generalized stacking fault energy (GSFE), as shown in Fig. 1(b), estimated by performing molecular dynamics (MD) simulations. The calculated barrier energies and twinnabilities revealed that the addition of Ti increased the tendency of dislocation glide and deformation twinning. Ti-06 HEA exhibits excellent strength-ductility trade-off, where the yield strength and compressive strength reached up to 1458 ± 8 MPa and 2011 ± 12 MPa, respectively, with an appreciable fracture strain of 26 ± 0.3 %, shown in Fig. 1(c). Further, MD simulation was employed to model the deformation mechanism of current HEAs under compressive loading. The results show formation of continuous stacking fault networks including intrinsic stacking faults, extrinsic stacking faults, deformation twins and dislocations along which plastic deformation carried-out in Ti-06 HEA. Due to activation of multiple deformation twins and stacking faults and their complex interaction contribute to the appreciable plasticity, and increased sessile stair-rod dislocation results in enhanced strength in Ti-06 HEA. This

pioneering work provides further insights into the significance of SFE effect on the deformation behavior and also sheds light on designing of high-performance HEAs.

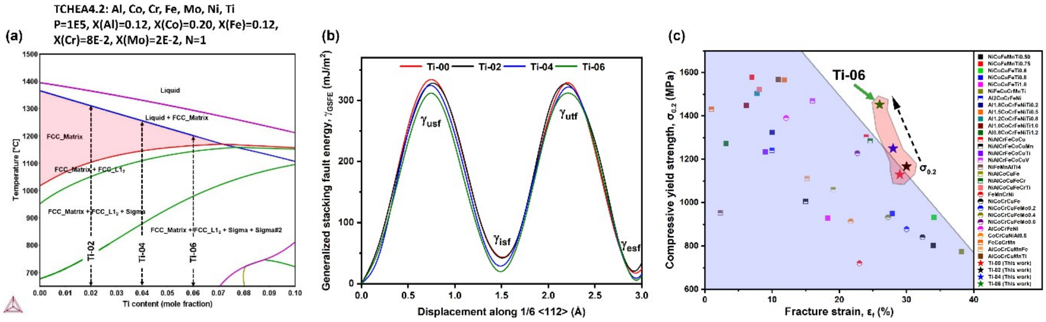


Fig. 1: (a) The pseudo binary phase diagram of the (NiCoAlCrFeMo)-Ti alloy system, (b) generalized- stacking fault energy of FCC {111} <112> slip of $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) HEAs and (c) comparison of the compressive properties of the present alloys with other HEAs

Keywords: High entropy alloy, Spark plasma sintering, Generalized stacking fault energy, Solid solution strengthening, Twin boundary, Molecular dynamic simulation

# Evaluation of Mechanical Performance of Heat-Treated IN939 Fabricated by PBF-LB at its service temperature

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## Abstract

This study evaluates the mechanical performance of IN939 superalloy, fabricated using Powder Bed Fusion-Laser Beam (PBF-LB) and subjected to post-process heat treatment, at its service temperature of 850°C. The primary focus is to understand how heat treatment affects the microstructural evolution and mechanical properties of IN939 for high-temperature aerospace and industrial applications. High-temperature tensile and compression tests at 850°C are conducted to gather data on yield strength, ultimate tensile strength, and ductility. Microstructural analysis using SEM and EBSD reveals significant modifications in grain structure and phase stability due to heat treatment, which are directly correlated with enhanced mechanical properties. The strain hardening behavior is assessed using the Hollomon and Ludwik equations, showing a decrease in the strain hardening exponent at 850°C, indicating increased susceptibility to localized deformation. The results demonstrate that heat-treated IN939 exhibits substantially improved mechanical performance at 850°C, with higher yield and tensile strength while maintaining adequate ductility. These improvements are attributed to refined microstructure and enhanced phase stability from heat treatment. This study underscores the importance of optimizing heat treatment parameters to ensure the alloy's reliability and effectiveness in high-stress, high-temperature environments.

**Keywords:** Powder bed fusion-laser beam (PBF-LB), High temperature mechanical performance, Heat treatment, Microstructural evolution

# A study of dry sliding wear performance of 304 stainless steel reinforced with TiB2 particles

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**Abstract**

AISI 304 Stainless steels have been widely used as engineering materials in industries due to their excellent corrosion resistance, heat resistance, workability and biocompatibility. However, strength, hardness and wear performance of stainless steel are comparatively low, especially at high temperature, thus limit their usage in some extreme environment in industries effectively. One viable way to address these problems is Incorporation of hard ceramic particles, which can improve the mechanical and tribological properties of steel. Steel-Matrix Composites (SMCs) reinforced with $TiB_2$ particles offer great potential for a wide range of applications. In the current work, AISI 304 stain steel-based composites has been developed with 2-4 vol% $TiB_2$ reinforcement by powder metallurgy method. Pressure assisted hot- pressing was used to achieve uniform distribution of $TiB_2$ particles in steel matrix. The sliding wear performance of the composites was evaluated using pin-on-disc apparatus under different loads of 25, 30 and 35 N, and sliding speed of 0.08, 0.11 and 0.13 m/s. High chromium $100Cr_6$ ball with hardness of 62HRc was used as counterpart material. To determine the underlying wear mechanism, the worn-out surfaces were analysed using Field-Emission Scanning Electron Microscopy (FESEM) and Energy-Dispersive Spectroscopy (EDS). The results of the dry sliding tests revealed that, the presence of $TiB_2$ reinforcing particles significantly reduced the volume loss while simultaneously improving the wear performance of the steel matrix. The incorporation of $TiB_2$ particles was beneficial in improving the wear resistance over the entire range of load and sliding velocities used. Significant deformation traces in the form of micro ploughing, delamination and grooving was observed in the unreinforced steel indicating adhesive wear as the dominant wear mechanism. Upon adding $TiB_2$ to steel matrix, the adhesive wear mechanism changed to abrasive wear without any flake-like wear scars on the worn surface. However, deeper grooves and scratches were observed at higher load and sliding speed that lead to deterioration of wear resistance. A mixture of adhesive, delamination, and abrasive wear were observed as the predominant wear mechanism at higher load and sliding speed. The composites were able to sustain higher load compared to the unreinforced steel. Wear test results indicated that the $TiB_2$ content and wear test parameters were important factors influencing the specific wear rate.

**Keywords:** steel matrix, $TiB_2$ reinforcement, dry sliding wear, microstructure

# Characterization of Ti(100−X)MgX (X = 5, 10, 30 and 50) alloys synthesized by mechanical alloying

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**Abstract**

$Ti_{(100-X)}Mg_X$ (X = 5, 10, 30 and 50) alloys were prepared by mechano-chemical synthesis in a high energy planetary RETSCH PM400 planetary ball mill. The elemental powder blends of Ti and Mg (purity >99.9%) with appropriate amount were milled at a rotational speed of 300rpm in a WC coated vial with 10 mm diameter WC balls. Toluene was used to avoid agglomeration during milling. Gradual phase transformation during milling was studied by X-ray diffraction and high-resolution transmission electron microscopy. Powder blends of all the four compositions show the evolution of fcc powder alloy formation. Structural instability due to plastic strain, increasing lattice expansion and negative (from core to boundary) hydrostatic pressure is responsible for the above mentioned phase evolution. The lattice parameter of the fcc phase is a function of both the alloy composition as well as the milling duration.

Keywords: Mechanical alloying, X-ray diffraction, Transmission electron microscopy, Ti-Mg alloy

# Optimizing oxide dispersoid content towards enhancing mechanical properties of ODS Ni-based high entropy alloy

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**Abstract**

The oxide dispersion strengthened high entropy alloys (ODS HEAs) represent an advanced material that integrates the distinctive properties of high entropy alloys with the strengthening effect of oxide nanoparticles. The excellent high-temperature stability, strength, hardness, and corrosion resistance of the ODS HEAs thus offer new avenues for developing structural materials to meet high-temperature applications like aerospace, nuclear power plants, etc. The current research work provides a comprehensive approach for optimizing oxide dispersoids in oxide dispersion strengthened high entropy alloy (ODS HEA) to enhance the strength-ductility alliance, thereby widening its applicability. The study focuses on fabrication of ODS HEA featuring a composition of $Ni_{47}Al_6Co_{18}Cr_8Fe_{12}Ti_8W_1$ at. % via mechanical alloying (MA) and spark plasma sintering (SPS). The investigation encompasses variations in $Y_2O_3$ content, including 1 vol. %, 3 vol. % and 5 vol. %. The effect of $Y_2O_3$ addition on the microstructural evolution and mechanical properties of the sintered alloys was evaluated. Phase analysis reveals that presence of $Y_2O_3$ promotes the formation of $Y_2Ti_2O_7$ complex oxide precipitation in ODS HEAs. A significant enhancement in both hardness and strength is evident in the pristine HEA upon $Y_2O_3$ addition. However, a reduction in these properties is observed in the 5 vol.% $Y_2O_3$ ODS HEA due to agglomeration of $Y_2O_3$ nanoparticles. Notably, the ODS HEA containing 3 vol.% $Y_2O_3$ exhibits exceptional mechanical characteristics, achieving a compressive yield strength of 1517 MPa and a compressive strain of 27%, demonstrating a synergistic combination of strength and ductility. Enhancement of the mechanical properties in the ODS HEA is ascribed to both oxide dispersion strengthening resulting from addition of $Y_2O_3$ as well as presence of in-situ formed $Y_2Ti_2O_7$ complex oxide coupled with solid solution strengthening effect of the HEA matrix.

Keywords: High Entropy Alloy, Oxide dispersion strengthening, Mechanical alloying, Spark plasma sintering, Solid solution strengthening

# An Experimental Investigation on Surface Finish & Tribological Behaviour of Selective Laser Melted Titanium Alloy by Abrasive Flow Finishing Process

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**Abstract**

The manufacturing of a precise complex component is concerned with the most critical phase of final finishing operation. Most of the traditional finishing process has limitations, while addressing challenges with finishing inaccessible, intricate, complex shape components need to be addressed with non-traditional finishing methods. Abrasive flow finishing (AFF) is an extensively employed post-processing technique to finish additively manufactured parts. This process uses polymer rheological abrasive medium (abrasive medium) to finish internal and external surfaces.

The aim of this research paper is to study surface roughness of SLM printed Ti6Al4V alloy by using the Abrasive Flow Finishing process. Optimum process parameters are obtained by comparing the mechanical & tribological properties for a Ti6Al4V alloy samples printed using SLM technique by varying its process parameters like Laser Power, Scanning Speed, Hatch Distance, Layer Thickness, to attain the optimum SLM conditions. The outcomes of work have clearly facilitated in developing a better surface roughness of selective laser melting process Ti6Al4V. Further, an attempt is made to develop an economic AFF medium by using viscoelastic polymers i.e., soft styrene and soft silicone polymer. The experimental study showed that the nano surface finish could be achieved by varying the viscosity of the developed medium on the additive manufactured components.

**Key words:** Selective Laser Melting, TI-6Al-4V, Abrasive Flow Finishing Process, Tribological & Mechanical Properties.

# Development of novel high-strength high-conductivity Cu-Ni alloy through wire arc additive manufacturing and vacuum arc melting – Performance comparison on Mechanical and electrical properties analysis.

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Copper-based alloys possess numerous advantageous properties that make them suitable for a wide range of applications. These properties include high electrical conductivity, high thermal conductivity, good strength, excellent ductility, and good corrosion resistance. Additive manufacturing technology offers in-situ design freedom, which has the potential to reduce both cost and time. In this study, a Cu-2Ni alloy was fabricated using synchro feed pulse mode wire arc additive manufacturing technology (WAAM) and the vacuum arc melting process. Elemental mapping of the fabricated copper alloy from both processes showed that nickel was not segregated and was evenly distributed throughout the copper. The tensile strength of the copper alloy in the building direction was found to be twice that of pure copper, though there was a decrease in ductility. In the XRD graph, copper and nickel peaks merged together, forming a new phase. Additionally, the microhardness in the building direction was higher than in the scanning direction and vertical section.

Keywords: Additive manufacturing, copper-nickel alloy, mechanical properties, hardness, WAAM

# Evolution of amorphous phase in multicomponent γ brass during prolonged mechanical alloying

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## Abstract

The $Cu_5Zn_8$ γ-brass is complex intermetallics in the binary Cu-Zn system. Mukhopadhyay et al. [1] has discerned amorphization in such complex intermetallics during nanostructuring through mechanical milling due to accumulation of defects. Therefore, it is of utmost importance to understand the influence of milling intensity on the structural features. In the present work efforts were made to understand the structural transformation during mechanical alloying of the $(CoCuFeMnNi)_{25}Zn_{75}$ (at. %) multicomponent γ-brass. The BCC $Cu_5Zn_8$ - type multicomponent γ brass was formed after 20 h of milling. However, milling was extended until 60 h to understand the structural features. The TEM investigation confirmed the existence of amorphous phase. The phase fraction of amorphous phase and intermetallics in 60 h milled powder were found to be ~83% and ~17% respectively. The amorphous domain was ~1.69 nm and the size of intermetallics was in the range of 1.73 nm. Furthermore, the Miedema model confirmed the stability of amorphous phases with having size less than ~8 nm.

keywords : γ brass intermetallic, amorphous phase, mechanical alloying References :

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# Effect of Addition of CNTxGnPyhBNz Ternary Hybrid Nanofillers on Mechanical Performance of Al Nanocomposites: A Comparative Study

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**Abstract**

In the present study, the objective is focused on the synthesis of a unique combination of ternary hybrid nanofillers composed of one-dimensional (1D) carbon nanotube (CNT), one-dimensional (2D) graphite nanoplatelet (GnP) and hexagonal boron nitride (hBN) in different weight ratios, followed by the fabrication of Al-based hybrid nanocomposites reinforced with the various CNT-GnP-hBN ternary hybrid nanofillers. Leveraging the synergistic effects of these various nanofillers, the aim was to improve the mechanical and tribological properties of the Al-based hybrid nanocomposites. The Al matrix was reinforced with 1 wt.% of the various CNT-GnP-hBN ternary hybrid nanofillers, each comprising varying proportions in weight fractions of the individual nanofillers. Powder metallurgy (PM) technique was used to develop the Al-based hybrid nanocomposites by reinforcing the Al matrix with the various CNT-GnP-hBN ternary hybrid nanofillers. The fabrication process of the various nanocomposites was done using both the conventional sintering and spark plasma sintering (SPS) techniques. In order to assess the impact of the CNT-GnP-hBN ternary hybrid nanofiller on the characteristics of the Al-based hybrid nanocomposites, pure Al samples were also developed using similar technique. The incorporation of the CNT-GnP-hBN ternary hybrid nanofiller into the Al matrix revealed a significant enhancement in wear performance compared to the pure Al sample developed under similar conditions. However, it was observed that as the hBN content increased the nanocomposites exhibited a decrease in both relative density and hardness.

Keywords: Hybrid nanofillers, Powder metallurgy (PM), Spark plasma sintering (SPS), Hexagonal boron nitride (hBN), Wear

# In situ observation on recrystallization and grain growth in cast and selective laser melted SS316L using High-Temperature Confocal Scanning Laser Microscopy

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## Abstract

In this study, the main focus is to investigate the recrystallization and grain growth phenomena of SS316L samples manufactured by conventional method and additive manufacturing techniques. Conventionally, samples were prepared by cast and wrought method, which were rolled to 50% thickness (referred as C&W), and compared with additively manufactured (AM) samples prepared by Selective laser melting (SLM) technique. Typically, AM samples have a non-equilibrium microstructure, due to the rapid heating and cooling, which occurs during AM process. It enforces us to understand the impact of temperature on microstructural variation and how it leads to recrystallization and grain growth. Hence, in this work, our prime concern is to study the evolution of the as-deposited (SLM) microstructure at various temperatures and compared with C&W samples. In addition, the effect of holding times at various temperatures is investigated in detail. All experiments have been performed for C&W and SLM samples by using a High Temperature-Confocal Scanning Laser Microscopy (HT-CSLM) technique focusing on recrystallization and grain growth. Initially, C&W and SLM samples were heated to 850°C, 1000°C, 1300°C, and 1400°C temperatures at 200°C/min rate and hold for 100 s, 100 s, 200 s, and 180 s, respectively. It was found that the grain structure for SLM samples being more stable than C&W samples. In C&W samples, the recrystallization phenomenon starts at ~850°C with fine grains becoming visible, while in SLM sample microstructure changes appears at ~1150°C. In C&W samples, twin boundaries start to form
~1350-1360°C, but not in SLM specimens. There is complete twin formation at 1400°C and thick grain boundaries in C&W, whereas SLM specimens lack twining while shows thick grain boundaries. For grain

growth experiment samples were heated to 1000°C at rate of 200°C/min and hold at 1000°C for 1 hour. In another experiment, the samples were heated to 1100°C at 200°C/min rate and hold for 15 min, then temperature was increased to 1150°C and hold for 1
h. Finally, it has been observed that there is significant grain growth in C&W samples at 1000°C and 1100°C, while it remains unchanged in SLM samples. However, during hold at 1150°C, the grain size increases in SLM samples and this increase is more pronounced in C&W samples. Further, we explore the reasons underlying the stability of AM samples, in terms of stored dislocation density, and also segregation of alloying elements to various defects such as grain boundaries or cell walls.

Key words: SS316L; Selective Laser Melting; High Temperature Confocal Laser Scanning Microscope; Recrystallization; Grain growth.

# Development of Mo-based alloys by conventional and pressureless sintering

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## Abstract

Mechanical alloying has emerged as a promising technique for the fabrication of Mo-Ni- based alloys, which are challenging to produce using conventional methods due to significant disparities in melting points and restricted mutual solubility. This study explores the synthesis of six unique alloy compositions through mechanical alloying: S1 ($Mo_{80}Ni_{10}Si_{10}$), S2 ($Mo_{80}Ni_{10}Co_{10}$), S3 ($Mo_{80}Ni_{10}Si_{5}Co_{5}$), S4 ($Mo_{79}Ni_{10}Si_{10}(Y_2O_3)_1$), S5 ($Mo_{79}Ni_{10}Co_{10}(Y_2O_3)_1$),
and S6 ($Mo_{79}Ni_{10}Si_5Co_5(Y_2O_3)_1$) (composition in weight percent). The synthesized powders were consolidated at 1500 °C in hydrogen atmosphere for 1.5 hours. Adding Ni, Si, and Co to Mo facilitated liquid phase sintering, thereby enhancing densification, while $Y_2O_3$ addition played a crucial role in grain refinement and improving mechanical properties. The introduction of Ni and $Y_2O_3$ resulted in a bimodal grain size distribution. After 20 hours of milling, oxide particles were encapsulated within the Mo particles. Studies using high- resolution transmission electron microscopy (HRTEM) and selected area diffraction (SAD) reveal the formation of nanocrystallites in oxide dispersion-strengthened (ODS) Mo alloys after 20 hours of milling. Notably, alloys with $Y_2O_3$ exhibited the minimum particle size and a bimodal distribution. X-ray diffraction (XRD) analysis of the sintered samples revealed the formation of hard and brittle intermetallic phases, such as $Mo_3Si$ (cubic), $Ni_3Si$ (cubic), and MoNi (orthorhombic), across all compositions. Elemental mapping confirmed the presence of $Y_2O_3$ oxides within the Mo matrix for alloys S4 to S6. Among the compositions, sintered alloy S6 achieved the highest relative density at 89.74%. Alloys S2 and S3 recorded the highest hardness values at 9.08

GPa and 8.85 GPa, respectively, due to the extensive formation of intermetallic phases. Mo alloys incorporated with $Y_2O_3$ particles showcased enhanced wear resistance, attributed to oxide dispersion strengthening and the presence of intermetallic phases.

Key words : Mo alloys; mechanical alloying; sintering; hardness; wear

# Modelling microsegregation during laser-based additive manufacturing of SS 316L

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## Abstract

SS 316L is a widely used alloy in automotive, marine and aerospace applications. Due to its suitable properties like high thermal conductivity and weldability, it is one of the most widely used materials for additive manufacturing processes like laser powder bed fusion and directed energy deposition. High solidification rates are experienced during these processes leading to non-equilibrium conditions. Due to this, there is segregation of the elements in dendritic and interdendritic solidified regions. Segregation of elements like Cr and Mo have been reported in literature. The aim of this study is to predict the microsegregation during laser powder-bed fusion of SS 316L considering the remelting during the multi-track and multi-layer laser passes. For this, the temperature history during the process is captured using a Finite Element Model. A multicomponent microsegregation model based on a model developed by Yao et.al.
[1] , with extensions to include multicomponent interactions, is used to simulate the microsegregation during the process, considering the major elements. The thermal gradients and the cooling rates from the FEM model are used as inputs to the model. Different locations in the multiple layers in both transverse and longitudinal directions are identified for the same. The effect of rapid solidification and thermal history on the predicted segregation is analyzed in detail and the importance of including these effects is emphasized. The results are also compared with experimental data from literature [2] [3].

**Keywords:** microsegregation model, laser powder bed fusion, SS 316L, thermal history

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# Investigation of microstructure and corrosion behavior of Wire-Arc additive manufactured austenitic stainless steel

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## Abstract

The current work investigates the microstructure and the corrosion behavior of wire-arc additive manufactured (WAAM) 316 L austenite stainless stee1. A 316 L wall with to-fro deposition strategy was fabricated using cold-metal transfer wire arc additive manufacturing technique, as this deposition strategy is efficient, minimizes material wastage, and free from deposition failure. The microstructure of the manufactured 316 L wall was characterized using advanced characterization techniques such as Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD). The microstructure composed of austenite matrix with fine fraction of delta ferrite. The carbides were expected to be present in the microstructure, which seems too small to be characterized using the employed characterization techniques. The corrosion behavior of the base material and the manufactured wall was assessed using Potentiodynamic Polarization (PDP) test. The corrosion behavior of manufactured wall was evaluated in as-fabricated and thermally aged conditions. It was assessed that the thermally aged sample showed a relatively poor corrosion resistance compared to the as-fabricated, owing to the sensitization.

key words : WAAM, stainless steel, 316 L, austenite

# X-ray diffraction line profile analysis of ball milled nanocrystalline iron: Application of Warren-Averbach and modified Warren-Averbach methods

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## Abstract

A comparison has been carried out between two different methods of X-ray diffraction line profile analysis for the determination of crystallite size and microstrain namely the traditional Williamson-Hall (W-H) method and the Warren-Averbach (W-A) method (based on the Fourier analysis of diffraction lines) . Theoretical background behind these two methods has been revisited and these methods have been applied to ball milled nanocrystalline Fe powder. Correction of instrumental broadening of diffraction lines has been performed based on the so-called Stoke's deconvolution. Traditional Williamson-Hall analysis indicates dislocation induced anisotropic microstrain broadening of diffraction peaks in the severely plastically deformed ball milled Fe. The evaluation of detailed dislocation microstructure in the severely plastically deformed ball milled Fe has been carried out by both the modified Williamson- Hall and the modified Warren-Averbach methods.

The results show that both the methods yield comparable values for the crystallite size, microstrain, dislocation density and dislocation character (fraction of screw/edge dislocations) in the ball milled Fe. Additionally, the modified Warren-Averbach method determines the precise values of the dislocation outer-cutoff radius and the dislocation arrangement parameter. Prolonged ball milling leads to strong asymmetry of the Fe diffraction peaks due to dislocation heterogeneity in the plastically deformed Fe which poses serious problem in the diffraction line broadening analysis.

**Keywords:** X-ray diffraction, Diffraction line broadening, Williamson-Hall, Warren-Averbach, modified Warren- Averbach, Ball milling, nanocrystalline Fe

# Phase evolution during mechanical alloying of Ti-Fe-Si ernary eutectic system

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## Abstract

This work is focused on a comparative study of experimental observation of phase evolution during mechanical alloying (MA) of Ti-Fe-Si eutectic powder compositions ($Fe_{42}Ti_{14.5}Si_{43.5}$ ($E_1$), $Fe_{25}Ti_7Si_{68}$ ($E_2$), $Fe_{58}Ti_{8.5}Si_{33.5}$ ($E_3$) and $Fe_{29}Ti_{66}Si_5$ ($E_4$)) using hardened steel and tungsten carbide (WC) grinding media. Ti-Fe-Si based system is cheaper and amorphous alloy of this system could be a potential candidate for bio-implant materials. XRD analysis revealed evolution of various intermetallic phases during milling depending on the powder composition and the type of grinding media. Formation of partial amorphous phase was observed in $E_2$ and $E_4$ powders after 60 h of MA using hardened steel grinding media.
However, with prolonged MA up to 100 h again different complex intermetallic phases appeared under the effect of various contaminations coming from the grinding media. When WC grinding media was used for $E_1$ and $E_4$ powder compositions, the wear of the grinding media increased, and higher level of contaminations got incorporated with the powder materials to form different intermetallic phases and there was no trace of amorphous phase formation.

**key words**: Mechanical alloy, Eutectic, Amorphous, Intermetallic.

# Microstructure and Microhardness Evolution in Wire Arc Additive Manufactured Al5356 alloy after High-Pressure Torsion Processing

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## Abstract

The processing of Aluminium alloys using Wire Arc Additive Manufacturing (WAAM) has accumulated significant research interest following technological advancements in the manufacturing sector. WAAM is a material addition technology that enables the creation of large and complex objects through the layer-by-layer fusion of metallic wires via an electric arc. Al5356 alloy is particularly notable for its high shear strength and excellent corrosion resistance compared to other elements in the Aluminium series. WAAM has many challenges, such as porosity, inhomogeneity in grain size, etc. HPT can overcome these issues by applying high pressure and high torsion. High Pressure Torsion (HPT) is a Severe Plastic Deformation (SPD) technique that exerts high pressure and shear strain on the material, inducing significant microstructural changes. Recent studies have demonstrated that HPT can lead to notable alterations in the material properties, particularly at higher shear strains.

In the present work, Al5356 single brick block (Height = 135mm, Width = 200mm and Thickness = 25 mm) was prepared using WAAM and cut into disk-shaped samples having 10 mm diameter and 1 mm thick, along transverse and longitudinal sections to analyse microstructure in WAAM-manufactured wall. Later, the same-sized disks from the transverse and longitudinal direction of the WAAM specimen were used for HPT processing with one turn. The analysis was carried out from the centre to the edge region of HPT samples. The microstructure characterisation was performed using an Optical and Field Emission Scanning Electron Microscope. Electron Backscatter Diffraction (EBSD) was also used to study the crystallographic orientation of the grains before and after HPT processing. The Vickers microhardness tester was employed to measure the microhardness of the WAAM and HPT processed samples. For HPT samples, the microhardness measurement was carried out from the center to the periphery of the disk. The results showed that processing Al5356 by HPT significantly refines its grain size. After one turn of HPT, the microstructure became more homogeneous and equiaxed compared to the WAAM Al5356 samples without HPT processing. Additionally, hardness showed significant improvement after HPT processing. HPT processing resolved the issues associated with the WAAM sample and presented a promising approach for producing high-performance Al5356 alloy components with superior mechanical properties.

Keywords: Wire Arc Additive Manufacturing, Al5356 Aluminium alloy, High Pressure Torsion, Microstructure characterisation, Microhardness

# Effect of Mechanical Milling on Isothermal Oxidation Behaviour of Laser Surface alloyed CoNiCrAlY on Inconel 718 Substrate

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**Abstract**

Nano-crystallization has improved the chemical and physical properties of materials. One of the simplest approaches for nano-crystallization of material is mechanical milling. In the present study the effect of mechanical milling on isothermmal oxidation behaviour of Laser surface alloyed CoNiCrAlY has been investigated. A commercially available CoNiCrAlY powder (with the composition of 32 wt.%Ni, 21 wt.%Cr, 8 wt.%Al, 0.5 wt.%Y, balance: Co) of make PAC 9950AMF was milled for 10 and 25 hours at 300 RPM using stearic acid as a process control agent (PCA), in tungsten carbide (WC) balls and vials in a ball to powder ratio of 10:1. Then as received and milled powders were mixed with binder i.e 3% PVA solution to make a slurry. Then slurry was preplaced on Inconel 718 substrate with thickness of 500µm. After drying, preplaced CoNiCrAlY is melted by the laser beam having 1800W power and scan speed of 50mm/sec. The laser surface alloyed samples were subjected to detailed characterization by scanning electron microscopy (SEM) and X-ray diffraction technique (XRD). The microstructure of the alloyed region was found to be dendritic in nature and consisted of γ, γ', γ'', β, δ and η phases. Finally, the isothermal oxidation behaviour of the coupons was measured from 800°C to 1000°C for the maximum time period of 100hrs. The isothermal oxidation study showed the formation of predominantly alumina TGO layer in case of milled laser surface alloyed sample compared to un-milled sample. Mechanism of oxidation has been established through a post oxidation microstructure analysis of the oxide scale.

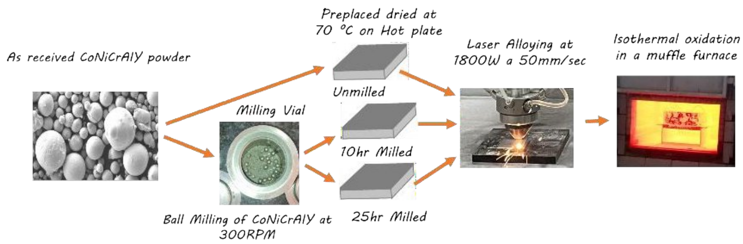


Fig.1: Experimental flow chart for isothermal oxidation of laser surface alloyed un-milled 10hr and 25hr milled CoNiCrAlY powder.

**Keywords:** CoNiCrAlY, Laser surface alloying, microstructure, high temperature isothermal oxidation.

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# Impact of Coating Thickness on Microstructure and Mechanical Behavior of HVAF- Sprayed Ni-Based Superalloys

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## Abstract

High Velocity Air Fuel (HVAF) spraying demonstrates significant potential for surface coating and repair. This study evaluates the impact of varying thicknesses of Ni-based superalloy coatings, specifically IN625 and IN718, applied using HVAF. The microstructure and mechanical properties of these coatings were assessed using micro-hardness, coating cohesion, flexural, and coating-substrate adhesion tests. Results indicate that HVAF coatings maintain the original material phases from the powder. Cross-sectional analysis revealed robust bonding between the melted particles and the substrate, though porosity increased with coating thickness. Splat morphologies varied, including deformed, fully melted, partially melted, and unmelted particles. Thicker coatings (3 mm) displayed more undeformed splats with spherical bumps, which diminished in thinner coatings (1.5 mm and 0.5 mm). Pull-off adhesion tests indicated a decrease in adhesion strength with increasing thickness, attributed to higher porosity. The interface strength exceeded 65 MPa for defect-free coatings, while defective interfaces failed at lower stresses. Flexural strength decreased with thickness due to compressive residual stress and delamination, with coatings achieving up to 70% of the flexural strength of wrought material. Post-treatment with oxyacetylene flame spraying effectively reduced porosity, resulting in a denser of the coating. Moreover, IN718 coatings, in general, demonstrated superior performance compared to IN 625.

**Keywords:** HVAF coatings, Inconel superalloys, Adhesion strength, mechanical properties, flame spray.

# Enhancement of hot corrosion and hot oxidation resistance behaviors of selective laser melted Ti6Al4V by ultrasonic shot peening

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## Abstract

Selective Laser Melting (SLM) is an emerging technology in manufacturing industries due to its numerous benefits such as minimum material wastage, design complexity and dimensional accuracy. In the present study, electrochemical corrosion, high temperature corrosion and ultrasonic shot penning (USSP) has been attempted for Ti alloy (Ti6Al4V) fabricated by SLM technique. The results shows the 20% improvement in micro hardness after USSP along with that improvement in electrochemical corrosion resistance in 3.5 wt. % NaCl solution and high temperature corrosion resistance in air, $Na_2SO_4$ + 25% NaCl, and $Na_2SO_4$ + 50% $V_2O_5$ environments at 750℃. The corrosion rate found to be minimum in USSP samples exposed under all environments. The samples exposed to $Na_2SO_4$ + 50% $V_2O_5$ environment was severely affected by the corrosion. Various techniques were used to characterize the hot corrosion products and the results confirmed the formation of $TiO_2$, $Al_2O_3$, $V_2O_3$, $V_2O_5$, $Na_2TiO_3$ oxides. Additionally, microstructural changes were observed compared to non-USSP sample. Both USSP and non-USSP samples showed flaky martensite with noticeable changes in flake length.
Keywords: Selective laser melting, ultrasonic shot penning, electrochemical corrosion, XRD

# Structural Analysis of RF Plasma Spheroidized Glass-Ceramic Powders Using Raman Spectroscopy

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## Abstract

This paper explores the suitability of glass ceramic powder synthesized using radio frequency plasma spheroidization process for additive manufacturing applications. Glass ceramic powders are crucial components in additive manufacturing, provided their unique properties, such as high strength, low thermal expansion and high resistance to thermal shock. Raman spectroscopy is a powerful analytical tool used to measure the unique vibrational fingerprint of the sample. From that information, the sample's chemical, structural and physical properties can be determined. This study employed Raman spectroscopy to analyze the glass ceramic powders synthesized using a radio frequency plasma spheroidization process. The Raman spectra of the glass ceramic powders revealed distinct peaks corresponding to the molecular vibrations of the glass ceramic components. The spectra were analysed to identify the powder's chemical composition and phase structure.

Keywords: Glass Ceramics, Spectroscopy, Polymorphy, Crystallinity

# Optimizing the heat treatment processes for additively manufactured ti-6al-4v for enhanced ductility

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## Abstract

Additive Manufacturing (AM), commonly known as 3D printing, has gained wide spread attention in recent years for its ability to produce complex and customized components with various materials. This abstract focuses on the application of additive manufacturing on Ti6Al-4V, a titanium alloy known for its excellent strength-to-weight ratio and corrosion resistance a highly versatile and widely used alloy in additive manufacturing, offering significant advantages in producing high-performance, customized, and complex parts for critical applications across various industries. Post-processing techniques play a crucial role in enhancing the mechanical properties and reliability of AM Ti-6Al-4Vcomponents. Optimizing the heat treatment processes for additively manufactured (AM) Ti-6Al-4V is critical to enhance its ductility and overall mechanical performance. Ti-6Al-4V, a widely used titanium alloy, often exhibits anisotropic microstructures and residual stresses when produced through additive manufacturing, leading to suboptimal ductility and potential
performance issues in critical applications. This study investigates the effects of various heat treatment protocols, including annealing, solution treatment, and multi-step heat treatment processes, on the microstructure and mechanical properties of AM Ti-6Al-4V. The objective is to identify an optimized heat treatment regimen that alleviates residual stresses, refines the microstructure, and improves ductility without compromising strength. Comprehensive
microstructural analyses and mechanical testing were conducted to evaluate the influence of different heat treatment parameters. Results indicate that additively manufactured Ti-6Al-4V components should undergo heat treatment at 950°C for 4 hours or a multi-step heat
treatment for over 8 hours at various temperature levels. These treatments enhance ductility to approximately 15% while retaining strength levels comparable to those of conventionally processed and heat-treated Ti6Al-4V. Therefore, a carefully controlled heat treatment process for additively manufactured Ti64 can significantly enhance the ductility of AM Ti-6Al-4V, making it more suitable for demanding applications in aerospace and biomedical industries.

Keywords: Additive Manufacturing , Ductility , Tensile properties, Heat Treatment.

# Study of the elastic properties and compressive behavior of porous copper fabricated using powder metallurgy route and having different porosities and pore morphologies

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## Abstract

Porous copper having different porosities and pore morphologies has been fabricated via the space holder technique using the powder metallurgy route. $K_2CO_3$ and NaCl were employed as the space holders and five different mixture ratios of $K_2CO_3$:NaCl were used viz. 1:0, 2:1, 1:1, 1:2 and 0:1. The elastic property characterization of the porous copper samples was carried using the non-destructive ultrasound phase spectroscopy technique. The results showed that the samples were transverse isotropic in nature with lower elastic constants along the uni-axial green compaction direction, due to the pore flattening that occurred during green body fabrication. Moreover, the elastic constants were observed to be decreasing with increasing amount of porosity. The optimum elastic properties were observed in the porous copper samples having $K_2CO_3$:NaCl = 1:2. The compressive stress-strain behavior of the samples showed three different regions - the initial elastic region followed by the plateau region and finally the densification region. The yield stress decreased and the energy absorbed before densification increased, with an increase in porosity. While the stress-strain response was found to be similar for both monomodal and bimodal porous copper samples at lower porosity levels, after a critical porosity of ~50%, the strength of the bimodal porous copper samples was considerably higher. The effect of the uni-axial green compaction pressure on the elastic anisotropy of the porous copper samples having $K_2CO_3$:NaCl = 1:2 was investigated by varying the pressure systematically from 120 to 180 MPa. The results showed that while the average elastic anisotropy increased when the pressure was increased from 120 to 160 MPa, at 180 MPa applied pressure, the anisotropy decreased due to the presence of lower melting point NaCl particles, which facilitated the sintering of the Cu particles, thereby leading to enhanced densification. The yield strength and Young's modulus of porous copper samples are plotted in the Ashby material property map and it is observed that the samples having dual pore morphologies are potentially attractive for lightweight elastic hinges.

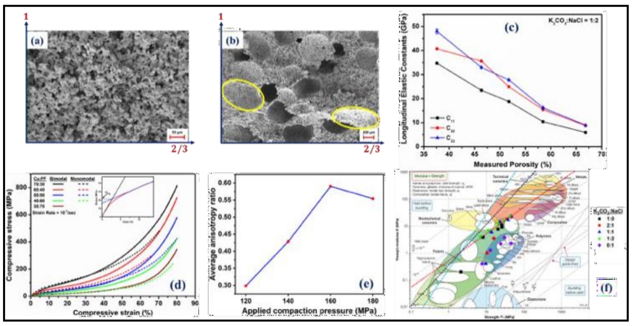

Figure 1: SEM micrographs of (a) monomodal, (b) bimodal porous copper, (c) variation of longitudinal elastic constants of porous copper, (d) compressive stress-strain behavior of porous copper, (e) variation of average anisotropy ratio with applied compaction pressure and
(f) Young's modulus and yield strength of porous copper samples in Ashby material property map

**Keywords**: Porous copper, Elastic properties, Ultrasound phase spectroscopy, Compressive behavior, Anisotropy

# Single-Crystalline CMSX-4 Superalloy builds with Laser-Directed Energy Deposition (L-DED) using Multi-Scale Models and Experiments

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## Abstract

Additive manufacturing (AM) is rapidly becoming a viable alternative for producing complex geometries, making it a potential choice for manufacturing aerospace components. The high- pressure turbine blades in a jet engine not only have complex geometry but also require stringent microstructural specifications such as single-crystallinity. The combination of complexities in the topology and microstructure makes it challenging to identify the right process parameters for additive manufacturing of these blades.

This work describes a novel workflow for identifying these parameters, involving physics-based modeling at the melt pool length scale, and microstructure modeling at the grain and dendritic length scales. We introduce a diffuse-interface-inspired model to simulate the melt- pool shape during multi-layer deposition. The thermal histories obtained from this model are used in a Potts-based grain-structure model to determine the approximate texture during solidification. By combining the process and grain-structure model, we determine the parameter space for single-crystalline builds. Experimental analysis confirms that the identified parameters produce single-crystalline microstructures.

Furthermore, the thermal histories are utilized in phase-field simulations to determine the primary dendrite arm spacing (PDAS) for the CMSX-4 alloy. Comparison of these PDAS with experimental measurements serves as validation of the solidification conditions derived from the process model. Thus, the complementary utilization of experiments and modeling provides insights that not only allow the identification of appropriate additive parameters for epitaxial growth but also aid in designing strategies for building complex shapes.

Keywords: L-DED; Single-crystal; CMSX-4; Epitaxial; Additive manufacturing

# Solid state Layer Deposition Using Friction based Advanced Manufacturing Technique

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**Abstract**

This study highlights the potential of friction-based AM techniques in successive deposition of aluminium alloy. Friction Surfacing, a solid-state progressive technique, is an advancement of traditional friction stir welding process. The process involves the rotation of a tool at high speed, generating sufficient heat to soften and plastically deform the material, which is then deposited onto a substrate in successive layers. The deposition rate which is influenced by the tool rotational speed and feed rate, along with the dwell time it plays a critical role in achieving the desired layer thickness. The ability to precisely control the microstructure and mechanical properties makes these techniques ideal for applications requiring high reliability and performance. AA2219 alloy is widely used in aerospace and automotive industries due to its favorable mechanical properties. In this work, AA2219 consumable tool was prepared and deposited over the steel substrate with rotation speed of 1200rpm and feed rate of 10mm/min. The microstructural quality of the deposited layer was studied through an optical microscope and scanning electron microscope (SEM). The layer-wise deposition in this method allows for controlled build-up of material ensures a high degree of accuracy and repeatability, making it ideal for additive manufacturing of metals especially AA2219 alloy.

Key words: Additive Manufacturing, Friction stir Surfacing, Aluminium alloy; Layer deposition.

# Phase-Separated Bulk Cu70Fe30 (at%) Alloys with Bimodal Grain Size Distribution for Enhanced Strength and Ductility

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**Abstract**

Cu-Fe alloys can be used in a wide range of applications, including automotive components, aerospace components, structural applications, high performance bearings, electrical contacts and connectors. However, synthesizing homogeneous Cu-Fe alloys is challenging, as Cu and Fe are insoluble in each other due to their high positive enthalpy of mixing, which is 13 kJ/mol. In this study, a metastable $Cu_{70}Fe_{30}$ (at%) single-phase face centered cubic (FCC) solid solution $\gamma^S$ was produced from the elemental powders of Cu and Fe through mechanical alloying for 20 h. Consequently, the alloyed powder was consolidated by SPS at $0.6T_m$ (622°C) and $0.7T_m$ (772°C) temperatures, where $T_m$ represents the linear-interpolated melting point of $Cu_{70}Fe_{30}$ alloy (1219 °C). Scanning electron microscopy (SEM), X-ray diffraction (XRD), electron backscatter diffraction (EBSD) and differential scanning calorimetry (DSC) analyses were conducted on the MA powders and the consolidated SPS bulk samples. Compression and hardness tests were conducted on the SPS samples to evaluate the mechanical properties. The $0.7T_m$ SPS sample exhibited an excellent ultimate compressive strength of 1056 MPa, and a ductility of 23% due to the bimodal grain size distribution in the microstructure as shown in Fig. 1, which includes an ultrafine-grained γ and α phase mixture, large discontinuous γ clusters formed from the phase separation of $\gamma^S$ during SPS, and a small amount of $Fe_3C$ phase. This $Fe_3C$ phase was observed due to carbon contamination from the milling media. During compressive deformation, the bimodal grain size distribution contributes to high strength through the fine grains (γ+α phase mixture) and enhances ductility through the larger grains (γ clusters).

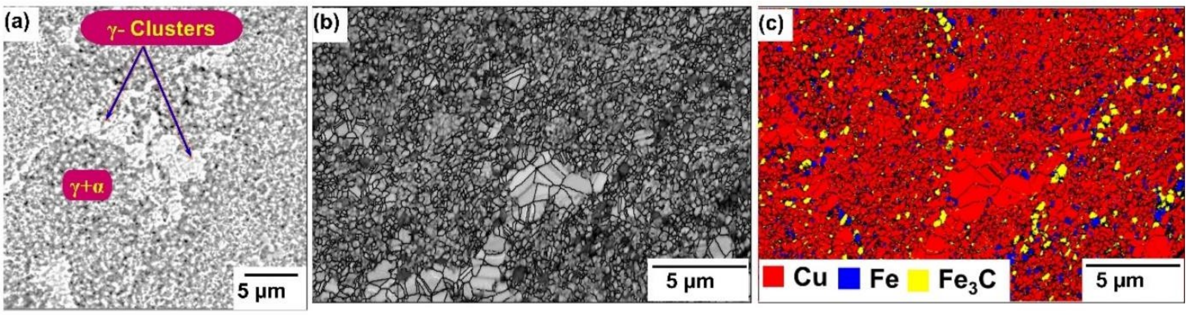


Fig. 1. (a) SEM image of $0.7T_m$ SPS sample, (b) EBSD band contrast and grain orientation

image and (c) EBSD phase map

**Keywords:** Cu-Fe insoluble alloys, Mechanical alloying, Spark plasma sintering, Phase separation, Bimodal grain size distribution.

# Single-crystalline CMSX-4 superalloy builds manufactured through directional solidification and laser-directed energy deposition (L-DED) routes

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## Abstract

Single crystalline Ni-based superalloys are preferred in the hottest parts of the aero-engine due to absence of the grain boundaries which improves high temperature creep strength. Conventionally, Directional solidification processing (DS) is used to produce columnar and single crystalline (SX) microstructures in Ni based superalloys. However, traditional manufacturing involves multiple complicated steps and requires long-term homogenization heat treatments before the component can be used in the final application. Additive manufacturing (AM) has revolutionized the manufacturing sector because of its ability to produce near-net-shaped components in a single step using a computer-aided design (CAD) model of the part. In addition to that, high thermal gradients and solidification rates associated with the AM processing favour epitaxial growth and results in microstructural refinement compared to the conventional processing.

The objective of this study is to understand and compare the microstructure, segregation behaviour and mechanical properties of the CMSX-4 superalloy single crystals manufactured through DS and laser based directed energy deposition (DED) AM routes. In-house developed vertical Bridgman furnace is used to generate the superalloy single crystals through seeding technique as a function of thermal gradient and solidification velocities. Laser based DED machine is used to manufacture superalloy single crystals of [001] orientation by epitaxial growth from the substrate using raster scan strategy as a function of the laser power, scanning speed, powder flow rate and layer height.

Microstructural analysis of DS and AM processed single crystals revealed a dendritic microstructure with a larger dendrite arm spacing in the former case. Compositional analysis of DS single crystals revealed severe segregation of Re and W to the dendritic regions; Ta, Al and Ti to the inter-dendritic regions compared to AM builds. Mechanical properties are also evaluated and compared in the as printed and heat-treated conditions.


**Keywords**: Single crystal; Directional solidification; Laser based additive manufacturing; epitaxial growth; mechanical properties.

# Study of the microstructural and mechanical properties of 316L stainless steel Fabricated using ultrasonic vibration-assisted CMT wire arc additive manufacturing

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## Abstract

Wire Arc Additive Manufacturing (WAAM) is an advanced technique used to produce medium to large metallic components. Despite its advantages, one significant limitation is the formation of coarse columnar grains within the manufactured parts, which negatively impacts their mechanical properties. This drawback restricts the broader application of WAAM in various engineering fields. Ultrasonic vibration can be used to refine grains and improve their mechanical properties of SS 316L. In the current investigation, an ultrasonic generator was used to produce ultrasonic frequencies, and a sonotrode was employed to vibrate the substrate at different frequencies. X-ray diffraction was conducted to determine if any phase changes occurred after the application of ultrasonic vibration. The microstructure before and after using ultrasonic vibration was analyzed using both an optical microscope and a scanning electron microscope. Mechanical properties, including hardness, tensile strength, and fretting wear resistance, were also evaluated. The results demonstrated that after applying ultrasonic vibration, the grains became more refined, resulting in increased hardness, as hardness and grain size are inversely proportional. The tensile strength and fretting wear resistance increases post using ultrasonic vibration. The findings also indicated that as the frequency increases, the grain size initially decreases and then increases. This insight is valuable for fabricating parts with desired grain sizes in ultrasonic vibration-assisted WAAM. Thus, employing ultrasonic vibration significantly impacts the properties of the deposited structure.

**Keywords:** Wire arc additive manufacturing, Ultrasonic vibration, SS 316L, Fretting Wear

# Microstructural characterization and mechanical properties of heterogeneous bimodal copper

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## Abstract

Owing to high thermal and electrical conductivity, good corrosion resistance and high melting point, copper (Cu) is widely used in thermal, automobile, aerospace, and electronic applications. However, the low mechanical properties of pure Cu limit its engineering applications. The mechanical properties of Cu can be enhanced through various strengthening mechanisms, including the addition of alloying elements in solid solution, particle dispersion, precipitation strengthening, severe plastic deformation, and grain refinement. However, these strengthening mechanisms resulted in a sharp decline in ductility, exhibiting the long-standing dilemma of strength–ductility trade-off in Cu. Recently, a heterogeneous bimodal microstructure design consisting of fine-grained (FG) regions and coarse-grained (CG) regions has been proposed as an effective strategy to overcome the strength–ductility trade-off. In this study, the heterogeneous bimodal Cu is developed by powder metallurgy route with a coarse- to-fine powder ratio of 50:50 (vol%.). The coarse and fine powders are mixed by magnetic stirrer, in which the coarse powders serve as a source for CG regions, while the fine powders act as a source for FG regions. The XRD patterns of the Cu powders and sintered samples reveal peaks of the pure Cu phase without any Cu oxide peaks. The SEM micrographs demonstrate a heterogeneous bimodal grain microstructure containing two distinct regions, one of which is fine-grained and the other is coarse-grained. Furthermore, the EBSD analysis also confirms the fine and coarse grain regions in the microstructure. The compression test is performed by the universal testing machine. The results show that the bimodal Cu sample exhibits a better balance of strength and ductility compared to pure Cu and milled Cu.

**Keywords**: Copper, Hardness, CG and FG regions, X-ray diffraction, EBSD analysis.

**Coarse Powder**

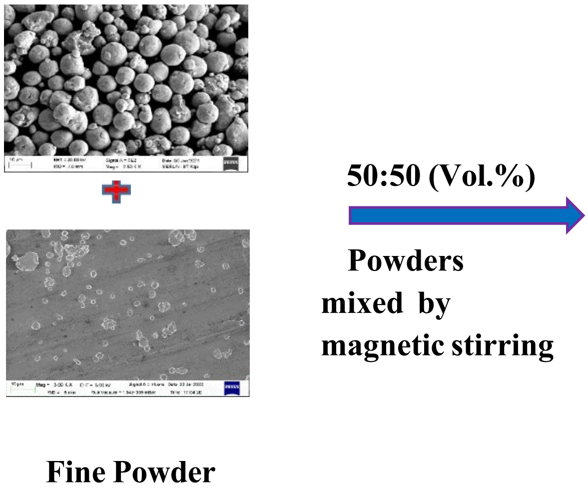


Fig. 1: Heterogeneous bimodal microstructures

# Structural and Thermo-electric Behaviour of High Entropy bisbtesesn Alloy Synthesised by Mechanical Alloying and Spark plasma Sintering

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**Abstract**

High entropy alloys (HEAs), are now being explored as possible candidates for numerous engineering applications, including structural and energy ones. Their advantages over traditional engineering alloys are the reason for this. The synthesis and consolidation of BiSbTeSeSn high entropy alloy for thermo-electric applications is investigated in this work. With the aid of high energy ball milling under optimum processing conditions (milling speed, ball-to-powder ratio, process control agent, environment, etc.), the equi-atomic composition of BiSbTeSeSn alloy doped with sodium (Na) was synthesised. To comprehend the high entropy solid solution, nanostructure, etc., structural characterisation was carried out using techniques including X-ray diffraction (XRD) and electron microscopy. The thermal stability of the produced alloys was investigated using differential thermal analysis (DTA). Subsequently, the powders that were ball milled were consolidated using spark plasma sintering. Studies on the sintered alloy's seebeck coefficient, electrical conductivity, and thermal conductivity were conducted. It was used to calculate the power factor and figure of merit. The high entropy solid solution of the nanocrystalline BiSbTeSeSn alloy is confirmed by the XRD measurements. Additionally, the good thermal stability of the nano-crystalline BiSbTeSeSn alloy is displayed in the sintered alloy. However, because the BiSbTeSeSn HEA alloy is more metallic in composition, its thermo-electric properties are reduced.

Keywords: High Entropy Alloy, BiSbTeSeSn, Mechanical Alloying, Spark Plasma Sintering,

# High-Temperature Mechanical properties of Haynes 282® Nickel base superalloy processed through Laser Powder Bed Fusion Additive Manufacturing Process

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## Abstract

In order to increase an efficiency and reduce the emission of greenhouse gases, there is an urge to increase the operating temperature of advanced ultra-supercritical (AUSC) power plants. Currently, Ferritic/martensitic dual-phase steels are the material of choice for such applications. However, the dual phase steel has temperature limitations, and so in order to further increase the operating temperature of AUSC, the development of alternative materials with high-temperature capabilities is critical. Nickel base superalloys are possible alloy classes that can be used in an A-USC power plant. Among available nickel-based superalloys, Haynes 282® is an ideal candidate for the A-USC application. Haynes 282® is a precipitate-strengthened nickel-base superalloy (combination of L12-ordered coherent γ´ precipitates and carbides) and exhibits better creep and oxidation resistance along with good processability (Thermo-mechanical processing and welding). At present, this alloy is processed through conventional casting followed by thermo-mechanical heat treatment. Some parts in A-USC have intricate shapes and require precision dimensional clearance, which is difficult to achieve through conventional processes. In this study, we explored the Laser powder bed fusion additive manufacturing (LPBF-AM) of Haynes 282® nickel-base superalloy. The process parameters were optimized based on the distribution of defects and microstructural evolution. The heat treatment parameters were optimized based on the distribution of precipitates in the matrix and the mechanical properties. The creep behavior for the optimized heat treatment cycle was further explored in the temperature range of 560-760°C and stress values of 300,400 and 500 MPa. The active deformation mechanisms during the creep were discussed based on the obtained Norton's creep exponent (n) and activation energy (Q) values and are correlated with the crept microstructure. The detailed microstructural analysis was carried out using a correlative EBSD-TEM and APT analysis. Further, the effect of varying load, speed and distance on wear behavior at elevated temperatures was studied and a detailed comparison with conventional Haynes 282® nickel superalloy is made.

**Keywords:** Nickel base superalloys, Creep, Additive Manufacturing, correlative microscopy techniques.

# Grain size effects on interdiffusion in multicomponent alloys

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## Abstract

Interdiffusion between metals and alloys is frequently encountered in engineering components and devices, which is often an assembly of different types of materials, for e.g., in flip-chip technology, bond coating, production of $Nb_3Sn$ superconductors, nanotubes and laminate structures. The development of the interdiffusion zone (IDZ) is expected to be altered with the change in grain size of one or both end members, which can affect the interface properties in relevant applications. The present study focuses on investigating the phase growth during interdiffusion by employing a novel sandwich couple approach comprising of CG-M/Sn/UFG-M materials (where CG denotes coarse-grained (~250 µm), UFG denotes ultrafine-grained (~200 nm), and M represents CoNi and CoFeNi). The interdiffusion experiments have been conducted in the temperature range of 175- 215 $^0$C. The CG-M and UFG-M samples have been fabricated using arc melting and spark plasma sintering (SPS) techniques, respectively. The composition of phases formed has been confirmed through electron probe microanalysis (EPMA) and micro-x-ray diffraction (XRD) measurements.

It has been demonstrated that the phase transformation in IDZ is controlled by both thermodynamics and kinetic factors. For e.g., in CoNi diffusion couples at 175 $^0$C, only the $CoNiSn_3$ intermetallic phase is observed at the CG interface, while the UFG CoNi/Sn interface displayed the formation of the $CoNiSn_2$ phase. At 200$^0$C, the formation of the $CoNiSn_2$ phase together with the $CoNiSn_3$ phase is observed at the CG interface, whereas only the $CoNiSn_2$ at the UFG interface. The preferred formation of $CoNiSn_3$ at the CG interface is due to faster diffusion of Sn, whereas the thermodynamically more stable $CoNiSn_2$ phase appears at the UFG side.

Time-temperature-dependent measurements for UFG-M materials revealed accelerated phase growth compared to CG-M materials across all systems. The enhanced kinetics at the

UFG-M/Sn interface was attributed to an increased fraction of grain boundaries (GBs), resulting in a greater contribution of GB diffusion to the overall diffusion flux. By employing the sandwich diffusion couple strategy, the study ensured that all comparisons between CG and UFG interfaces were conducted under identical conditions, enabling reliable correlations to be established.

Keywords- Grain boundary diffusion, phase growth, Ultrafine grained material, correlative microscopy

# Effect of Ti modification and T6 heat treatment on the mechanical properties of the additively manufactured Al 2024 alloy.

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## Abstract

The current study investigates the impact of annealing temperature on mechanical properties such as strength, hardness, and microstructural evolution of laser powder bed fabricated, Ti modified Al 2024 alloy. Al 2024 is a precipitation hardened Cu, and Mg based aluminum alloy that finds widespread applications in various industries. The titanium acts as a grain refining agent for the aluminum alloys and reduces the solidification cracking in aluminum alloys. The addition of titanium in additively manufactured Al 2024 alloy can lead to the formation of ultrafine grained (UFG) structure with average grain size of 0.4 μm. The formation of UFG structure also improves the mechanical properties of the Al 2024 alloy. The Al 2024 alloy has Al2Cu, and Al2CuMg as its main strengthening precipitates. These precipitates are evolved during heat treatment process and are responsible for the high strength observed in the Al 2024 alloy. Hence, optimal evolution of these precipitate is very essential for producing high strength, additively manufactured Al 2024 alloy. The mechanical properties were evaluated using compression, and hardness test. The microstructural behavior and phase evolution were analyzed using a variety of techniques such as x- ray diffraction, scanning electron microscopy, and transmission electron microscopy.

key words : Additive manufacturing, structure property correlation, Fracture toughness, Laser powder bed fusion.

# Laser powder bed fusion of AISI 4140 high strength low alloy steel: optimization of process parameters

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## Abstract

Laser powder bed fusion, often referred to as selective laser melting, is the predominant technique in metallic additive manufacturing. It enables the production of intricate components with complex shapes by depositing metallic powders layer by layer, resulting in a nearly net- shaped final product. Experiments on single tracks were conducted to investigate the impacts of scan speed and laser power on the behavior of the tracks during laser powder bed fusion. For the high strength low alloy steel AISI 4140, bead mode, the melt pool dimension, and the track stability were investigated. The laser power for the tracks were varied between 150 W and 400 W, while the laser scan speed ranged from 300 mm/s to 1400 mm/s. The bulk specimens were built using identical parameters as those employed in the single-track testing. High porosity was seen at both high and low energy input densities. This was attributed to the presence of un-melted particles and keyhole pores, respectively. An increase in laser scanning speed results in the observation of discontinuities in the tracks. As the laser intensity increases, the depth of penetration of the bead also increases, indicating a shift in the bead morphology from conduction mode to transition mode or keyhole mode. This would lead to an increase in the occurrence of porosity flaws. The occurrence of balling can be elucidated by considering the Marangoni convection and the Rayleigh instability in relation to the flow of the molten material. The contact angle is a direct measure of the wettability of the bead. The experimental investigation revealed that the tracks became unstable when the droplets solidified prior to spreading out over the substrate, resulting in a contact angle exceeding 90°. Through the analysis of the track and bead morphology, a refined set of parameters was derived that can be utilized for printing specimens. The examination of the bulk specimens revealed the presence of martensite formation in the microstructure. Vickers hardness testing was performed in the vertical direction, starting from the bottom and moving towards the top. The hardness exhibited minimal variance, indicating a high degree of homogeneity.

Keywords : LPBF, HSLA steel, single-tracks

# Role of process parameters on microstructure and mechanical property variations in an additively manufactured 316L Stainless steel

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## Abstract

Additive Manufacturing (AM) is a cutting-edge technique for producing components on demand, enabling the creation of complex geometries while simplifying the production process. Our current research focuses on understanding how various process parameters impact the formation of specific microstructural features and the resulting changes in hardness and modulus. We characterized the 316L stainless steel samples deposited under different conditions of selective laser melting technique using Electron Backscatter Diffraction (EBSD) and nanoindentation. Both the average value and spread in the hardness and modulus distributions varied between top and bottom regions along the build direction. For samples deposited at 700 m/s scanning speed, in spite of similar variations in laser power, the hardness and modulus values remain almost similar between the top and bottom regions. While at 800 m/s scanning speed, increasing the laser power increases the difference in modulus values between the top and bottom regions. A direct correlation between the difference in hardness values and Kernal Average Misorientations could be observed. Here, the differences in local orientation gradients (i.e. KAM) are related to the geometrically necessary dislocations, and a higher KAM value correlates well with a high hardness value. Similarly increase in hatch distance, while maintaining constant scan speed and laser power, results in a corresponding rise in dislocation density and a subsequent increase in hardness value.

Keywords: 316L stainless steel; selective laser melting; EBSD; GND; nanoindentation

# Surface Mechanical Attrition Treatment of Spark Plasma Sintered Titanium Aluminide: Microstructural and Mechanical Behaviour Analysis

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## Abstract

Titanium Aluminide (TiAl) alloys are promising materials for high-temperature and aerospace applications due to their excellent strength-to-weight ratio and oxidation resistance. However, their inherent brittleness and surface properties require enhancement for broader applications. In this study, Spark Plasma Sintering (SPS) was utilized to fabricate TiAl specimens, followed by surface modification through Surface Mechanical Attrition Treatment (SMAT). The modified surfaces were extensively characterized using Electron Backscatter Diffraction (EBSD), Scanning Electron Microscopy (SEM), and 3D profilometry to evaluate the microstructural changes. Mechanical properties, including hardness and surface roughness, were assessed to understand the impact of SMAT on the treated surfaces. Furthermore, the corrosion resistance of the SMAT-treated TiAl samples was evaluated, providing insights into the effectiveness of the surface modification process. The results indicated significant improvements in both the mechanical and microstructural properties of the TiAl alloy, with enhanced corrosion resistance, highlighting the potential of SMAT as a viable technique for improving the performance of TiAl components in demanding environments.

# The role of inter-layer rotation in minimising mechanical anisotropy during laser powder bed fusion additive manufacturing of an IN718 alloy

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## Abstract

Laser Powder Bed Fusion (LPBF) is an additive manufacturing technique that utilises a laser as the heat source and metal powder as the feedstock. Several critical parameters, including laser power, scan speed, step over distance (hatch spacing), and interlayer rotation significantly influence the mechanical properties of the printed components in the LPBF process. This study investigates the impact of two distinct deposition strategies (0 and 67 interlayer rotation) on the microstructural and room temperature tensile properties of Inconel 718 samples in parallel and perpendicular to the build direction. The contributions to strengthening from grain boundaries, texture, and dislocation-dislocation interactions were quantified using the Hall-Petch, Taylor, and Bailey-Hirsch models using Electron Back Scattering Diffraction (EBSD) data and correlated with the experimental investigations.
It was found that the interlayer rotation during depositions significantly influenced the grain size, aspect ratio, dendritic arm spacing, crystallographic orientations, and the overall mechanical behaviour. The 0 ° interlayer rotation results in a strong texture, characterised by the presence of columnar grains with orientation parallel to the build direction. In the perpendicular to the build direction, bimodal structure was found to be stabilised which led to higher yield and ultimate tensile strength perpendicular to building direction and higher elongation in parallel to building direction. On the contrary, the 67 ° interlayer rotation reduces both grain sizes and the texture intensity, respectively. This led to nearly similar strength and elongation in parallel and perpendicular to building direction for a 67 ° interlayer rotation.

# Optimal Reinforcement Distribution for Multi-scale Segregated Structures to Boost Aluminium Metal Matrix Composite Performance

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## Abstract

Recently, there has been interest in the unique design opportunities that arise from the controlled distribution of reinforcements at an intermediate or mesoscopic scale. With their distinctive discontinuous segregated microstructure arrangements, multi-scale segregated microstructure composites are a relatively new class of composites that combine metallic properties like excellent thermal conductivities, toughness, formability, hardness and strength with ceramic properties like modulus, low thermal expansion, high-temperature durability, improved hardness and strength. In the current work, high-energy ball milling and rotor mixing are used to generate conventional aluminium (Al) matrix composites (with homogenous reinforcement distribution) and discontinuous segregated aluminium matrix composites with 10% weight percentage of aluminium nitride (AlN) as reinforcement. The development of these composites involve 10 hours of high-energy ball milling followed by 30 minutes of rotor mixing. Further microstructure modifications are done based on the percentage distribution of composite region and matrix region in suitable ratios. The importance of segregated microstructure formation is demonstrated by structural, mechanical, and thermal characterisations, which also highlight how more customisation of the composite and matrix distribution broadens the range of useful applications for a given system.

Keywords: Aluminium metal matrix composites, segregated microstructure, thermal conductivity

# Mechanical alloying in Cu-Ru immiscible binary system: X-ray diffraction investigation

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## Abstract

Cu and Ru are completely immiscible at equilibrium even at very high temperature (> 1059ºC) due to their positive enthalpy of mixing ($\Delta H_{mix}$ ~ 7 kJ/mole). Mechanical alloying is a well-known non-equilibrium synthesis method for alloy creation between immiscible elements. Nevertheless, reports on mechanical alloying between Cu and Ru are rare in the literature [1]. The present investigation is an attempt to create metastable Cu-3wt%Ru single phase alloy by high energy ball milling of Cu and Ru powder (purity ~ 99.9% for both) for different milling durations (~ 20h to 170h). Alloy formation and defect microstructure have been studied by X-ray diffraction (XRD), differential scanning calorimetry (DSC), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Surprisingly, even after 170h milling of Cu-3wt%Ru powder, XRD results show presence of prominent diffraction peaks from both Cu and Ru phases indicating no significant solid solubility between Cu and Ru. However, notable changes in the lattice parameters of Cu and Ru have been observed along with significant lattice parameter anisotropy for Cu phase. Furthermore, large broadening of Cu and Ru peaks are observed and detailed XRD line broadening study for Cu phase indicates generation of dislocations and planar faults in the Cu matrix along with severe reduction in the average crystallite size of Cu. Currently, formation of such nanostructure, defects creation and segregation of Ru in Cu grain boundaries are being investigated in detail by SEM and TEM along with spectroscopic techniques. Additionally, DSC results of Cu-3wt%Ru powder ball milled for various durations are being studied in order to understand the underlying thermodynamics of alloy formation and micro/nanostructural changes in the Cu-Ru system.

**Reference:** C. Suryanarayana, Mechanical alloying: A critical review, MATER. RES. LETT, 10 (2022) 619 - 647; https://doi.org/10.1080/21663831.2022.2075243

**Keywords:** Mechanical Alloying, Cu-Ru, Immiscible, ball milling, XRD, DSC, SEM, TEM

# Influence of Nitrogen on the printability & microstructure of CoCrMoFe alloy produced by Laser- Powder bed fusion(L-PBF)

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## Abstract

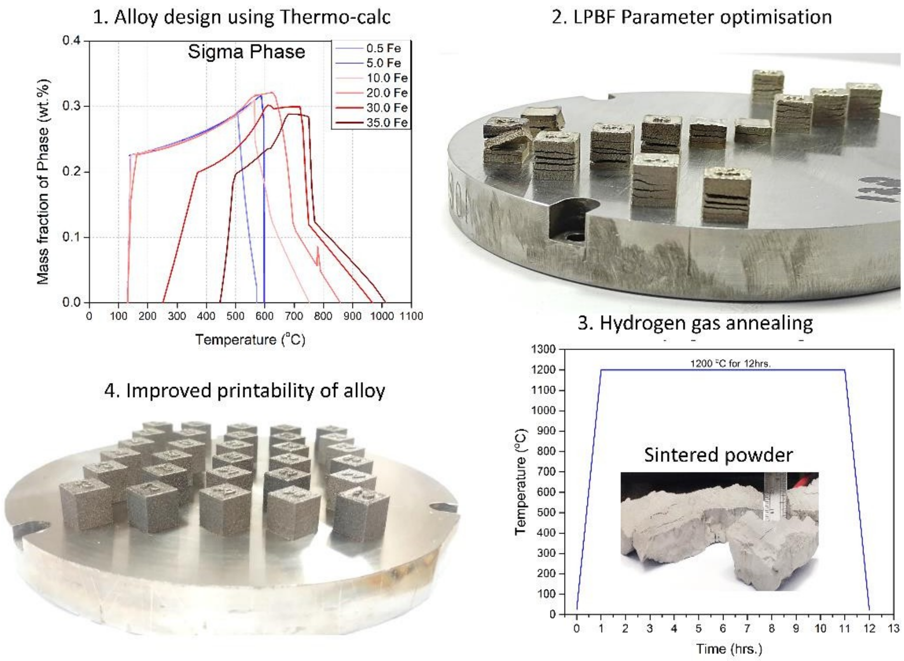
A careful selection of materials with desirable biocompatible qualities is necessary for the design of prostheses for maxillo-facial restoration of patients having a large wound from trauma. Medical grade ASTM F75 Co- Cr-Mo alloys are the hardest known biocompatible materials commonly used in medical implants, partial denture frameworks, and crown & bridge substructure restorations in dentistry.

Co-Cr-Mo alloys are preferred for dental applications owing to their excellent tribological and mechanical properties. However, the toxicity and the cost due to the high concentration of cobalt is a major concern. In this study, an attempt is made to develop a novel, low-cost CoCrMoFe alloy composition by the reduction in the Cobalt concentration by the addition of Iron (Fe) that can be printed using a laser powder bed fusion-based additive manufacturing process. The designed alloy is envisaged to possess reduced toxicity potential and excellent mechanical, biocorrosion and tribological properties compared to commercially used expensive CoCrMo alloys.

The alloy composition is developed using the Calphad approach, and a grid search method is employed to develop a robust set of process parameters for producing parts with minimal defects. Poor printability of CoCrMoFe alloy has posed a difficult challenge to achieve a crack-free specimen. In order to improve the printability, the infusion of Nitrogen gas into the powder was achieved by Hydrogen gas annealing at 1200$^{o}$C for 10 hrs. Nitrogen being a strong FCC stabilizer helps in suppressing BCC phase formation and As-printed specimen displays single phase FCC crystal structure owing to the rapid solidification phenomenon experienced in L-PBF.

This novel method of improving the printability of complex alloy compositions by the virtue of nitrogen infusion has shown its potential of mitigating solidification cracking in LPBF process.

Keywords: Hydrogen gas annealing, Laser-Powder bed fusion, Biomaterials, Co-Cr-Mo alloy


1. Alloy design using Thermo-calc
Sigma Phase
0.5 Fe
5.0 Fe
10.0 Fe
20.0 Fe
30.0 Fe
35.0 Fe
Mass fraction of Phase (wt.%)
Temperature (°C)
2. LPBF Parameter optimisation
3. Hydrogen gas annealing
1200 °C for 12hrs.
Sintered powder
Temperature (°C)
Time (hrs.)
4. Improved printability of alloy

# Characterization of Additively Manufactured Cu-1Cr-0.1Zr for Liquid Rocket Engines

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## Abstract

Cu-1Cr-0.1Zr alloy possesses balanced thermal conductivity and strength at elevated temperatures for rocketry. Through additive manufacturing(AM), flexibility in design coupled with manufacturing intricate parts with reduced number of joints results in enhanced buy-to- fly ratio. Present work provides detailed characterization of Cu-1Cr-0.1Zr copper alloy manufactured through LPBF (Laser Powder Bed Fusion) for liquid rocket engines.
Test coupons of Cu-1Cr-0.1Zr were manufactured with optimized LPBF process parameters. Chemical and gas analysis were performed on specimens. Solution treatments on as-printed coupons were performed between 900-1030°C to ensure complete dissolution of the melt pools and re-crystallization of microstructure, where 980°C solution treatment was identified to be the most suitable. Differential Scanning Calorimetry analysis was carried out to identify the ageing temperature range and experiments were performed between 400 – 600°C with different holding time periods. Tensile properties were evaluated for temperatures ranging from RT to 650°C in both solution treated and solution treated + aged condition. Microstructural analysis provided insights into the grain structure and defects like voids and lack of fusion, while fractography offered valuable data on fracture behaviour. Thermal conductivity, coefficient of thermal expansion, and specific heat capacity were measured upto 800°C for comparison with other copper alloys used in liquid rocket engines. Further, studies on the effect of simulated brazing and post brazing heat treatment on AM Cu-1Cr-0.1Zr was carried out. These findings contribute to the understanding of the usability of Cu-1Cr-0.1Zr in the thrust chambers of liquid rocket engines operating at high temperatures.

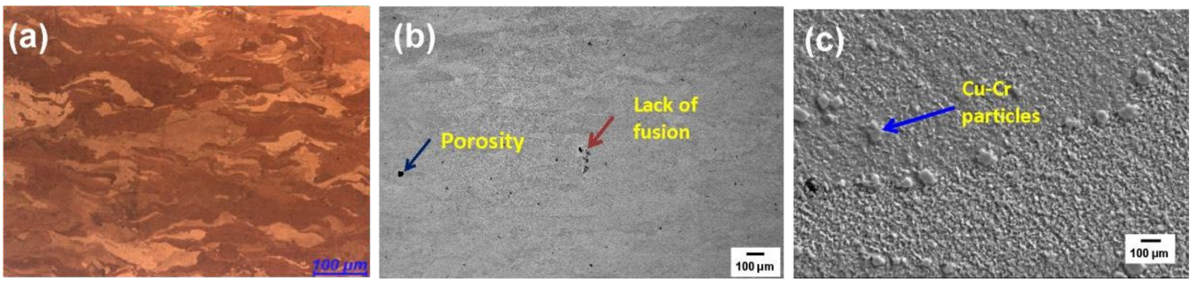


Fig. 1: a) Optical micrograph, b) SEM micrograph of Cu-1Cr-0.1Zr, c) SEM micrograph showing Cu-Cr particles

**Key words**: Cu-1Cr-0.1Zr, Laser Powder Bed Fusion, ageing, brazing, physical properties

# Stress relaxation behaviour of laser powder bed fusion additive manufactured AlSi10Mg at elevated temperatures (30 – 250°C)

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## Abstract

AlSi10Mg is a widely used cast alloy in the automotive and aerospace sectors for its high specific strength and stable microstructure up to 225°C. The hard Si phase dispersed in a soft aluminium matrix bears the load resembling that of a metal matrix composite. Recently, this alloy has been processed extensively via laser powder bed fusion additive manufacturing technique due to its excellent weldability. The high cooling rates involved in the LPBF-AM result in a fine interconnected eutectic that provides superior mechanical properties compared to conventional cast counterparts. The time-dependent deformation behaviour of LPBF AlSi10Mg under different prestress (repeated stress relaxation) and restrain (single stress relaxation) conditions at operating temperatures (i.e., 100 – 250 °C) has not been understood well. To investigate this, as-printed LPBF AlSi10Mg specimens were subjected to monotonic and repeated stress relaxation tests in tensile mode, with an initial strain rate of $10^{-4}$ $s^{-1}$, over a temperature range of 30 – 250 °C. The activation energy of the as-printed LPBF AlSi10Mg was found to be influenced by both the eutectic network and temperature. The Si phase contributes to back stress, increasing resistance to deformation, but at 250 °C, this resistance diminishes due to changes in the microstructure. Further, the Caillard and Martin logarithmic model was applied to understand the relaxation behaviour, and the experimental results were consistent with the model's predictions across the tested range.

# Magnesium Based Composites Catalysed by Amorphous Ti-V-Ni Alloys For Hydrogen Storage

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## Abstract

Magnesium based materials have been sought after for their low cost and high hydrogen absorption capacity (>6 wt.%).However, their high absorption temperature (>350˚C) and slow kinetics has restricted their use for commercial applications such as on-board and stationary. In the current, work it is proposed to utilize T-V-Ni amorphous alloys as a catalyst for hydrogen storage in magnesium nanocomposites. Earlier studies have indicated that Mg-based composites catalyzed with Ti-Zr-Cu-Ni amorphous catalyst have exhibited promising results [I]. Replacing Zr by V leads to increase in the hydrogen absorption capacity of the alloy as V is lighter than Zr and makes the alloy lightweight. Two compositions have been evaluated for the role of catalyst: $Ti_{41.5}V_{41.5}Ni_{17}$ (AM1) and $Ti_{61}V_{22}Ni_{17}$ (AM2). Earlier reports have indicated hydrogen absorption capacity of 1.2 wt.% at 573 K and 20 bar for these alloys [II]. Mg-5 wt.% AM1 and Mg-5wt.%AM2 composites have been synthesized by mechanical alloying and tested for hydrogen sorption properties in standard Sieverts apparatus. It is expected that the composite shows hydrogen storage capacity of 6 wt.% at 200˚C under 5 bar pressure. Kinetics of the hydrogen absorption and desorption is also expected to increase with 5.5 wt.% absorption in 10 min at 250˚C. Multiple pathways provided by the amorphous alloy catalysts coupled with the nanograin formation and other defects introduced during ball milling lead to enhanced storage capacity.

Keywords: Hydrogen Storage, Magnesium, Ball-milling, Amorphous alloys

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# Yttria stabilized cubic zirconia (YCZ)– Multi walled Carbon nanotube (MWCNT) composites with controlled grain sizes

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## Abstract

Yttria-stabilized cubic zirconia (YCZ) is a well-known ceramic used in various high-performance applications. It is known for a low thermal conductivity (especially in the porous form), high oxygen ion conductivity and good biocompatibility and chemical inertness. Some applications include thermal barrier coating in gas turbine and Jet engine turbine blades, as an electrolyte in solid oxide fuel cells, dental applications and hip prosthetics and as an oxygen sensor. Multi-walled carbon nanotubes (MWCNTs) which consist of multiple layers of rolled graphene sheets. Addition of MWCNTs to 8mol% Yttria stabilized cubic zirconia(8YCZ) leads to composite materials with enhanced mechanical strength, toughness, fracture resistance with improved the electrical and thermal conductivity [1].
8YCZ is known for a high grain growth rate [2] leading to the reduction in some of it's properties. Addition of Multi-walled carbon nanotubes (MWCNTs) also inhibits grain growth by acting as points to grain boundaries. Finer grain size, improves mechanical properties including hardness and toughness. This study aims on the preparation of 8YCZ with controlled and consistent grain size.
Distilled water with the pH maintained at 12 was taken as the medium. Following the slow addition of 8YCZ powder with constant magnetic stirring, a 0.5 vol fraction of -COOH functionalized MWCNTs were dispersed. Resulting powder mixture was dried taking care to avoid any separation of constituents, followed by spark plasma sintering (SPS). Resulting samples were analyzed for density, microstructure, hardness and thermal stability using SEM, XRD and annealing treatments. The method opens up a possibility of forming MWCNT- 8YCZ composites with enhance properties in biological applications. Further, formation of 8YCZ with pores in multiple length scales leading to a higher fracture toughness and potential applications in thermal barrier coatings.

**Key words**:- Spark plasma sintering (SPS), Yttria stabilized cubic zirconia , MWCNT, Grain growth, Thermal stability, Mechanical Properties.

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# "Enhancing Operational Efficiency and Productivity in Reheating Furnace Roof Burner Design through Strategic Nozzle Arrangement"

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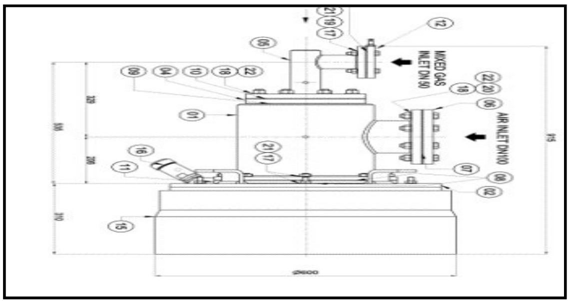
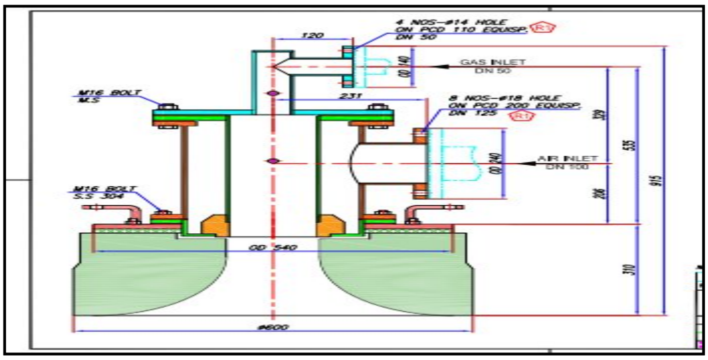
## Abstract

In the earlier design of the Reheating furnace roof burner (Radial burner), the operational efficiency and productivity were significantly compromised due to frequent nozzle clogging, resulting in uneven billet temperature distribution. This issue not only led to suboptimal heating outcomes but also necessitated prolonged cleaning procedures, causing substantial downtime and reduced throughput in the production process. Recognizing these challenges, a comprehensive redesign of the burner arrangement was undertaken to address these critical issues and enhance overall furnace performance. The primary concern with the previous design stemmed from the propensity of gas nozzles to clog frequently, disrupting the uniformity of heat distribution across the billet. This inconsistency not only affected the quality of the reheated billets but also imposed considerable operational inefficiencies. Moreover, the extensive time required for cleaning and maintenance of the clogged nozzles further exacerbated the problem, leading to reduced productivity during these downtime periods. In response to these challenges, the new burner arrangement process was meticulously developed to optimize several key aspects of the furnace's operation. Central to this redesign effort was the strategic placement and spacing of the gas nozzles, aimed at improving the flow dynamics and minimizing the likelihood of nozzle clogging



**OLD BURNER**




**NEW BURNER**

**Key words** : Nozzle clogging, Billet temperature distribution, Furnace performance

# Effect of Fin Geometry on Thermal Performance of Al-Si-MWCNT composite based CPU Heat Sink

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## Abstract

Aluminium Heat sinks are essential components in electronic cooling systems of central processing units (CPUs) of high performance server computers, designed to facilitate heat dissipation from the electronic circuit to the surrounding environment, thereby preventing overheating. The efficiency of a heat sink is significantly influenced by its fin geometry, which includes parameters such as fin type, shape, size, spacing, and orientation. Different types of fins, including straight, pin, and wavy fins, offering varying performance and efficiency in heat transfer applications are being used in CPU heat sinks. Pin fins are particularly advantageous due to their increased surface area and ability to enhance turbulence in the flow, leading to improved heat transfer efficiency compared to straight fins and offering lower pressure drops than wavy fins.

This study focuses on analysing various geometrical parameters of pin fins, such as shape, size, and arrangement, to determine their influence on thermal performance of the CPU heat sink. A comprehensive analysis is conducted to evaluate the thermal resistance, heat transfer coefficient, and overall thermal performance of heat sinks with different pin fin configurations. The study explored geometries such as cylindrical, elliptical, rectangular, and diamond pin fins. Additionally, the effects of varying the pin fin height, diameter, fin density, and orientation are examined.

The results indicate that the geometry of pin fins significantly impacts the thermal performance of CPU heat sinks. Cylindrical pin fins show moderate thermal resistance and heat transfer rates. Whereas rectangular and diamond pin fins offer increased surface area for heat dissipation but introduces higher pressure drops, affecting overall performance. Elliptical pin fins exhibit improved thermal performance due to their streamlined shape, enhancing fluid flow and heat transfer compared to cylindrical, rectangular, and diamond pin fins. Fin height with an appropriate aspect ratio (height to diameter) is identified as a critical parameter, with taller fins generally improving heat transfer but also increasing pressure drop. Furthermore, fin density is another critical parameter that greatly influences heat transfer efficiency and fluid flow rate. Optimizing these parameters has been identified as critical and highly recommended for improving heat sink thermal performance. As an outcome of the study, elliptical pin fin geometry based CPU heat sink for 14$^{th}$ generation high performance I7 processor is identified to be capable of dissipating the highest heat flux while maintaining the nominal pressure drop among the various heat sink geometries studied here. Further improvement in heat sink performance is recorded while in-house developed Al-Si-MWCNT composite is considered as a workhorse material for heat sink development.

**Keywords:** Pin fin heat sink, Heat transfer, CPU, Thermal resistance, Geometry, Fin density

# Improvement in EAF Roof Delta Refractory Life

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## Abstract

In Electric Arc Furnace (EAF) operations, the roof's central component, known as the delta, is a critical refractory part exposed to significant thermal, chemical, and mechanical stresses. The delta's bottom surface, in particular, faces direct exposure to high temperatures and slag splashes, leading to frequent unplanned stoppages due to refractory failures, which result in production losses. Traditionally, deltas made from 82% alumina constables have a lifespan of approximately 150 heats. This study aimed to enhance the delta's lifespan through changes in refractory composition and design. By utilizing a refractory material composed of 92% alumina and 5% chrome (sol-gel) and redesigning the delta from a flat bottom to an arch shape, the impact on the delta was minimized, reducing sticking and increasing its average lifespan to 400 heats (increased around 2.5 times). These improvements significantly reduce production downtime and improve overall EAF operation efficiency.

**Keywords**: Electric Arc Furnace (EAF), alumina, chrome, sol-gel, thermal stress, refractory composition, refractory design, spalling resistance.

# Recent Advancements in Materials used for Automotive Industry

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## Abstract

The automotive industry uses a wide variety of materials to build cars, comprising of steel, aluminum, iron, rubber, petroleum products, copper etc. To meet the present day demands these materials have evolved over a period of time. These have become more safe, sophisticated and has aesthetic finish. While manufacturing a car it is essential to minimize its mass. It helps in maintaining the basic characteristic of an automobile which is, using less powerful engines so that it consumes less fuel and thereby emit less harmful gases into the environment. When we lower the weight of a car it automatically reduces the load on the suspension and further increases its lifespan. This paper discusses the recent advancement in the types of material that can be used as effective materials for a light weight car without compromising its strength and speed.

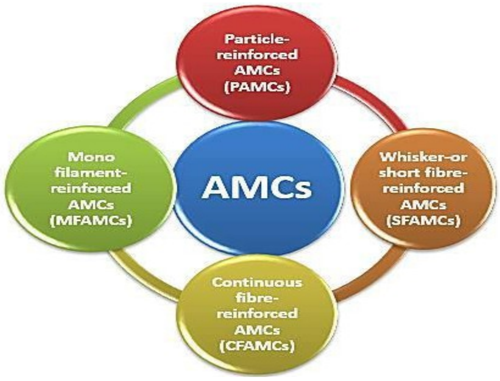


Fig. 1: Aluminum Metal Composites.

**Keywords:** steel, aluminum alloys, metal matrix composites, polymers, plastics and composite materials.

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Sharon, F. (2014). Additive Manufacturing Technology: Potential Implications for U.S. Manufacturing Competitiveness. Journal of International Commerce and Economics. Retrieved fr

# Development of aluminium metal matrix composites using microwave casting: A review

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## Abstract

Aluminium metal matrix composites (AMMCs) have drawn much interest, and they are now extensively used in various industries, including aerospace and automotive, because of their superior qualities over their parent alloy. Developing lightweight, high-strength, high-corrosion, and wear-resistant AMMCs has led to novel fabrication and characterization techniques. This review inspects a novel approach to microwave casting and its impact on the mechanical and microstructural properties. The research carried out will provide insight into a novel fabrication technique for achieving improved mechanical properties, including density, strength, and hardness, by examining the interaction between the reinforcement and matrix. A Detailed review of microwave casting and the interaction of microwave with the matrix and reinforcement to obtain improved mechanical properties, such as strength, hardness, density, etc., is presented in this work. The matrix reinforcement interactions examined using a scanning electron microscope (SEM), electron backscattered diffraction (EBSD), transmission electron microscope (TEM), optical microscope (OP), etc., were illustrated. This article discusses the details of the matrix and reinforcement interactions with microstructural characterization, including bonding of the reinforcement with the matrix, wettability, dislocation interactions, particle-stimulated nucleation, etc. The procedure of microwave casting and all the factors influencing the mechanical and microstructural properties when developing AMMCs are thoroughly examined in this article. The review will assist researchers in identifying the most effective matrix-reinforcement combination and process parameter optimization to enhance AMMCs for specific uses. Additionally, future difficulties with processing AMMCs were stated.

**Keywords:** Aluminium metal matrix composites, Reinforcement, Microwave casting, Microstructure, Mechanical Properties.

# Tribometry analysis of Ni-P-Graphene oxide/Carbon nano tubes composite coatings prepared by electroless deposition process

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## ABSTRACT

Ni-P coatings with or without graphene oxide (GO) and carbon nano tubes (CNT) were deposited over mild steel substrate by electroless deposition process. The morphology, hardness and wear behavior are co-related to understand the response of nanoparticles (GO and CNT) addition into the Ni-P coatings. With nanoparticle addition morphology is found to be smooth and compacted. The hardness of CNT incorporated Ni-P coatings was found higher than that of GO incorporated Ni-P coatings which shows that the hardness is highly susceptible to the size and the dispersion of nanoparticles. The nanosized CNT led to even dispersion and the particle size of evenly dispersed CNT was found 327.01 nm whereas it was found 538.71 nm for GO, which eventually contributing for excellent wear properties because even dispersion of nanoparticles promotes the finer and smoother surface morphology. Further, the wear depth with time is found to be lower for Ni-P-CNT composite coatings due to tubular structure of CNT, which favors the continuous reinforcement network into the Ni-P matrix and strengthen it. The coefficient of friction is also lower for CNT incorporated Ni-P coatings because of the higher load transfer capability and resistance to wear, than GO containing Ni-P coating. Moreover, the wear rate is calculated from the mass loss and found to be minimum for CNT incorporated Ni-P coatings.

**Keywords:** Graphene oxide, Carbon nano tubes, electroless process, wear resistance, hardness.

# Synthesis, characterization of Mg-Al-O based Spinel by Mechanochemical process

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**Abstract**

Spinel based materials are found to have application as refractory, catalyst substrate, photocatalytic applications, semiconductors and others. Variable process routes like solid-state reaction, sol-gel, co-ppt, hydrothermal and others are carried to synthesis the material. It is generally represented as AB2O4 where A stands for bivalent metal at tetrahedral site, and B stands for trivalent metal at octahedral sites. In the present research, mechanochemical method is adopted to synthesis Spinel based on MgAl2O4. AR grade of precursors like MgO, Alumina is taken for the synthesis after proper weighing at high precision balance. Ball:sample ratio is maintained at 10:1 throughout the milling operation using WC balls and toluene as medium for wet operation. Milling duration is carried for 10, 15 and 20 hours respectively. Thermal analyses of the milled sample are done to identify the crystallization zone for undergoing annealing to develop the required phase. Depending on thermal analyses, 2 stage annealing is carried leading to phase Spinel. Crystallite size is estimated using Scherrer's formula and noted to be about 25.64nm 28nm 25.31nm respectively after annealing at 1100°C, 1150°C and 1200°C for 4 hours duration. Dense agglomeration is noted with polygonal particulates shapes with some location resembles with fish scale structure. FTIR analyses of all the samples are carried and it exhibits M-O coordinations of the spinel Magnesium aluminate. M-O coordination of Al-O, Mg-O is obtained from the analyses supporting the XRD phase development. Raman spectra analysis is also carried to have justified information in depths of the bond formations.

key words: Spinel, Phase, Thermal Analysis, Morphology, Bonding analysis

# Sustainable Ceramic Material from Leached Residue after Recovery of Potash from Manganese Mining Overburden Waste

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## Abstract

The development of ceramic materials from mine overburden plays a crucial role in addressing the increasing waste generation and depletion of natural resources. Conversion of alumino-silicate rejects into first-rate ceramics largely preserve the clay minerals for future usage. Further, it reduces the overall cost of production and supports ecological situation by decreasing the dilemmas associated with waste storage. Accordingly, a sustainable process is developed from manganese mining overburden waste, which involve two process steps, where the first step focus on the recovery of potash for its use as fertilizer by hydro-chemical treatment of manganese mining overburden and the second step converts the leftover residue as refractory through heat treatment process. manganese mining overburden was collected from Dongri Buzurg Mine, Bhandara, Maharashtra and subjected to various characterization techniques to determine its chemical (XRF) and mineralogical (XRD) composition. The X-Ray Diffraction analysis revealed that the major mineral phases in the manganese overburden material include quartz, muscovite, microcline, and chamosite. The overburden material comprises 71.54% $SiO_2$, 12.66% $Al_2O_3$, 5.05% $K_2O$, 4.11% $Fe_2O_3$, 2.09% $Na_2O$, 1.63% MgO, and 1.10% CaO as its major constituents. The change in mineral phases in the leached residue has been characterized by X-ray diffraction and scanning electron microscope with energy dispersive X-ray spectroscopy, which shows the presence of quartz, albite, calcite magnesian, and hematite. The leached residue powders were sintered at various temperature-time combinations, exhibiting a porous microstructure at 900°C and a dense microstructure at 1300°C. The porosity/density in the samples can be controlled by the sintering parameters to obtain either dense materials for structural application or porous materials for refractory applications. The developed ceramic materials were subjected to various testing and characterization procedures to evaluate their properties, including strength, thermal stability, and resistance to aggressive environments.

Keywords: Mine Overburden; Leached Residue; Sintering; Ceramic materials; Refractory materials

# Development of Electron beam physical vapor deposition of Fe2AlB2 alloy

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## Abstract

Materials like MAB (ternary transition metal boride) phase alloys are formed by interleaving layer(s) of III-A or VI-A element between metal borides (MB) layers. They are considered as the subclass or derivative of MAX phase alloys as they share similar interesting properties. They have their own unique crystal structure and bonding characteristics which make them share the properties of both metal and ceramic. They exhibit good thermal stability, electrical and thermal conductivity, oxidation resistance, hardness and damage tolerance. Depending their compositions and hybrid properties, they serve as a candidate material for applications leveraging in aerospace and defence industries, electronic devices and thermal management sectors. They are also used as coating material for performance enhancement in various industries. Though MAX phase alloys can be coated using variant coating processes like plasma spraying, cold spraying, magnetron sputtering, high velocity oxy fuel and high velocity air fuel coating processes, they have not been explored widely in terms of MAB phase alloys. Coating of MAB phase alloys with tailored compositions and properties offer a challenging direction in the alloy development. Electron beam physical vapor deposition is one of the prominent coating techniques that has been constantly under exploration for its usage with advanced materials and high-performance coating applications. Also, electron beam physical vapor deposition of $Fe_2AlB_2$ is a novel coating approach which have not been reported so far. $Fe_2AlB_2$ alloys serve as a potential coating material owing to its mechanical properties, oxidation resistance, thermal fatigue, damage tolerance, wear resistance and radiation resistance. $Fe_2AlB_2$ alloy is suitable for different applications like heat exchangers, inserts, bushings, electrical contacts, heat sinks, semiconductors and light weight aerospace and structural components.

In the present investigation, physical vapor deposition is developed by evaporating $Fe_2AlB_2$ target using electron beam on to a AA2024 substrate in a vacuum environment with the chamber pressure of $8 \times 10^{-6}$ *torr*. $Fe_2AlB_2$ target was produced by synthesizing the powders via powder metallurgical route which involves mechanical milling followed by pressure-less sintering and cold pressing them in to pellets. The Fe/Al/B elemental powders are pulverised in a planetary ball mill and sintered in an argon atmospheric tubular furnace. The synthesis is carried out with the molar ratio of 2 (Fe) :1 (Al) :2 (B), milling time of 5 h and sintering temperature of 1150° C with 1 h holding. The as-synthesized powders are characterized using x-ray diffractogram and Raman spectroscopy. The volume fraction of phases is computed from X-pert high score software. The coating substrate is prepared by grit blasting to enhance the adhesion. Substrate is maintained at 300 °C during deposition. Coating thickness of around 10 μm is achieved. The $Fe_2AlB_2$ coating is analysed using X-ray diffractogram and nanoindentation. Thus, the electron beam physical vapor deposition of $Fe_2AlB_2$ phase alloy on aluminium alloy substrate is explored. Improved coating performances can be envisioned through coating parameter optimization.

**Keywords**: MAB phase alloys, $Fe_2AlB_2$ phase alloy, Physical vapor deposition,

Nanoindetaion

# Exploration of cost-effective methods for recycling of end-of-life and waste FRP composite products.

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## Abstract

With the skyrocketing use of fiber reinforced polymer (FRP) composites in various sectors of global economy, FRP composites are playing a pivotal role in our modern world, offering a diverse range of applications and thereby have significantly raised the awareness of their waste disposal methods. Significant amount of composite wastes containing valuable fibers accumulate from various applications every year. These composite wastes must be recycled cost-effectively without causing negative environmental impacts. The recyclability is supposed to be supported by subsequent reuse and reincorporation to create a successful closed-loop recycling process. The energy intensiveness of the manufacturing of the fibers specially carbon fibers is nearly 14 times higher than that of steel. Addressing the recycling issues, various techniques of recycling such as mechanical recycling, chemical recycling, pyrolysis, fluidized bed technique etc. have been developed. Advanced recycling techniques such as electrochemical recycling, high voltage fragmentation, microwave assisted chemical degradation etc. have emerged in recent times. The chemical recycling and its hybrid versions have proved very effective in terms of retaining of the fiber properties post-recycling fabrication and subsequent reuse. The post-recycling treatments such as the surface modification of reclaimed fibers are now being incorporated for enhancing the properties of the composites fabricated from such fibers. This area i.e. reclaiming fibers from waste composites and subsequent use of reclaimed fibers remains largely unexplored by both industries and academics in terms of commercialization. The reclaimed fibers do present a wide arena of research for fabrication of surface/interface modified and mechanically tunable composites with widespread possibilities of applications in fields of construction, mobile structures, crash/safety barriers etc. The microwave assisted chemical degradation technique has gained a good momentum in the past decade. The matrix degradation is accelerated by the energizing microwaves resulting in matrix degradation within minutes. The microwave irradiation cycles have been optimized for the chemical solvents used. Primarily peroxy acids have been found to be sustainable in terms of environmental concerns. Almost complete degradation of matrices has been observed in the experiments.

Keywords: FRP composites waste, recycling techniques

# Isolating the Role of Thermal and Athermal Effects on Densification during Flash Sintering Using Novel Experiments and Finite Element Modelling

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## Abstract

The contributions of Joule heating and thermal runaway to the ultra-fast densification achieved through flash sintering remain a subject of ongoing investigation. In this work, we have attempted to settle the debate using a combined experimental and modelling approach. We have flashed a hollow cylinder inside which a 3YSZ sample is kept such that no current passes through it which we have dubbed as indirect flash sintering. We have also conducted flash sintering experiments where the same 3YSZ specimen is flash sintered by passing current through a sample dubbed as direct flash sintering. Additionally, FEM simulations are performed to estimate the temperature/ heating rate inside the 3YSZ sample during the flash sintering. The indirect flash-sintered sample experienced a similar temperature as a direct flash-sintered sample but showed significantly lower densification. This research indicates that Joule heating and thermal runaway are unlikely to account for the ultra-fast densification seen in flash sintering.

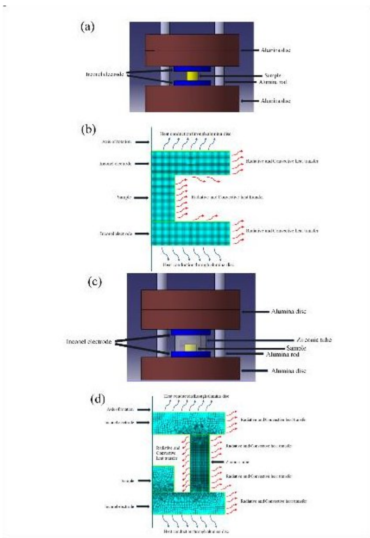


**Figure 1.** (a) Schematic diagram of the direct flash sintering setup, (b) shows the corresponding axis-symmetric FEM mesh for the modelling of the direct flash sintering experiment, (c) schematic diagram of indirect flash sintering setup and (d) the corresponding axis-symmetric FEM mesh for the modelling of the indirect flash sintering experiment.

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# Low Cement Castable Installation by Gunning with loss <5%

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## Abstract

Monolithic or unshaped refractories have several advantages from the point of view of application and performances over the shaped refractories.

- A variety of installation techniques have been developed for different application areas of refractory castables, evolving from traditional casting using moulds, to time saving options such as conventional dry gunning and shotcreting.
- However, dry-gunning is a well-proven installation technique for smaller repairs and is often a cost-saving procedure.
- In dry gunning, good practices (such as selection of an appropriate pump, nozzle, and experienced installation team) along with proper dry gunning formulations are of the utmost importance for achieving the targeted properties specially Gunning loss.
- The target was to reduce gunning loss below 5% without compromising on end properties of gunned castable.

14TH

Fig. 1: (Virtually very little gunning loss)

**Key words** : Low Porosity Low Rebound Gunning Material

# Structural aspects of radiation damage in Indian-origin natural zircon

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**Abstract**

In addition to the currently employed borosilicate glass technology for nuclear waste management, other materials like monazite and zircon are also being explored for immobilizing radioactive waste elements. These materials can be naturally occurring or synthetically produced in laboratories. Natural materials, in particular, are ideal for studying the long-term effects of radiation damage, as they inherently contain various elements, including radioactive ones, in both trace and substantial amounts. The presence of these elements can lead to crystal structure deformations or radiation damage in the host material, which becomes significant over extended periods of geological storage.

Although the possible use of zircon for nuclear waste management applications have been suggested in literature, there have been very few studies on Indian zircon. Application of zircon in nuclear waste management requires a thorough understanding of the effects of doping and radiation damage on the physical and chemical properties of the host material. With this focus, we conducted X-ray diffraction (XRD) and X-ray absorption spectroscopy to investigate the effect of radiation damage of the structural properties of Indian natural zircon recovered from the southern Indian site. The composition of the sample was analyzed using Total Reflection X-ray Fluorescence (TXRF). From XRD data analysis, it was found that the degree of crystallinity was approximately 63.8%, indicating the simultaneous presence of both crystalline and disordered regions. These changes are likely due to the presence of various radioactive and non-radioactive elements. The X-ray absorption near edge structure (XANES) showed slight modifications in the white line feature and some disorder compared to the synthetic version. A reduced coordination number observed from Extended X-ray Absorption Fine Structure (EXAFS) suggested the presence of disorder in the local structure. This study is valuable for understanding the structural stability of zircon, particularly in the context of nuclear waste management applications.

Key words : Nuclear waste, Zircon, XRD, EXAFS

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# An Investigation of High Temperature Wear Properties of Additively Manufactured TiC Reinforced Stellite 6 Metal Matrix Composite Coatings

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**Abstract**

Nowadays, additive manufacturing techniques are widely used as advanced deposition methods to process a wide range of coating materials, including metals, ceramics, superalloys, and composites. They offer unique advantages such as low heat input, high precision with a precise heat source, and design flexibility to manufacture intricate shapes compared to conventional deposition techniques. Stellite 6, a superalloy composed of cobalt, chromium, tungsten, and carbon (Co-Cr-W-C), is often utilized as a hardfacing material due to its exceptional wear resistance and its ability to withstand corrosion and oxidation at temperatures up to 600°C.

In the present study, an effort has been made to elucidate the high temperature sliding wear behavior of Stellite 6 reinforcing with TiC particles with different proportions (10, 20, 30 vol.%). To examine the effect of temperature and TiC content on high-temperature wear properties of Stellite 6, a reciprocating sliding wear test has been conducted at 150 °C, 300 °C, and 450 °C under unlubricated conditions. Further, worn surfaces were investigated under a Scanning Electron Microscope (SEM), Raman spectroscope, and 3D optical profilometer. It has been observed that the formation of severe oxides occurred at elevated temperatures, contributing to changes in wearing conditions at mating interfaces. A correlation between the role of composite oxides as tribo-layer and their tendency of formation with TiC additions has been established to justify the trends in wear volume loss of the composite coatings. Stellite 6 with 30 vol.% TiC exhibited the best high-temperature wear properties among the fabricated MMC coatings up to 450 °C.

**Keywords:** Additive Manufacturing; High temperature wear; Coatings, MMCs; Stellite 6.

# Medium and high entropy rare-earth oxides for photocatalytic hydrogen production and dye degradation applications

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## Abstract

Ceria is widely used for catalytic applications such as automotive exhausts, thermo-chemical hydrogen production and $CO_2$ splitting, respectively, due to its attractive redox properties. Significant efforts are being carried out to further enhance the catalytic performance through chemical doping. Very recently, rare-earth based medium and high entropy oxides were developed for photo-catalytic hydrogen production applications. These materials showed superior catalytic properties in contrast to pure ceria, due to generation of large amount of oxygen vacancies in the lattice. However, large-scale synthesis of these exotic materials is always a challenge due to processing complexities and expensive raw materials.

In this work, ceria-based medium and high entropy rare earth oxides (HE-REO) were synthesized using solid-state method, using commercially available, less expensive carbonate precursors. The as-synthesized materials are found to be in single-phase, which is evident from the X-ray diffractograms of calcined samples. The powder morphology and the chemical composition were studied using a field emission scanning electron microscope (FESEM) and energy dispersive spectroscopy. The atomic arrangements, band-gap and elemental analysis were examined using high-resolution transmission electron microscopy (HRTEM) and electron energy loss spectroscopy (EELS), respectively. The catalytic performance of as-synthesized HE-REO materials was correlated with the oxygen vacancies, through Raman spectroscopic analysis and further substantiated with HRTEM images. The photo dye-degradation activity of the RE-HEOs is active in the visible range, which is in concomitant with UV-vis band-gap calculations. BET studies were carried out to evaluate the surface area of as-synthesized samples. Electron paramagnetic resonance (EPR) studies were conducted on as-synthesized samples which confirmed the presence of un-paired electrons. Finally, the as-synthesized HE-REO was then examined for hydrogen generation through photo-catalytic water splitting reaction.

Key words: Rare-earth oxides, dye degradation, hydrogen production.

# Single-step synthesis of antimony doped tin oxide nanocrystalline powders using flame spray pyrolysis

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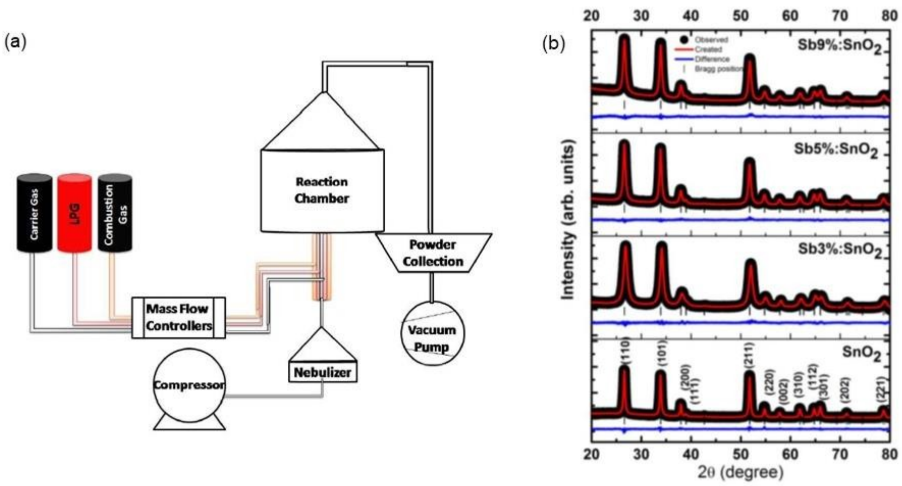
**Abstract**

Tin Oxide ($SnO_2$) is a transparent conducting oxide with a wide band gap and n-type semiconducting properties, offering 90% transparency in the visible spectrum and low resistivity around $10^{-3}$ Ω·cm. In this study, antimony-doped tin oxide (ATO) nanoparticles were synthesized with antimony concentrations ranging from 0 to 5 mole % using the flame spray pyrolysis method shown in Figure (a). The Rietveld refinement of the XRD patterns (Figure (b)) revealed that the particles are nanocrystalline and phase-pure, with crystallite sizes around 15 nm. The bond lengths in the crystal structure were determined to be 2.052 Å for Sn–O1 and 2.057 Å for Sn–O2. HRTEM analysis confirmed that the particle sizes range from 5 nm to 15 nm. DRS spectra indicated that the as-synthesized powders are transparent in the visible region, with the direct bandgap energy, evaluated from the Tauc plot, found to be 3.95 eV. A variation in the bandgap was observed with changes in antimony doping. The benefits of the flame spray pyrolysis method over traditional synthesis techniques for producing fluorine-doped tin oxide (FTO) powders were also discussed.




(a) Flame Spray Pyrolysis schematic (b) XRD patterns of Antimony doped tin oxide powders after Rietveld analysis

Keywords: Transparent conducting oxides, $SnO_2$ ceramics, Flame spray pyrolysis, Nanocrystalline powders, Rietveld refinement

# (CoCUuMgNiZn)O based high entropy oxide powders synthesis by single-step solution combustion synthesis

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**Abstract**

High-entropy oxide (HEO) ceramics have garnered significant interest in the scientific community due to their distinctive properties, characterized by an entropy in the system exceeding 1.5R. One well-established HEO composition is (CoCuMgNiZn)O, first reported by Rost et al. In this study, we investigated the synthesis and characterization of CoCuMgNiZn and other elements using a single-step solution combustion synthesis method. X-ray diffraction (XRD) analysis revealed that the material is predominantly single-phase, with only a few minor peaks present, each with a volume fraction of less than 5%. Scanning electron microscopy (SEM) showed that the as-synthesized powder has a porous morphology, while transmission electron microscopy (TEM) revealed that the individual particles are ultrafine, ranging from 50 nm to 100 nm. The potential applications of these particles as solid-state electrolytes are also discussed.

Keywords: High entropy oxides, Multi-component oxides, Solution combustion synthesis, Porous ceramics, Nanoceramics

# Experiences with Side firing of Coke oven Battery for warming up of refractory bricks.

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**Abstract**

Recovery coke ovens are crucial to integrated steel plants, ensuring a steady supply of coke and gas for steel production. At JSW Vijayanagar Works, 10 Recovery coke oven batteries are operational: eight with 4.30m tall ovens and two with 6.25m tall ovens. Additionally, one battery is under heating and another is under construction.

This paper discusses the experiences in heating up Battery B of Coke Oven#5, emphasizing precise temperature control across three refractory zones. Key control mechanisms include gas pressure, draft, orifice adjustments, and burner features such as primary and secondary air. The heating (warming up) process is known as "side firing", which involves heating the refractory brick with specially designed burners at the oven door bottom. These burners, fuelled by coke oven gas, heat a temporary brick lining ("small oven") that absorbs the flame's thermal shock, allowing hot combustion products to enter the oven chamber.

Gas flow is controlled using an orifice plate above the stopcock, with flow regulated by maintaining gas line pressure. Suction in the branch flue and damper adjustments in the waste heat box (WHB) help direct combustion products from the oven chamber to the heating wall, through the regenerator via inclined flue, and subsequently into the branch flue tunnel and chimney via the buss flue and waste heat boxes. Flame length is adjusted using secondary air, while primary air controls the volume and reach of exhaust components to the middle of the oven. Silica refractory undergoes critical recrystallization phase changes at temperatures of 123°C, 163°C, and 573°C, where significant expansion occurs. The warming process involves slow heating from a minimum of 4°C to a maximum of 50°C per day according to the heating curve ensuring the silica refractory's expansion rate is limited to 0.03% per day. Expansion load is continuously monitored and controlled by releasing spring tension in the buckstay columns. After reaching 750°C, the heating system is switched to a permanent mode called "under firing" to build up to the 1150°C required for commissioning.

This paper details the procedures and control measures implemented to manage the temperature and expansion of the silica refractory in Battery B of Coke Oven 5, achieving the recommended standard expansion over an 84-day period. The findings highlight the importance of meticulous control in ensuring the structural integrity and operational efficiency of coke ovens, which are vital for sustaining the steel plant's production capabilities.

**Key words** : Side-firing, under-firing, silica refractory, recrystallization, temperature, small oven, heating wall, waste heat box

# Increasing reliability in refractory installation and reduction of blowpipe rejection in the Blast furnace blowpipe nozzle

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**Abstract**

The blowpipe is a critical component in the production of hot metal (crude steel) in blast furnaces, with the refractory castable used in the blowpipe nozzle serving to prevent heat loss from the hot blast and protect the metallic cylinder from the high temperatures of the air blast.

The refractory layers in blowpipes typically require replacement every year. However, during the application of new refractory castings, blowpipe nozzles were frequently rejected due to various issues. This led to material wastage, increased man-hours for rework, and reduced availability of blowpipe nozzles when needed.

To address these challenges, new solutions were developed and implemented to improve the accuracy of blowpipe centering during the casting process. As a result, the rejection rate of blowpipe nozzle refractory due to centering issues was significantly reduced from 25% to zero.

This paper outlines the successful elimination of blowpipe rejection through the implementation of modified tools, equipment, and working procedures. These improvements have provided tangible benefits for hot metal production operations by enhancing the reliability of tuyere stock readiness, ensuring better alignment with production demands.

**Key words:** Blast furnace Blowpipes, Rejection, Defects, Benefits.

# Innovative approaches in Steel Making refractories while making Value added steel production

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**Abstract**

To Coup the Market demand JSW VJNR has started journey for Value added steel production (VASP) almost a decade back, while making the value added steel, especially automobile grade and electrical steel grade due to the stringent quality norms of these grade the impact on the refractories was a challenge starting from pre-treatment to cast end.

Unplan Down of KR Impeller resulting in less number of KR heats, metal trickling in converter MHP resulting in non-operation of plugs for making the VSAP, Carbon Pick up from MgO-C bricks from Steel ladle, Very Low life of RH Snorkel resulting in less production of VASP.

This study explores the effects of design changes in refractory bricks and the application of slag coating on KR (Kambara Reactor) impellers to address issues related to alumina spalling. In industrial operations, KR impellers are subjected to extreme thermal and mechanical conditions, leading to alumina spalling, which compromises their performance and lifespan. By implementing modifications to the brick design and applying a protective slag coating, the resistance to spalling was significantly improved. The redesigned bricks provided better thermal stability and reduced mechanical stress, while the slag coating formed a protective barrier against aggressive slag attack. These enhancements resulted in extended impeller life, reduced maintenance requirements, and improved operational efficiency.

**Keywords:** Brick Design, Slag Coating, KR impellers, alumina spalling, thermal stability, mechanical stress.

# Characterisation of different carbon sources in Blast Furnace Trough castables

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**Abstract**

:$Al_2O_3$–SiC–C (ASC) castables are commonly used in blast furnace troughs due to their impressive thermal-mechanical performance and excellent slag corrosion resistance. By the incorporation of carbon (C) into ASC castables, their slag corrosion resistance can be significantly enhanced, as carbon is not wetted by molten slag, has a low coefficient of thermal expansion, and high thermal conductivity. But due to its poor oxidation resistance property antioxidants are added to protect the carbon bonds. The aim of this current study is to investigate the properties of different sources of carbon with respect to purity, particle size, pH, mineralogy, thermogravimetry and microstructure and to evaluate their effect on the rheological behavior and thermo-mechanical properties of trough castables. Based on the outcome of the properties evaluated, optimization of carbon content in the castable formulation is to be done.Thereafter the oxidation and slag corrosion behavior will be subsequently investigated.

Keywords: Purity of carbon sources, rheology, oxidation resistance and slag corrosion resistance

# Investigative Analysis on Using Calcium Formate as an Additive to Reduce the Setting Time of Cement Mortar Lining in Ductile Iron Pipe

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## Abstract

Ductile Iron (DI) pipe is used for potable water distribution, irrigation, sewage transport, and industrial usage. However, due to the continuous flow of water, there is a potential risk of corrosion and the subsequent leaching of iron into the potable water supply. Therefore, Cement Mortar lining (CML) is used as an inert ceramic layer to prevent leaching and corrosion.

The CML is the slowest process in manufacturing of the DI pipe. The objective of this work is to reduce the setting time of CML by incorporation of suitable additive. The Calcium Formate was found to be the most suitable additive for this purpose. In the work, different concentration of Calcium formate was mixed with CML and their properties were evaluated by Cold Crushing Strength (CCS), Vicat, XRF, XRD, FESEM, EDS, DTA, TGA and FTIR. It is observed that the optimum concentration of Calcium formate is 0.5 % wt./wt.%. It increases the compressive strength of CML by 10-15 kN while simultaneously decreasing the setting time by 20%.

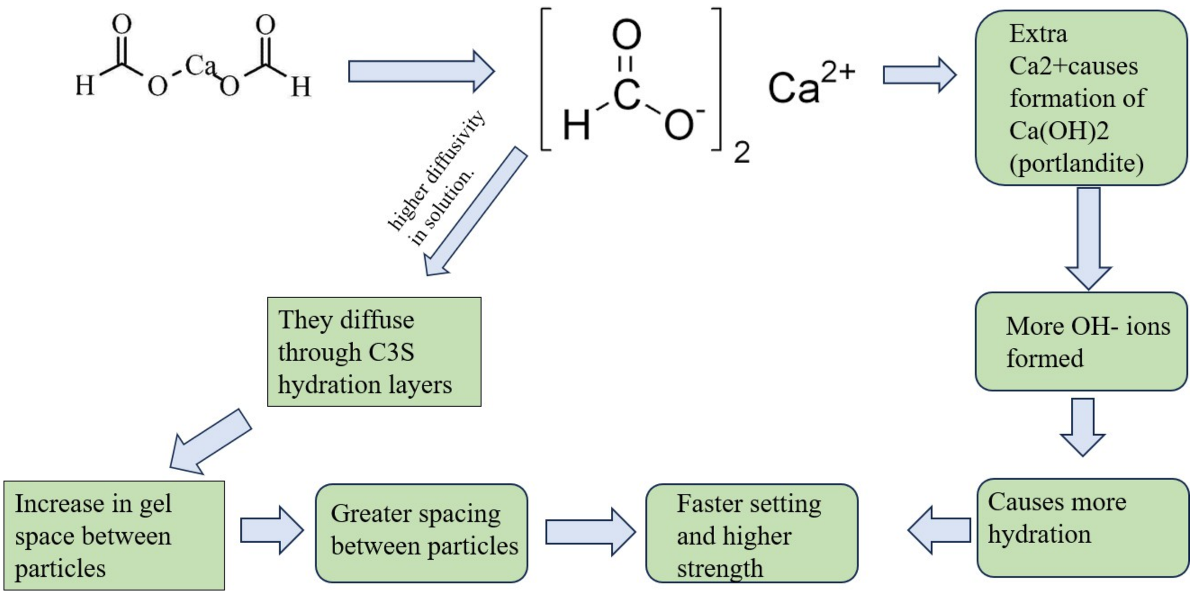


Fig. 1: Schematic showing the Role of Additive in CML setting time reduction

Key words: Cement, Mortar, Compressive Strength, Setting time, Calcium Formate

# Effect of systematic variation of K2TiF6 flux content on the microstructure, mechanical properties, and tribological behavior of Al-B4C composites

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## Abstract

Al-$B_4C$ composites are considered an attractive material choice for many application areas in aerospace, automotive, marine, space, defense, and so on. This can be attributed to very high hardness, low density, high-temperature strength, chemical inertness, and non-toxic nature of the $B_4C$ ceramic particles. Further, due to the self-lubricating property of these particles, the composites can also be potentially used in several tribological applications like pistons, piston rings, cylinder liners, bearings, brushes, brake discs, pads, etc. This work focused on the combined effect of in-situ formed intermetallic phases and extraneously added $B_4C$ reinforcement particles in AA6061 matrix composites in both as-cast and T6 heat-treated conditions under varying amounts of $K_2TiF_6$ flux addition. The flux concentration was varied as 40%, 70%, and 100% by weight of a constant 6 wt.% $B_4C$ addition during the fabrication via mechanical stirring followed by squeeze casting. Notably, the ability of $B_4C$ retention within the matrix was observed to be significantly enhanced when the flux concentration increased from 70% to 100%. This could be attributed to enhanced interfacial adhesion between the matrix and the reinforcements and the formation of Ti-rich intermetallic phases, which were not adequately generated in the instance of 40% flux. Additionally, the incorporation of the flux led to the formation of in-situ Al-Ti intermetallic phases, the size and content of which were affected by the flux content. The inclusion of the ex-situ $B_4C$ and in-situ Al-Ti phases led to improved hardness and strength. The presence of the Al-Ti phases also enhanced the tensile toughness of the composites. However, a reduction in the same was observed due to the harder ex-situ $B_4C$ particles. Further, contributions from different strengthening mechanisms, such as grain refinement, load transfer, thermal mismatch, and stiffness mismatch between the matrix and both the reinforcing phases, were thoroughly investigated. The thermal mismatch strengthening due to the in-situ Al-Ti and ex-situ $B_4C$ particles played the most dominating roles, followed by grain size refinement. This study also examined the wear performance of both the cast and T6 heat-treated composites at three different normal loads, 10, 20, and 30 N, under a dry reciprocating sliding action. Both the in-situ and ex-situ phases affected the friction coefficient and wear rate of the fabricated composites; however, their synergistic influence on the overall wear behavior was strongly load-dependent. The findings in this study underscored the critical role of $K_2TiF_6$ in optimizing and enhancing the performance of AA6061-$B_4C$ composites for advanced engineering applications by controlling the evolution of the in-situ and ex-situ reinforcements.

Keywords: AA6061-$B_4C$ composites; $K_2TiF_6$; Microstructure; Mechanical property; Wear behavior

# Case Study on Life Improvement Journey of 350 Tons Capacity Steel Ladle at JSW Steel Ltd, Dolvi

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## Abstract

JSW Steel Ltd, Dolvi SMS-2 is the 1st plant in India who commissioned 14 no's 350 Tons capacity Steel Ladle to produce 5 MTPA steel. At Dolvi SMS-2 steel process route is BOF-LHF-RH-Degasser-Slab Caster. Refractories play a crucial role in steel production, as they protect the steel ladle from corrosion and wear, ensuring the quality of the steel produced. However, they face several challenges, such as: erosion and corrosion caused by the action of molten metal and slags, thermal and mechanical degradation due to high temperatures and thermal fluctuations, the formation of defects and cracks in the refractory surface, the need for greater durability and abrasion resistance, optimizing refractory design and installation to improve refractory performance. Steel Ladle undergoes treatment like alloying, homogenization, de-sulfurization, non-metallic inclusion modification/removal and vacuum de-gassing are referred to as the secondary refining of steel. All the above mentioned causes act more severely in high capacity steel ladles for life degradation of refractories. In this case study we will discuss challenges faced for stabilization of steel ladles from refractory material quality, thermal calculation, CFD modelling, design and engineering perspective. The main issues faced during stabilization i.e. spalling and high erosion at steel ladle bottom due to high impact of molten metal, high metal return after casting due to vortex formation, less tap weight, high corrosion at transition zone of ladle due to marangoni effect, heavy corrosion at slag zone and freeboard refractories etc. To overcome of all the issue and stabilize the ladle performance following actions are taken i.e. Implementation of alumina magnesia carbon (AMC) refractory instead of corundum spinel refractory at bottom, slope design bottom trail taken with vortex buster, Spinel carbon brick developed at Transition zone area to minimize marangoni effect, thermal heat flow calculation with reduced refractory thickness, CFD modelling for slope bottom and vortex buster. With all this improvement steel ladle life achieve 125 heats with single repair.

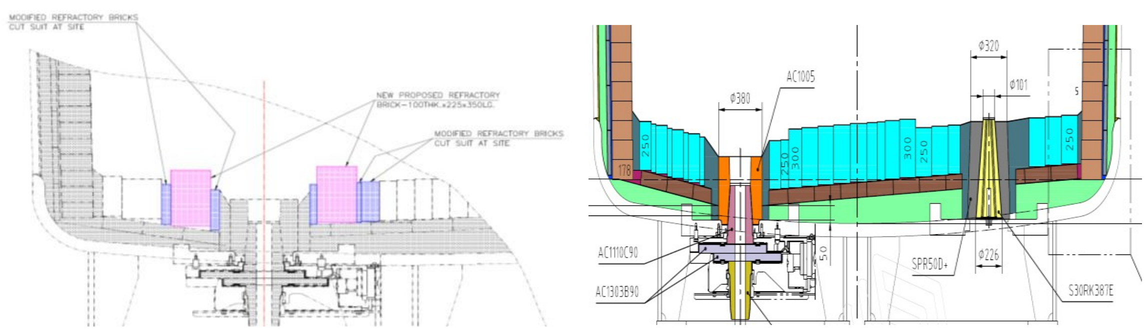


Fig. 1. Modified slope bottom design with vortex breaker and AMC

Key words: Steel Ladle, AMC, Corundum Spinel, Spinel Carbon, Vortex Breaker

# A critical Review of recent Research on the Effects of Various reinforcements types on the Mechanical, Physical Properties and Microstructural Characterization of Aluminum Metal Matrix Composites

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**Abstract**

Materials are the prima facie for any product. From the early human civilization to the present day, many materials are used depending on the necessity. Steels (density = 7600 kg/m3) are the popular materials however with the advancement in the technology wide range of materials from steel to aluminum (density = 2700 kg/m3) to plastic etc. as such are widely used. Aluminum alloys are widely used in many engineering applications such as building ships, aerospace industries, automotive industries, marine industries and rail industry due to its lightweight and performance characteristics. Aluminum alloy based composites are also vastly used due to the enhancement of the properties with the incorporation of reinforcement/s. In the present article, of all the Aluminum alloys, 7xxx series Aluminum alloy based composite materials are reviewed with respect to the use of reinforcement/s, the manufacturing method, physical, mechanical, corrosion and tribological characteristics. The specific combination of Aluminum alloy with suitable reinforcement/s provides a tailored solution for areas where increased strength, wear resistance, and thermal management are required. The primary focus of the present research lies in the development of a material that possesses a reduced weight compared to the as received Al alloy i.e., $\rho_{MMC} < \rho_{Al}$ alloys.The mechanical properties of Metal Matrix Composites (MMCs) are significantly affected by several factors including the characteristics of the reinforcement and matrices, the strength of the interfacial bonding, the dispersion of particles within the matrix, the shape and size of the particles, the percentage content of particles, and the procedures used in processing. This review analysis indicates that MMCs has significant potential to effectively meet both current and future demands.

**Key words :** Aluminum metal matrix composites; Reinforcements; Mechanical properties; Characterization.

# SPECIALTY HIGH STRENGTH AND ABRASION RESISTANCE REFRACTORY FOR EMERGENCY FAST REPAIRS OF DAMAGED FLOOR AREAS

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**Abstract**

Conventional types of castables, after placement in floor areas, require several steps including setting, curing (achieved by covering the castable with wet burlap, plastic sheeting, or periodically misting with water), and drying. This process typically takes about 48 to 72 hours, reducing productivity due to the delayed movement of heavy material transfer vehicles (HMVs). It can also lead to steam explosions or cracking within the castable, which diminishes the performance and longevity of the material.
However, the use of the TRICAST series of TOPCRETE products offers a versatile solution, being patchable, rammable, and castable depending on the application requirements. These products are ideal for use in anode casting floors in aluminum smelters, high-strength floors in aluminum cast houses and foundries, coke oven plant quenching towers, power plant coal silos, concrete silo rebuilds and repairs, steel plant floor repairs, and damaged concrete pillars or structures.
These specialty products utilize a unique liquid binder system for easy and precise mixing, controlled setting, rapid dry-out, and heat-up. They are resistant to heat, hot metal splashes, chemicals, and other harsh conditions. They also form a chemical bond with existing fired refractories, requiring no ambient or pre-heating. Unlike conventional castables, repairs using this product are ready for operation within 4 to 6 hours due to their fast hardening, strong bonding with existing refractories, high thermal shock resistance, and exceptional strength and abrasion resistance.
Another series of TOPCRETE can be used for repair and patchwork in cement kilns, including cooler and kiln burning zones, as well as patching and gap-filling work on bricks and in power plants.

Fig.1 Casting of High Strength Floor

Fig.2 No cold Joints

Fig.3 Repaired burner tip with Topcrete

Key words: Floor castable, emergency repairs, resistant to chemical and hot metal splash.

# Light-weight Al matrix composites reinforced with Al-Cu-Fe quasicrystals fabricated by mechanical milling and high-pressure spark plasma sintering

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Abstract:

The surge for light-weight materials has led to design and development of Al matrix composites with aperiodic and periodic intermetallics [1]. The AMCs reinforced with quasicrystal (QC) has gained impetuous in recent times. The present work deals with the fabrication and characterization of AMCs with Al-Cu-Fe based icosahedral quasicrystals (IQC) by mechanical milling followed by spark plasma sintering (SPS) [2]. The structural transformation of QC reinforcement to crystalline phases (B2-type and Al13Fe4) during sintering of these AMCs was observed. AMCs SPSed at 550 ℃ has appreciable compressive yield strength and ultimate strength ~ 519 MPa and 639 MPa respectively, with Young's modulus of 134 GPa. The SPS of milled powder was also carried out at high pressure (~500 MPa) but moderate temperature to avoid the formation of crystalline phases. The present study reveals the microstructural evolutions, the formation of transition layers at the interfaces and consequent strengthening of the present AMCs in comparison with conventional AMCs. The nature of the interfaces were dicerned through high-resolution TEM imaging and the diffusion of the elements were observed with the help of APT.

Keywords: Al matrix composites; mechanical milling; quasicrystal; high entropy alloys; interfaces.

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Y. Shadangi, K. Chattopadhyay, N. K. Mukhopadhyay, IN Patent Application: 202411016

# "Enhancing Operational Efficiency and Productivity in Reheating Furnace Roof Burner Design through Strategic Nozzle Arrangement"

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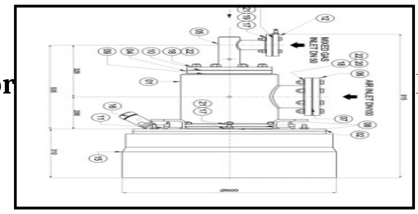
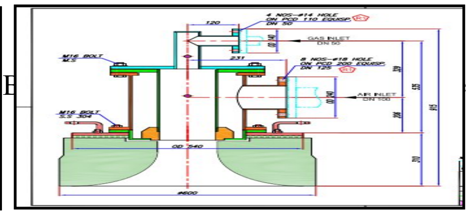
**Abstract**

In the earlier design of the Reheating furnace roof burner (Radial burner), the operational efficiency and productivity were significantly compromised due to frequent nozzle clogging, resulting in uneven billet temperature distribution. This issue not only led to suboptimal heating outcomes but also necessitated prolonged cleaning procedures, causing substantial downtime and reduced throughput in the production process. Recognizing these challenges, a comprehensive redesign of the burner arrangement was undertaken to address these critical issues and enhance overall furnace performance. The primary concern with the previous design stemmed from the propensity of gas nozzles to clog frequently, disrupting the uniformity of heat distribution across the billet. This inconsistency not only affected the quality of the reheated billets but also imposed considerable operational inefficiencies. Moreover, the extensive time required for cleaning and maintenance of the clogged nozzles further exacerbated the problem, leading to reduced productivity during these downtime periods. In response to these challenges, the new burner arrangement process was meticulously developed to optimize several key aspects of the furnace's operation. Central to this redesign effort was the strategic placement and spacing of the gas nozzles, aimed at improving the flow dynamics and minimizing the likelihood of nozzle clogging

**Key wor** E performance





# Development of Suitable Tap Hole Clay for Blast Furnaces

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## Abstract

The technology for Blast Furnaces has progressed in the last few years based on higher productivity, better quality of the produced hot metal, operational stability, safety and continuous life extension of the refractory lining. Tap hole clay performance is directly linked with the blast furnace performance. Tap hole clay used for plugging of the tap hole and ensures the protection of the hearth refractory. After injection, it assures the obstruction of blast furnace tap hole as well as the hearth tightness. Before Casting, it provides passage through drilling to assure a regular steady output of molten iron & slag. Due to poor quality of tap hole clay, we observed leakage, spitting, red ball formation and self-opening. To eliminate these issues new tap hole clay was developed with suitable properties. The comparative chemical and physical properties were evaluated. We obtained higher the strength and positive permanent linear change in the application temperature range of the tap hole clay. Marshal index test and adhesive test values with old and new clay was encouraging in the new clay. Slag corrosion resistance was performed at 1500-degree temperature for 5 hours soaking with blast furnace slag. Suitable type of binder system (composite type) was selected for the furnace operation. Extensive trial with the new clay was conducted and we obtained 20% reduction of the specific consumption of the new clay.

key words : blast furnace, tap hole clay, corrosion, cast duration

# Effect of Continuous Casting Parameters on Billet Oscillation mark depth and pitch in alloy steel

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## Abstract

In the continuous casting process for alloy steel, billet oscillation marks significantly influence both billet quality and the subsequent quality of wire rods. These marks appear as transverse indentations at regular intervals along the billet surface. They serve as critical sites for strain concentration and potential initiation points for cracks under subsequent deformation. This study investigates the effects of various continuous casting parameters on oscillation mark depth, pitch, and associated defects in alloy steel cast in 165 * 165 mm billets. Key parameters such as casting speed, mold oscillation frequency, and mold oscillation stroke were analysed to determine their impact on oscillation mark formation. Additionally, the study focused on fundamental parameters of the oscillation cycle, such as negative strip time and its ratio, to understand their influence on surface quality. Experimental data and statistical analysis were employed to compare different negative strip times and ratios across varied casting parameters. This comparison aimed to identify optimal casting conditions that minimize oscillation mark pitch and reduce the occurrence of associated defects. The findings provide insights into optimizing continuous casting processes for alloy steel, enhancing surface finish, and overall product quality in wire rod production.

**Key words** : Continuous casting process, oscillation marks, Negative strip

# Impact of Cooling Rate On Dendritic Arm Spacing of 55%Al-Zn-Si Hot-Dipped Alloy-Coated Steel

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## Abstract

55%Al-Zn-Si coating on base steel or Galvalume is known for its superior corrosion properties due to its chemistry containing high amount of aluminium. The anticorrosive behaviour of the coating majorly depends on spangle size and its distribution. Again spangle size is primarily influenced by upon various factors such as pattern of dendrite size and distribution, cooling rate, bath temperature, Si content and base material chemistry.

During the coating process, an interfacial Fe-Al-Zn intermetallic alloy layer forms at the interface between the steel substrate and the overlay coating. The surface of the Galvalume coating contains characteristic spangles, which consist of aluminium dendrites with a clearly measurable dendrite arm spacing (DAS). In our study, the effect of cooing rate on intensity of dendrite growth was focused. Plant trials conducted at continuous galvanizing line with unchanged Si content in base metal chemistry. Cooling rate after dipping was controlled to study effect of cooling rate on dendritic structure/DAS The surface morphology of the Galvalume coatings were studied using optical micrographs and SEM analysis. SEM-EDAX was carried out to study the dendritic and interdendritic regions and their effect on spangle size. It was found that the population of silicon particles observed in the coating increased with cooling rate. Finer alpha (a)-Al dendrite structures, i.e. smaller dendrite arm spacing (DAS), were associated with higher populations of silicon particles. Localization of silicon particles controls the nucleation sites and hence dendrite size and distribution.

**Key words** : 55Al-Zn-Si alloy; Hot-dipped coatings; Dendrite arm spacing(DAS)

# Designing Exothermic Mould Powder for Prevention of Steel Caster Defects

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## Abstract

The efficiency of continuous steel casting is heavily influenced by the performance of mould powders, which play a critical role in lubrication and preventing casting defects. This paper explores the design and optimization of an exothermic mould powder specifically engineered to enhance the quality of steel by minimizing casting defects. Addition of Exothermic agent in mould powder will increase heat to the meniscus. We delve into the critical parameters such as heat transfer, melting rate and melting point. Through a combination of experimental studies and thermodynamics modeling, we identify the optimal composition and properties of the exothermic mould powder to achieve desired performance outcomes.

Our study highlights the intricate balance required in the formulation of exothermic mould powder. By maintaining sufficient heat in the mould, preventing hook formation, controlling non-metallic inclusions, and preventing carbon pickup on strand surface, we target significant improvements in the casting process using exothermic flux. The exothermic flux exhibits superior thermal management, which is essential for preventing common casting defects such as surface cracks and subsurface imperfections.

Field results of the usage of exothermic fluxes show no carbon pickup on strand surface and leads to prevention in breakouts. The work is in progress for accounting results regarding the impact of exothermic powder on overall crack tendency and inclusion rating of hot rolled products. This paper emphasized the importance of tailored exothermic mould powder formulations in the steel casting and presents a robust approach to defect prevention.

**Keywords**: Continuous casting, caster defects, exothermic mould powder, steel quality.

# Effect of Mold Powder Properties on Mold Heat Transfer and Lubrication in CSP Caster: 2D Heat Transfer Mathematical Model

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## Abstract

CSP casting technology exhibits many techno-economic benefits, primarily through its capacity to achieve high casting speeds. However, the heat transfer in CSP caster is complex and dynamic in nature due to its higher casting speed and common operational issues like uneven heat extraction. Hence, this requires precise control and optimization of various operating parameters like mould heat transfer and lubrication to ensure uniform slab solidification. The mould powders play a crucial role for maintaining the stability of the continuous casting process, by controlling mould heat transfer and ensuring lubrication. In this study, 2-D heat transfer model for CSP is developed using Finite Volume method (FVM) on python software as shown in Fig. 1. The 2D heat transfer model was validated with the CON1D model. Additionally, the predicted slab surface temperature and average heat flux were compared with plant data, showing good agreement. This model can calculate the slab temperature profile by solving 2-D transient heat transfer equation at various operating conditions and steel chemistry. The effect of mould variables on the heat transfer is studied and found that thermal resistance due to gap between mould wall and steel shell dominates all other thermal resistance in the mould. Analysis using this model showed that fluctuations in the slag consumption rate directly influence the thickness of the solid and liquid slag layer in the gap between the mould wall and the steel shell. Therefore, the actual mould powder consumption rate must be maintained above the critical consumption rate of 0.41 Kg/Ton for effective mould lubrication. Additionally, this model will help to carry out the root cause analysis of slab breakouts and study the effects of various casting parameters on heat transfer.

**Keywords**: CSP, 2D heat transfer model, finite volume method, Powder consumption rate


Fig. 1: CSP 2-D Heat transfer model using FVM method

# Use of Low Fluorine Based Mould Powder to Reduce the Corrosion of Caster Machinery without Affecting the Casting Speed

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## Abstract

Mold powders are crucial for ensuring the surface quality of the final products, refining liquid steel and maintaining the stability of the continuous casting process. These powders are composed of a mixture of various oxides, carbon-based materials and fluoride compounds. The addition of fluorine or fluoride ($CaF_2$) is intended to regulate viscosity and fluidity temperature of mould powder during the casting process. However, there are certain concerns regarding the presence of fluorine in mold powders. During the casting operation, fluoride compounds can vaporize, releasing harmful gaseous substances, such as hydrofluoric acid, which pose serious health risks. Additionally, fluorine in mold powder can result in the formation of volatile, water-soluble fluorine compounds, particularly $SiF_4$. In continuous casting machines, these compounds can accumulate in the secondary cooling water, leading to a decrease in pH levels. This acidic environment increases the risk of wear and corrosion on plant and equipment components. In this study, efforts were made to reduce the corrosion of caster machinery by using a low-fluorine mold powder without compromising casting speed. A new mold powder containing 2.4% fluorine was tested as a replacement for the previous powder, which had 8.8% fluorine. Industrial trials were conducted over several months using both types of mold powders. The results showed that the fluorine concentration in the caster tunnel water was approximately 20 ppm lower when using the low-fluorine powder compared to the high-fluorine variant. As a result, the decrease in water pH, a common issue with high-fluorine powder, was no longer observed. The erosion rate of the Submerged Entry Nozzle (SEN) also decreased with the application of the low-fluorine powder, and no negative impact on casting speed was observed with the newly formulated mold powder.

**Keywords**: Mold powder, fluorine, casting speed, hydrofluoric acid, corrosion

# Crystallization Behaviour and Thermophysical Properties of CaO-Al2O3 Based Alternative Mold Fluxes for Continuous Casting of 3rd Generation AHSS

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## Abstract

Significant efforts are being made to develop Advanced High Strength Steels (AHSS) for automotive use, improving vehicle crashworthiness and fuel efficiency due to their high strength-to-weight ratios. AHSS are classified into three generations, with the first and second generations being commonly used. The second generation, however, poses processing challenges due to its high Mn content (~20 wt.%). To overcome these issues, the third generation of AHSS, which includes high-Al medium-Mn steels with lower Mn content (~5 wt.%), is being developed. Conventional CaO-$SiO_2$ based mold fluxes encounter challenges when casting third-generation AHSS due to interfacial reactions, resulting in compositional changes and surface defects such as transverse and longitudinal depressions, as well as breakout predictions (BOP).

This work aims to develop "non-reactive" CaO-$Al_2O_3$ based mold fluxes for casting high-Al and medium-Mn steels belonging to the 3$^{rd}$ generation AHSS family. These fluxes are designed to ensure adequate heat transfer between the solidifying steel shell and the copper mold while maintaining proper lubrication. The heat transfer is primarily influenced by the crystallization behavior of the flux, while lubrication depends on slag viscosity. The study examines the effect of varying w(CaO)/w($Al_2O_3$) ratios in mold flux composition on the crystallization behavior and important thermophysical properties such as viscosity, break temperature, and melting temperature. Crystallization kinetics were evaluated using Differential Scanning Calorimetry (DSC) across heating rates ranging from 10K/min to 25K/min, while viscosity was determined using a rotating viscometer.

The output of this study elucidates that on increasing the w(CaO)/w($Al_2O_3$) ratio from 1.00 to 1.33, crystallization tendency increases and the activation energy of crystallization decreases from 880.7 kJ/mol to 578 kJ/mol. However, this trend reverses as the ratio increases from 1.33 to 1.50, with activation energy rising to 1135.9 kJ/mol. The viscosity of the slags decreased from 0.36 Pa·s to 0.14 Pa·s at 1400°C, whereas the break temperature increased from 1340°C to 1380°C as the w(CaO)/w($Al_2O_3$) ratio increased. These properties were then correlated with the melt structure using Raman Spectroscopy, revealing the degree of depolymerization of the aluminosilicate chain in the melt. In contrast, an increase in the w(CaO)/w($Al_2O_3$) ratio leads to the depolymerization of the melt which affects all the thermophysical properties related to the mold flux.

**Keywords** : AHSS, Continuous Casting (CC), Mould Fluxes, Crystallization, Viscosity, Raman Spectroscopy

# Impact of MgO content on Crystallographic phases and properties of Mould Fluxes in Steel Continuous Casting Process

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## Abstract

Mould fluxes are crucial in the steel continuous casting process, and understanding the influence of MgO content on their crystallographic phases is essential for optimizing their performance. This research paper focuses on investigating the impact of MgO on the crystallographic phases of mould fluxes using thermodynamic software. Thermodynamic software is employed to simulate phase equilibria and predict the crystallographic phases that form at various MgO concentrations. Experimental testings have been done to correlate with the results of thermodynamic data.

The results reveal that increasing MgO content influences the formation and stability of different crystallographic phases in the fluxes. The presence of MgO promotes the formation of the Merwinite phase. Furthermore, the paper discusses the implications of the observed phase changes on the overall performance and effectiveness of the mould fluxes during the steel continuous casting process.

The findings of this study provide valuable insights for optimizing the MgO content in mould fluxes to enhance their properties and aiding in the development of tailored mould flux formulations for improved steel continuous casting processes.

**Keywords**: Mould fluxes, Thermodynamic Software, Crystallographic phases, Cuspidine.

# Study on electromagnetic and flow control mold parameters for development of clean steel slab for continuous casting process

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## Abstract

The present study investigates the impact of the flow control mould (FC mould G3) parameters on the flow flow profile during continuous casting process of steel slab, The FC mould G3 at SMS TSK utilizes simultaneous stirring and breaking mechanisms to control flow profile for control of inclusion and mould slag entrapment. The study analyzes the influence of various casting parameters like casting speed, mould width, argon flow, grades, upper AC current, and upper lower coils on the metal flow direction and meniscus velocity have influenced with FC mould. The impact of the FC mould G3 on sub meniscus velocity, standing wave, and inclusion content in continuously cast steel slabs along with mould level fluctuations is being studied using nail boards compared with conventional casting without application of flow control mechanisms. The experimental study using nail board dipping test was carried out to investigate the impact of flow control 3rd generation mould on flow direction, meniscus velocity, and standing wave and corelated with FC mould parameters for optimization. Finally, the study examines the impact of the FC mould G3 on reduction of inclusion content being studied using electrolytic extraction and scanning electron microscopy for clean steel.

**Key words:** Continuous casting, Flow control mould, Meniscus velocity, Inclusions, Steel Cleanliness

# Mitigating of segregation in billet casting: a trial on the synergistic effects of final electromagnetic stirring (fems) and soft reduction

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## Abstract

Segregation in billet casting can lead to inconsistent material properties, reduced product quality, and increased production costs. This trial investigates the combined effect of final electromagnetic stirring (FEMS) and soft reduction on reducing segregation in a billet caster. FEMS was applied during the solidification process to enhance melt mixing, reduce macro segregation, promote a more uniform solidification structure, reduce center-line segregation, improve the distribution of alloying elements, and reduce porosity. The trial was conducted on a billet caster, with a total of 20 heats produced under varying FEMS and soft reduction conditions. The results found a series of benefits, like a reduction in centerline segregation, leading to improved billet quality and reduced production costs; a reduction in macro segregation, resulting in more uniform material properties; a improvement in billet surface quality, reducing the need for additional processing steps; and a reduction in porosity, leading to improved billet cleanliness and reduced scrap rates. Based on the trial results, soft reduction was implemented to optimize the reduction rate, minimize porosity, prevent centerline segregation, and improve billet surface quality. The implementation of soft reduction enabled the production of high-quality billets with improved mechanical properties and reduced production costs to enhance customer satisfaction.

**Keywords**: Segregation, FEMS, billet caster, solidification structure, quality.

# Study of the effect of casting parameters on macro-structure and segregation in continuously cast round billets

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## Abstract

Solidification macro-structure of continuous cast billets is an important factor influencing the final properties of the finished product. The continuous casting process parameters have a direct influence on the solidification structure. The solidification of continuous casting is governed by extremely complex and co-related phenomena, including melt flow, heat transfer, species transport, formation of the initial strand shell in the mold region, formation of equiaxed crystals by nucleation and/or crystal fragmentation, and transport of the equiaxed crystals. Segregation mainly depends solidification shrinkage and crystal growth.

Total 50 samples of LHBR19M grade were cut from continuously cast billets of 380 mm diameter. These samples were etched with 1:1 ratio of HCl and water and their macro-structures were analyzed [Fig. 1]. The area of equiaxed crystal zone, columnar zone and chilled zone was calculated. A comparative study was conducted to find the correlation between effects of various casting parameters like superheat, casting speed, mold electromagnetic stirring (M-EMS), and secondary cooling on macro-structure of these samples. Macro segregation as well as any other defects, if present, were studied and their possible reasons were also investigated.

The basic observations from the above study can be summarized as below-
1. As the superheat is increased, the length of columnar zone and the thickness of central segregation are increased, while the percentage of equiaxed zone is decreased [Fig. 2]. Chances of central porosity are also increased with increase of superheat.
2. The increase in casting speed decreased the percentage of equiaxed zone. Also the degree of center macro-segregation was increased with the increase in casting speed.
3. Mold electromagnetic stirring (M-EMS) promoted the uniform and homogenous central equiaxed zone. Optimal stirring intensities (frequency and current) break the columnar grains and promote the growth of equiaxed grains effectively. The average central segregation is also well controlled by M-EMS.
4. Hard secondary cooling significantly reduces macro-segregation. Proper secondary cooling is necessary for minimizing the macro defects such as longitudinal and subsurface cracks.

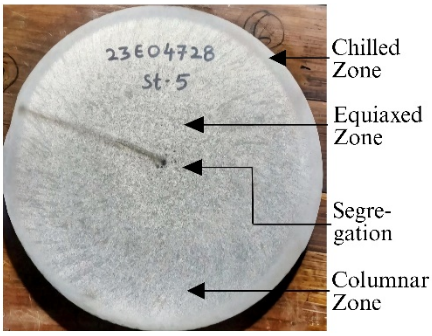

Fig. 1: Macro-structure of round billet

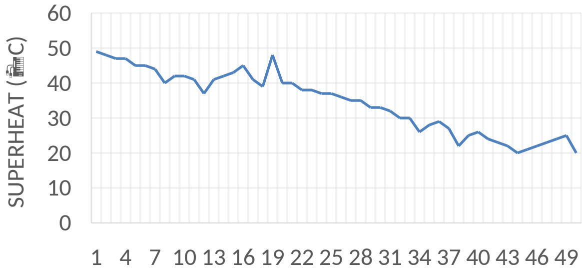

Fig. 2: % Equiaxed zone versus superheat

**Keywords:** macro-structure, segregation, continuous casting

# Casting and Forging Technology innovation

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## Abstract

Gerdau Summit, one of the global leaders wish to present paper on casting and forging technology suitable for various product mix of Steel grades required in Steel industry.

This includes manufacturing processes and introduction of newly developed metallurgical grades for best performance for various steel grades.

**Key Words** – Casting forging Metallurgy Grades

# Computational analysis of continuous casting system for casting U-6%wtZr slug

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## Abstract

Sodium bonded metallic fuel pins containing U-Pu-Zr ternary alloy as fuel slug and U-6wt.% Zr as blanket slug in T91 clad are being developed for future fast breeder reactors in India. In this study, U−Zr alloy samples were prepared using continuous casting method. Preparation of U-Zr alloy slugs through continuous casting process needs optimization of processing parameters such as, melt temperature, casting speed, cooling water flow rate in the cooling jacket. To arrive at the possible casting parameters and to reduce the number of experimental runs first computational analysis was carried out. The results were validated by simulating the continuous casting process for Copper and Copper-Nickel alloys. Using these simulated results many experimental runs were performed and the prepared slugs were further characterized. For casting of 5 mm diameter slug of U-Zr it was established that casting speed of 2mm/s and cooling water flow rate of 0.6 LPM (litre per minute) can be used as shown in figure 1.

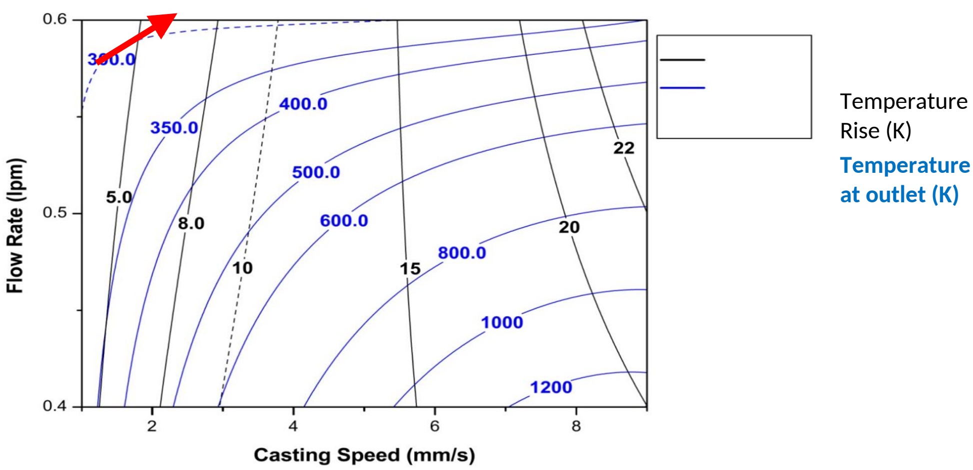


Figure 1 - Variation of the outlet temperature of the U-Zr cast slug and the temperature rise of cooling water at different casting speeds and flow rate.

**Keywords** : Continuous casting, metal fuel, computational analysis

# CFD analysis of submerged entry nozzle in the mold of continuous caster of steel

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## Abstract

The demand for high-quality and energy-efficient steel production is significant in emerging countries like India due to the substantial requirement for steel in modern times. The process of continuous casting is responsible for producing around 90% - 95% of the world's steel. In this process, the liquid steel is transferred from the ladle to the tundish by a sliding gate mechanism. The tundish then distributes the steel into the mold using a submerged entry nozzle (SEN). The primary aim of continuous casting was to achieve both superior quality and increased volume of steel production. To achieve this, it is necessary to have a well-designed submerged entrance nozzle and mold. This design is crucial for minimizing impurities in the steel and facilitating the production of a solid shell within the mold. This solid shell is essential for supporting the weight of the liquid steel core. The process of continuous casting is crucial for the efficient and high-volume manufacture of steel and several other metal alloys. However, the issue of maintaining good quality while producing a big amount arises in the rapidly advancing world. This work examines the functioning of a continuous caster and addresses the issues associated with the submerged entry nozzle. The present work is centered around the development of three-dimensional models and simulations to study the flow of liquid steel through a bifurcated nozzle inside the mold of a continuous steel caster. The main objective is to analyze the fluid flow and energy transfer phenomena. The k-ε model is employed to simulate the turbulence occurring within the mould, whereas the enthalpy-porosity model is utilized to simulate the solidification process. UDFs were created to account for the particular boundary conditions and heat flux conditions. Both fluid flow and solidification undergo grid independence testing and validation testing. Due to computational constraints, a dependency test with a tolerance of 20% error is deemed acceptable in turbulence modelling, but a tolerance of 10% error is acceptable in heat transfer modelling. The submerged entrance nozzle influences the velocity of the sub meniscus and the place where the jet impinges on the thin wall. Gaining a comprehensive understanding of how the nozzle alters the dynamics within the mold is crucial. A parametric research has also been conducted to examine the impact of several parameters, such as nozzle angle, nozzle submergence depth, and nozzle base, on the flow field and solidification profile.

**Keywords** : Submerged entry nozzle, enthalpy-porosity model, solidification, k-ε modelling

# CFD study on SEN design to reduce mold level fluctuations

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## Abstract

The rejection or downgrading of slabs due to mold or meniscus level fluctuation (MLF) based on surface criticality of slabs is very high at caster. Factors that influence MLF are submerged entry nozzle (SEN) design parameters like port angle, port outlet shape, port edge geometry and SEN bore diameter. Computational fluid dynamics (CFD) simulations were carried out to compare the design of existing SEN and recommend a suitable SEN design which results in low MLF at different operating parameters. Figure 1 shows the comparative result through the velocity vector profile of SEN (see Figure 1a) with existing 15° port angle and recommended SEN (see Figure 1b) with 25° port angle and port outlet of 80 mm height and 70 mm width having reducing bore diameter of 85 to 82 mm. Fluid flow pattern shown in Figure 1b clearly indicates that the liquid steel losses its velocity inside a large diameter bore SEN and it is directed downwards with 25° port angle with a reduce velocity due to larger port exit area and rounded off port edges. This creates a larger upper recirculation zone with low velocity resulting in less turbulence and low meniscus level fluctuations.

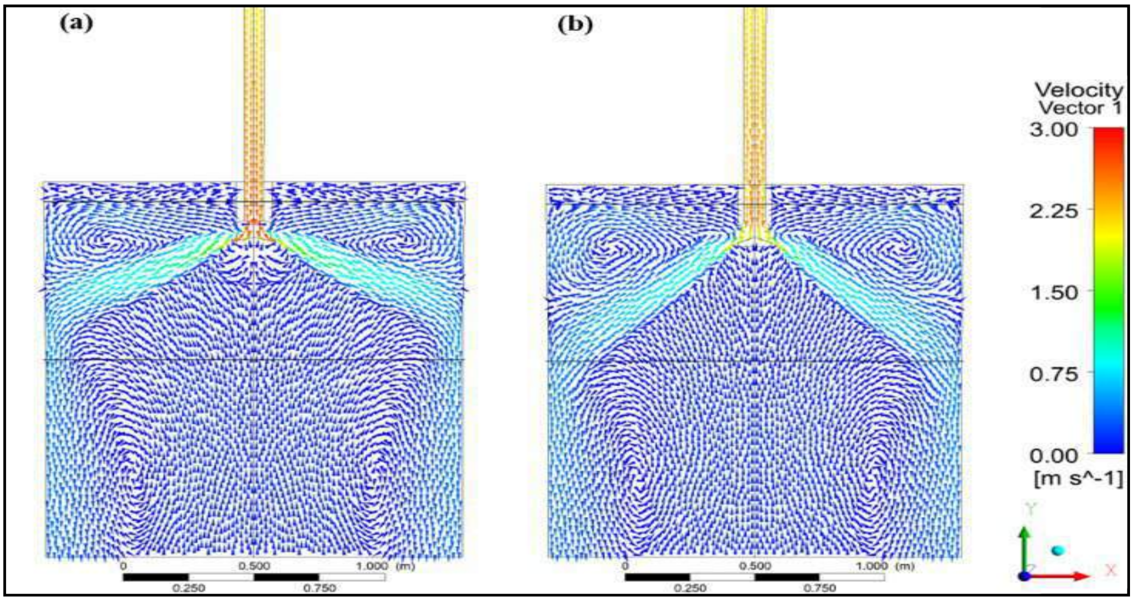


Fig. 1: Velocity vector at mid plane thickness a) 15° port angle; b) 25° port angle

**Keywords**: submerged entry nozzle, pot angle, port shape, meniscus level fluctuations, caster, mold

# Modelling and Simulation of a High throughput Submerged Entry Nozzle for Thin Slab Casting Process

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## Abstract

In the steel industry, thin slab casters play a pivotal role in producing high-quality steel efficiently. The design of a submerged entry nozzle (SEN) is crucial for managing the turbulence caused by the flow of molten steel in continuous casting mold. This aspect becomes particularly critical when employing a thin slab funnel-style mold, as it facilitates increased throughput in confined spaces. It is also crucial to maintain control over turbulence to prevent the occurrence of mold flux entrapment, which can lead to the formation of silver in the final product. Present study focuses on the development and analysis of a new submerged entry nozzle (SEN) design, aimed at enhancing the throughput of the thin slab casting process through detailed modelling and simulation approaches. The primary objective is to create a SEN that retains all essential SEN functions while facilitating the casting of molten steel at high throughputs of 5 tons per minute and above. An extensive parametric simulation study was conducted for four different cast section widths: 1000mm, 1300mm, 1500mm, and 1680mm. A comparison study was made between the conventional and new SEN design, focusing on flow stability within the funnel shape mold. The results showed that the new SEN design demonstrated significant improvements, indicating a more stable flow and the potential for substantial productivity enhancements.

**Key words**: thin slab casting, SEN design, turbulence, flow pattern, casting speed.

# CFD modelling on Ladle teeming operation to reduce slag entrainment and metal retention

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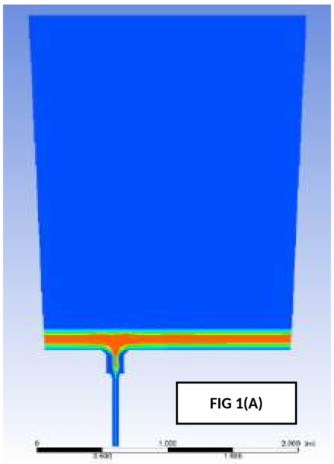
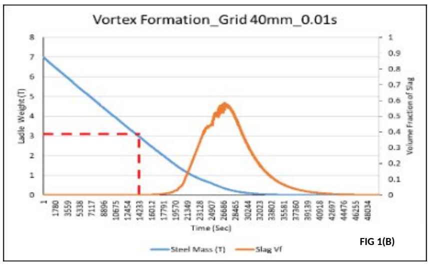
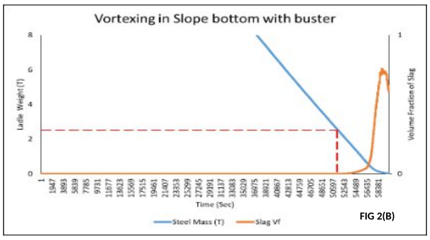
## Abstract

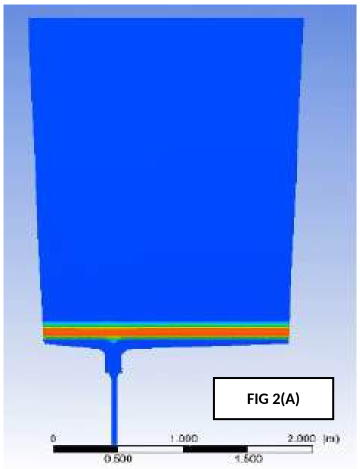
In the steelmaking process, slag carryover between vessels is unavoidable that can significantly impact productivity, quality, and cleanliness of the steels in subsequent processes. Slag carryover can lead to severe metal loss, affecting process yield. This issue is primarily due to mechanisms such as vortex sink and drain sink. To mitigate slag carryover, current practice involves retaining 1 ton of metal per heat in a 65-ton steel teeming ladle is modelled, as illustrated in Figure 1(A,B).

This project investigated reducing slag entrainment with minimal metal loss through modifications to the ladle bottom design, employing computational fluid dynamics (CFD) simulations with Ansys FLUENT software. The initial simulations validated the existing ladle design against actual plant conditions where slag entrainment in to tundish were evident at 1 ton metal retention in ladle. Subsequent simulations explored new ladle bottom designs, including changes to the well block, adjustments to the inclination angle of the ladle bottom slope, and the addition of vortex busters. Among these modifications, incorporating two fin-type rectangular vortex busters at the ladle bottom proved most effective for minimizing the slag entrainment at lowest possible metal retention to just   tons. as shown in Figure 2(A,B) thereby achieving better steel cleanliness with optimum steel yield.




**Key words** : Vortex, Slag entrainment, Tundish

# Unique AI approach to enhance slab surface quality at TSC

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## Abstract

The unconventional method of thin slab casting (TSC) demands high production rate while upholding rigorous quality standards. The peculiarity of TSC lies in the constant evolving and dynamic regime shift of parameters. However, this leads to frequent minor changes which gets reflected in data variability. So, static model is ineffective in preventive and predictive analysis of quality defects at TSC.
Longitudinal facial crack (LFC) accounts for half of the quality defects in thin slab casting at Tata Steel, Jamshedpur. Efforts to manage LFC defects have focused on controlling operational parameters to reduce the occurrence and spread of the cracks of the slab that is being generated within the funnel shaped mould of TSC. These parameters include speed, water flow, and properties of the mould powder, and other abnormalities in the caster. However, recent observations suggest that there may be other hidden parameters and patterns that contribute to the development of LFC defects in the slabs, requiring a unique approach to address this issue.
The implementation of a self-learning AI model had a dual impact: it not only minimized the rate of defects but also enhanced productivity. Initially, the model was developed using Python from an SQL database and subjected to trial runs on a separate test-database. Following multiple rounds of adjustments and false alarm mitigation, it was successfully integrated into the Intelligent Quality Management system for real-time monitoring of quality defects and process parameters. As a result, the incidence of LFC defects decreased by 11%, while the mould lifespan at Caster increased by 4%.

Fig. 1: Caption 1(Times New Roman 12 pts)

**Key words** :Thin slab caster, Longitudinal facial crack, funnel shaped mold, Predictive Modelling

# Numerical Modeling and Optimization of Continuous Casting Secondary Cooling for Efficient Heat Removal and Quality Improvement

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## Abstract

In the process of continuous casting secondary cooling, the heat is extracted from the surface of the slab by spraying water from arrays of nozzles. The goal is to achieve efficient and uniform heat removal without causing cracking in the slab. This study aims to develop and validate a reliable numerical model using Siemens gPROMS, which can accurately predict the formation of spray from flat-fan atomizers and the heat transfer between the impinging droplets and the moving hot steel slab. The model is based on an unsteady state zero-dimensional approach, which estimates the size of water droplets by considering their breakup, coalescence, and impingement. The droplet size is then used to calculate the heat transfer coefficient on the slab surface. Global system analysis (GSA) capability in gPROMS is used to carry out a detailed design space analysis to understand the impact of process variables on temperature profiles and key performance indicators (KPIs). Furthermore, these models are deployed in gPROMS to optimize the caster process, aiming to minimize defects and achieve the desired quality of the slab.

**Keywords** :Secondary cooling, water flux distribution, heat transfer, solidification, solute transport, numerical simulations, optimization

# The game changer for plate production: Ultra-thick slab bow-type casting

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## Abstract

Continuous slab casting is the undisputed number one casting technology for steel. But especially for the production of heavy and extra heavy plate the technology has been limited. To pass an ultrasonic test a reduction ratio from slab to final thickness of 3 to 4 is required. The high reduction ratio during rolling eliminates central porosity and segregation caused by the casting process. State-of-the-art thick slab casters operate at maximum thicknesses of about 400 mm, which limits the final plate thickness between 100 and 130 mm. For higher thicknesses still the outdated ingot or vertical casting route need to be applied, with all their disadvantages such as high yield losses, lower productivity, high operating costs, and inhomogeneous solidification structure.

Primetals Technologies has always been at the forefront of thick-slab casting. The latest machines sold for ultra-thick slab casting offer thicknesses up to 460 mm.

To successfully cast such thicknesses in a bow-type caster, a large number of special solutions must be implemented and fine-tuned. The starting point is an optimized geometry in terms of radius and roller layout, which is essential to improve bulging behavior and to increase slab quality. To prevent cracking during straightening, a continuous straightening process is applied over an extended length of three segments and can be combined with high-temperature casting. This is followed by hard reduction in the horizontal area of the machine, which is a solution to improve slab center quality. It reduces porosity and center segregation by applying a thickness reduction 5 times higher than conventional soft reduction right at the end of solidification.

A key feature for the positioning of the reduction step is the Single Roll DynaGap (SRD) segment, where the gap of each individual roller can be adjusted separately. These segments, combined with advanced automation solutions, allow fully dynamic alignment of the individual rollers to precisely apply the reduction at the end of solidification. Reduced center porosity and segregation make it easier to pass an ultrasonic test and reducing the amount of reduction required in the mill to <3.

This new generation of bow-type continuous casting machines with increased thickness and the option of hard reduction open up new opportunities to enter the heavy plate market, that could not be served by continuous casters before.

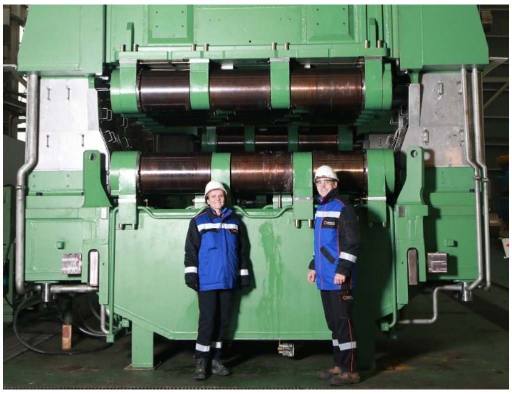

Fig. 1: SRD segment for ultra-thick slab casting and hard reduction

**Keywords** : Ultra-thick slab caster, Bow type machine, hard reduction

# Thermal Parameter Optimization for Enhanced Graphite Nodular Properties in Ductile Cast Iron through experiment and simulation

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## Abstract

This work explores the effect of thermal factors in the solidification of ductile cast iron, with a particular emphasis on the influence of cooling rate on microstructure and mechanical properties in ductile cast iron. Within the range of the eutectic transition, the material was solidified at two different cooling rates: fast and moderate. The principal aim was to determine the impact of modified cooling rates on attaining an improved graphite nodular property, which in turn affected the mechanical properties of the material. The study methodically examined quantitative nodular attributes such nodularity, nodule size, and nodule numbers using ImageJ software. Using Microsim, simulation was carried out to validate nodular properties such as nodule size and counts at these two cooling rates, with a primary focus on the temperature range of the liquid to solid transition.

A comprehensive approach was taken by the research technique, which included sample preparation, close observation, and in-depth structural property investigation. Advanced tools including optical microscopy, SEM, microhardness testing, and the Charpy impact tester were used to accomplish this. The study attempted to decipher the complex links between mechanical quality, microstructural features, and cooling rates during solidification using these methodologies. The investigation's results provide important new information about how to best utilize ductile cast iron's nodular features, furthering our knowledge of how temperature affects the material's mechanical behaviour.

**Keywords**: Ductile Iron; Cooling rate; Nodularity; Microsim; Simulation.

# Development of near-net shaped cast nanocomposite parts using high shear mixing technique

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## Abstract

Metal Matrix nanocomposites are considered to be the promising advanced materials in liquid metal casting for large volume manufacture. MMNCs based on aluminium exhibit drastic change of fracture mode from inter-granular fracture in monolithic metal to transgranular fracture in nano-composites, moderate to significant improvement in strength, moderate improvement of fracture toughness, significant improvement of creep resistance, thermal shock resistance, wear resistance and enhancement of dimensional stability at high temperatures. Synthesis of nanocomposites is challenging due to the difficulties in achieving homogeneous distribution of reinforcing particles in liquid metal. Although there are a few fabrication routes available for MMNCs, ultrasonic cavitation method or ultrasonication technique (UST) successfully combines the traditional casting with the cavitation-based dispersion of nanoparticles in molten alloys. A newer technique known as high shear mixing technique (HSM/HST) has been reported to disperse and distribute micron sized particulates in large volume Al and Mg alloys. A356-x$TiB_2$ (x =1, 2, 3, 4 wt.%) in-situ nanocomposite brake discs were fabricated by flux assisted synthesis coupled with intensive high shear mixing and vertical centrifugal casting techniques. The microstructure of the nanocomposites and the size and distribution of in-situ $TiB_2$ particles within the brake disc were characterized using optical microscopy, scanning electron microscopy and TEM. The nanocomposites contained fine sized α-Al phases, eutectic Si needles and clusters of $TiB_2$ particles. The dendritic structure of the α-Al phase in the alloy changed into the cellular structure with the addition of $TiB_2$ concentration. TEM analysis confirm the presence of nano $TiB_2$ particles and their clusters within the matrix and eutectic regions. A significant variations in the volume fraction of $TiB_2$ was absent from inner to outer regions of the disc. Hence, a small decrease in the hardness of the composites was noticed along the radial direction of the disc from the outer periphery to the inner part. Tensile and compressive strength of composites was increased with $TiB_2$ content till 3 wt.%. A similar trend was observed in the wear rate of the composites. A decrease in properties of 4 wt% $TiB_2$ composites was presumably due to the presence of large sized $TiB_2$ agglomerates and their debonding from the matrix during the testing.

**Keywords**: A356, High shear, nanocomposites, $TiB_2$

# A novel approach for simulating the solidification process in a Bridgman setup

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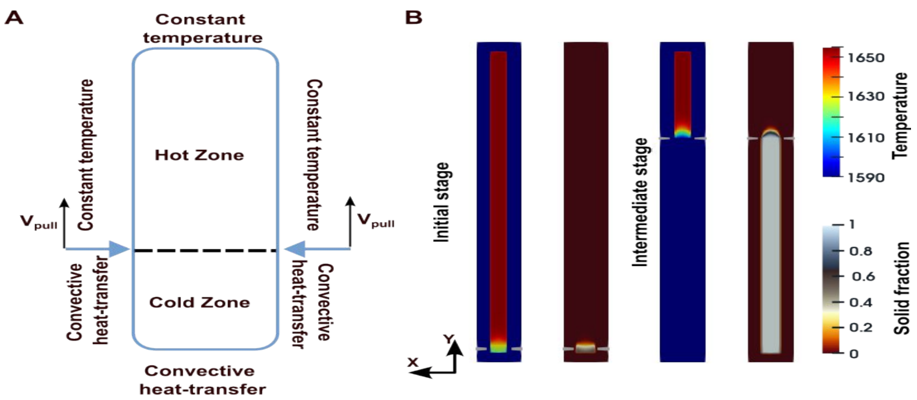
## Abstract

Slow cooling rates and large temperature gradients are crucial for single-crystal alloy casting. The Bridgman setup achieves this by slowly moving the crucible with molten alloy from its hot zone to a cold zone. During travel, the crucible exterior is maintained at a constant temperature in the hot zone, while the cold zone causes heat loss. We modeled the heat exchange and the transition of the alloy from the liquid to the solid phase in the crucible. A function based on enthalpy was used to couple the alloy solidification to the degree of its undercooling. The model was implemented using an approach based on the smoothed boundary method (SBM). We used a continuous field to modify the thermal diffusion equation of the model, which constrained it to regions where the field assumed significant values. The field also enables the application of boundary conditions at the region boundary, where its magnitude is varied smoothly.

To demonstrate the model, we simulated the directional solidification of CMSX-4 alloy in slender crucibles. The evolution of the solid phase indicated that the growth rate of the alloy crystal was unsteady in the initial stages and occurred at a constant rate later on. The change in growth rate was apparent from the morphing of the solid-liquid interface from a convex shape to a concave shape. At the interface, the temperature is close to the alloy melting point (1630 K), and the solid fraction was below unity. The uneven heat transfer that the cold zone induced at the bottom of the hot zone cooled the alloy. The heat transfer resulted in temperature gradients that are oriented parallel to build direction near the core region of the crucible. However, they had significant lateral components at the crucible periphery. The mean of thermal gradients across the solid-liquid interface increased initially but plateaued after its shape stabilized. The gain in either crucible velocity or hot zone temperature leads to a faster rate of the mean thermal gradient increase. But the maximum value it reached depended only on the temperature of the hot zone.

Fig. 1: (A) Time-varying boundary conditions on crucible and (B) directional solidification




**Keywords** : Bridgman setup, smoothed boundary method, temperature, and CMSX-4 alloy.

# Effect of La rare element on the cooling curves of binary aluminum alloys (Al-Cu, Al-Zn and Al-Ni)

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## Abstract

Grain refinement during solidification can be achieved by enhancing thermal undercooling and constitutional undercooling via increasing cooling rate, adding the appropriate solute elements, and increasing the number of effective heterogeneous nuclei through inoculation. Refined microstructures improve the mechanical properties such as yield strength, tensile strength and toughness of the alloys. This study investigates the effect of rare earth element La on the microstructure, nucleation behaviour and mechanical properties of binary Al-Cu, Al-Zn, Al-Ni alloys. The stir casting technique was used to fabricate the binary Al-X (X= Cu, Zn, and Ni) and Al-X-La alloys. The effect of La element on undercooling and other thermal parameters was also analyzed through cooling curve analysis. The cooling curve technique was used to investigate the potency of La solute in Al-X alloys during solidification. The first derivative of cooling curve was used to calculate the nucleation and eutectic arrest temperatures of binary alloys. The microstructure and mechanical properties of binary Al-X (X= Cu, Zn, and Ni) and Al-X-La alloys were investigated using optical microscopy and hardness testing. It was observed that the addition of La in binary Al-X alloys decreased the undercooling and significantly increased the hardness of Al-X alloys. On the basis of these parameters, the grain refinement mechanism for ternary Al-X-La alloys was proposed.

**Key words** : Solidification; Cooling Curves; Undercooling; Microstructures;

# Investigating Cooling Rate Dependencies of Hot Tearing in Aluminium 7075 Using Non-Mechanical Hot Tearing Models

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## Abstract

High-performance aluminium alloys are widely used in the automotive and aerospace industries due to their excellent mechanical properties, such as high strength-to-weight ratio and good fatigue resistance. However, the development of these alloys is often hindered by hot tearing during casting, welding, and additive manufacturing processes. The hot tearing tendency of an alloy varies considerably based on the cooling rate, residual stress, segregation, and secondary phases, which affect the volumetric balance within the intergranular region, strain relaxation, grain growth, and liquid backflow in the terminal stage of solidification. As a result, the hot tearing tendency of an alloy varies significantly. Therefore, predicting the hot tearing susceptibility at different cooling rates is essential.

In this study, the hot tearing behaviour of Al 7075 alloy was investigated using the Constrained Rod Casting (CRC) experiment with mould preheating temperatures set at 150°C, 200°C, and 250°C. Hot tearing susceptibility (HTS) was experimentally determined by examining the widths and locations of cracks in the rods. The experimentally calculated HTS was correlated with non-mechanical hot tearing models to investigate the role of cooling rate in factors responsible for hot tearing, such as shrinkage, material toughness near the solidus temperature, elemental segregation, and grain size. Understanding and quantifying these factors is essential for developing predictive models that can guide the optimization of processes, particularly for alloys like Al 7075.

For an accurate prediction of hot tearing as a function of cooling rate, back diffusion should be included in the non-mechanical hot tearing model. For this purpose, the cooling rate and secondary dendrite arm spacing obtained from the experiments were input into the DICTRA module to calculate the back diffusion-based solidification curve. This curve is essential for predicting hot tearing behaviour using non-mechanical criteria such as the Clyne and Davies model, Kou hot tearing model, and modified hot tearing models. To further understand the HTS of Al 7075 alloy, the solidification path and phase fractions were calculated for each alloy, and the validity of the back diffusion Scheil model was discussed.

# Minimization of cracking in 204Cu Grade Stainless Steel

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## Abstract

204Cu is a chromium-manganese austenitic stainless steel with an addition of 2-4% copper and nitrogen of 0.05- 0.25%. Due to its numerous benefits, these stainless steels can be used in different applications like Special holloware application, gas stove, sink, etc. During deep drawing of steel, cracking observed in the component, which causes high material rejection at customer end. So, the present work accounts for the minimization of cracking complaints in 204Cu. Scanning electron microscopy (SEM-EDS) were utilized to investigate the morphology and elemental analysis at the defect location. High concentration of "Na, K, Ca, Si, Al, Mg,O" was observed at the defective location which seems to be some sort of complex inclusion arising during continuous casting process. The data analysis was carried out by using AI software "Alteryx" for the identification of root cause and to find out the primary CTQ parameters contributing towards the cracking issue. The results from the analysis indicated that, lower SEN dipping of 110 mm & superheat less than 35°C were the primary contributors to the issue which also validates the results of SEM-EDS analysis. Modification were made in SEN Dipping(170-150-130),SEN Port angle(5° UP) and superheat range(>35°C) .These changes were significantly reduces the number of complaints due to cracking issue.

**Keywords:** Cracking, Alteryx, Inclusion, SEN dipping

# Microstructural and mechanical characteristics of microwave sintered ZrB2-TiC composites

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## Abstract

Zirconium diboride ($ZrB_2$) has been designated as an ultra-high temperature ceramic due to its distinctive concurrence of thermal, mechanical and physical properties, rendering it an ideal material for several applications viz., missile cones, leading edges and control surfaces of hypersonic spacecrafts, propulsion systems, refractory crucibles, furnace elements and plasma arc electrodes. However, the intrinsic brittleness and susceptibility to oxidation owing to the covalent character, limits the practical applications of $ZrB_2$, particularly in extreme environments such as aerospace, nuclear, and thermal protection systems. Therefore, the present study investigates the effect of TiC (10-30 vol.%) addition on densification and mechanical characteristics of $ZrB_2$ based composites sintered through microwave sintering. The TiC addition not only lowered the sintering temperature but also improved the fracture toughness of developed composites. The maximum relative density and microhardness were observed at 20 vol. % TiC. The maximum fracture toughness was achieved at 30 vol. % TiC due to the prominent toughening mechanisms viz., crack deflection, bridging and TiC particle pull out. The hardness and elastic modulus obtained from nanoindentation studies enhanced with the addition of TiC and composites containing 20 vol. % TiC exhibited the highest elastic modulus and hardness. The developed composites could be potentially utilized for extremely high-temperature space applications such as high-temperature electrodes, rocket nozzles, leading edges and nose caps of next generation supersonic aircrafts.

**Keywords:** $ZrB_2$-TiC composites, Microwave sintering, Vickers Hardness, Fracture toughness, Nano Indentation.

# Precision Crafting of Nano Scale Cu-Precipitates by optimizing heat treatment parameters

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## Abstract

This study is concerned with examining the synergetic effects of Ti, and Cu on quenched and tempered (Q&T) steels. Homogenised and forged steel blocks were subjected to Q&T treatments at 920℃ and 650℃, respectively to induce precipitation. Extensive study using scanning and transmission electron microscopy along with software simulation revealed the presence of (Ti, Cr)C and Cu-rich precipitates resulting in remarkably enhanced hardness and toughness of the steel. Precipitation evolution is studied with the help of MatCalc and Thermo-Calc simulation. Investigation using CCT curve simulated as a result of JMatPro envisage higher hardenability with increasing copper amount, which indicate substantial short-range diffusion, it could be resulting higher volume fraction of degenerate pearlite with increasing copper content as observed experimentally. A rich combination of strength, ductility and hardness i.e. 811MPa, 19.35% and 267±4 HV respectively has been observed after the tempering of 45 minutes along with remarkable tensile toughness of $146*10^5$KJ/$m^3$. It is evident that improved toughness is combined effect of grain refinement due to the presence complex carbides and nano-size shearable copper precipitates. Effect of variation in copper content has also been investigated and reported in relation to toughness and hardness. Evolution and transformation Cu precipitates from the BCC (coherent) →9R (semi-coherent) →FCC (incoherent) crystal structures has been investigated vividly along with corresponding change in mechanical properties. In the due course mechanical behaviour as a result of microstructural variation is concluded with the help of fractography and misfit extent of copper precipitates.

**Keywords:** Hardness, Precipitation, Tempered, Toughness and Quenched.

# Silicon Steel Production Lines for Grain Oriented (GO) and Non-Grain Oriented (NGO) Electrical Steels

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## Abstract

Decarbonization of the steel industry and electrification initiatives are leading to further growth in application of non-grain oriented (NGO) and grain oriented (GO) electrical steels.

Driven by the developing of the Electrical Mobility, the Cold Rolling area design is rapidly evolving to produce electrical steel strips optimized to reduce magnetic losses at high frequencies. Starting from an increased needs of an accurate base material "cleanliness", the design of Cold Rolling area has to be focussed mainly on final microstructure, thickness, surface finishing, accurate coating.

In the **Annealing and Pickling Lines APL,** it is needed to recrystallize the hot band with an appropriate grain size optimized also to reduce material brittleness and improving following "workability"; the descaling and pickling section must be designed to ensure an accurate scale removal combined with a reduced final surface roughness.

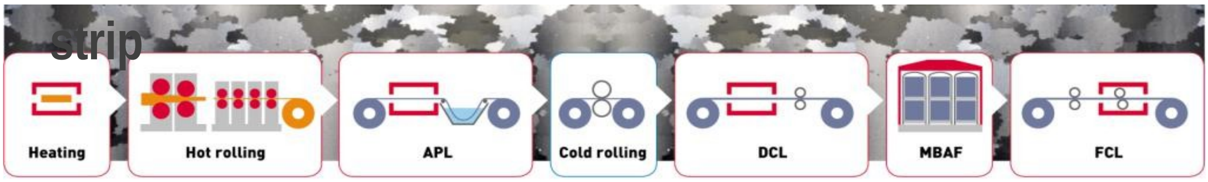
The **Reversible CRM and Lines** must be designed to allow processing of thicknesses below traditional thicknesses (0.35-0.8 mm) down to 0.15-0.27 mm through a single or double rolling /annealing process rolling and reduced final roughness (6-Hi , 18 Hi, 20 Hi mills are preferred) – this is even more important for **NGO EV Si steel**.

**Modern Annealing and Coating lines (ACL) for NGO as well as Decarburizing/ nitriding Lines (DCL) and Flattening and Coating lines (FCL) for GO** are designed to process lower thicknesses with accurate strip tension and thermal cycle control to get the top level magnetic and in case of EV Si steel also mechanical properties. Thermal process facilities with high energy efficiency and low NOx emission and Terminal equipment with special design, i.e., low inertia machines with accurate and innovative steering system have to be provided.

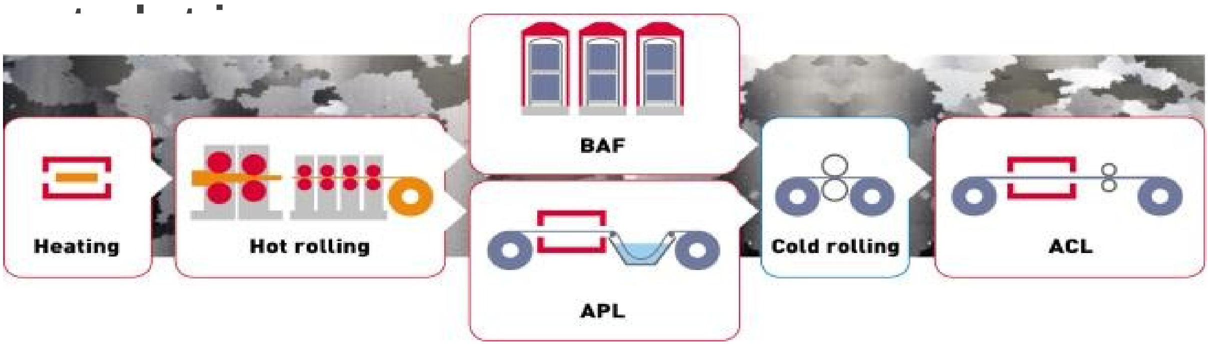
High efficiency electrolytic cleaning and brushing sections as well as advanced coating section (strip cooling, advanced varnish feeding and recirculation, automatic coaters with "closed loop gauge control" and coating room push pull ventilation) has been developed"

**In the Cold area production route**, Tenova development activities, fully integrated with Tenova-LOI Furnaces, are covering the COMPLETE RANGE OF PROCESS for Si Steel

**Production line for grain-oriented electrical steel strip**




**Production line for non-grain-oriented electrical**



# Optimizing Ni-Fe-Cu Binder Composition for Enhanced Mechanical Properties in Liquid Phase Sintered Molybdenum Alloys

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## Abstract

Molybdenum (Mo) is a refractory metal renowned for its remarkable mechanical properties at high temperatures but suffers from brittleness at room temperature. The inherent brittleness of Mo at room temperature and tendency to crack, complicates the fabrication of complex shapes through traditional casting and subtractive manufacturing methods such as machining, limiting the widespread industrial use of Mo. Liquid phase sintering (LPS) of refractory alloys presents a viable route for achieving enhanced mechanical properties while maintaining cost-effectiveness and near-net-shape capabilities. This study investigates the effects of various Ni-Fe-Cu ternary binder compositions (Ni-rich, Cu-rich, Fe-rich, and equal parts Ni-Fe-Cu) on the densification, microstructural and phase evolution, shape retention, and mechanical properties of Mo alloys. The microstructure was characterized using stereological quantification, while phase evolution was analyzed via XRD, EDS, and thermodynamic calculations. Mechanical properties were evaluated through hardness and compression testing. Results show that Fe-rich and equal-part binders lead to intermetallic formation, while Ni-rich and Cu-rich binders prevent this issue. Alloys with a Ni-rich binder achieved the highest sintered density (>99%), optimal Mo grain circularity, and low contiguity, resulting in superior mechanical properties, rivalling or surpassing other refractory alloys. This study underscores the potential of tailored Ni-Fe-Cu binder compositions to optimize the liquid phase sintering process for high-performance Mo alloys, paving the way for low-cost, large-scale production.

**Keywords**: Liquid Phase Sintering, Stereological Quantification, CALPHAD, Microstructural Evolution, Intermetallic Compound.

# Effect of spherodization on mechanical and corrosion behaviour of eutectoid wire rod steel

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## Abstract

Eutectoid wire rod have ample of application in automotive, construction and construction industry, there life span as well as mechanical behaviour of steels depend on the microstructure of material. In present study, microstructure of wire rod was alter with thermal treatment. Different weight fraction of spheriodized microstructures were achieved with the help of different heating and cooling cycles (3,5,7,9 cycles). In this process samples were heated above AC3 (780℃) then hold it there for 5 min and then cool it just below AC1 680℃ and hold it there for 5 min the whole process is called as 1 complete cycle. Spheroidization of wire rods is aimed at improving their mechanical properties, particularly enhancing ductility and toughness while maintaining strength; samples were investigate under tensile test and corrosion in two different electrolyte (for better understanding of the life span). It was observed that samples with higher fraction of spherodization shows lower resistance to corrosion but there is increase in the tensile properties. The poor resistance of corrosion is due to increase in surface area which changed during spherodization. The spheriodized cementite which act as cathode where ferrite act as anode which leads to accelerated corrosion. Depending on the spherical cementite morphology and distribution, impact toughness and hardness values were also evaluated. Parallely by increasing the number of cycles improves the ductility ~28% but reduced the strength ~30%. Fractography of all those samples were investigated which showed the presence of cup cone structure and near the fracture presence of carbides precipitates were also observed. During deformation it's also observed during transition from elastic to plastic; region can be divided into two parts i.e. uniform transition and non-uniform transition which clearly observed in tensile curves. Microstructures created by various heat treatments were also examined using a scanning electron microscope (SEM). In order to enhance comprehension of phase change, a comprehensive examination was conducted utilizing Dilatometer curves. The necessary microstructure and mechanical properties, like machinability and ductility, were also examined.

**Keyword**: Eutectoid steel; Spheriodization; Corrosion; Dilation curve; Microstructure analysis; Toughness; Machinability, Fractrography

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# Generation of virtual tensile behaviour for any isothermal aging condition from two references

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## Abstract:

The uniaxial tensile stress-strain characteristics and the resulting uniaxial tensile properties of structural alloys are of paramount importance for their application across a diverse array of industries, including aerospace, nuclear energy, automotive manufacturing, defence, petroleum extraction, and construction. Understanding how the structural alloy materials subjected to various heat treatment respond under tensile loading is essential for ensuring safety, performance, and reliability in critical applications. Conducting uniaxial tensile tests include test specimens, heat treatment and testing facilities. In absence of these, structural designer may face significant roadblocks due to the difficulty in getting immediate information regarding the uniaxial tensile behaviors of specific alloys subjected to particular aging conditions. Consequently, the absence of crucial uniaxial tensile data can lead to project delay, unexpected increase in cost and alteration in design.

In addressing this need, the current study introduces an innovative approach aimed at generating a virtual tensile behavior for an alloy subjected to any specified isothermal aging duration. This approach is predicated on utilizing two reference tensile behaviors associated with two nearby aging durations. The modeling and simulation processes employed are based on the comprehensive phenomenological model (CPM) [J. Mittra and N. T. Kumbhar, Metallurgical and Materials Transactions A:Vol. 51(4), 2020, pp. 1528-1542], which take into account the dislocation evolution within the material during the tensile deformation. A novel aspect of this research is the introduction of a method for interpolation and extrapolation of the necessary phenomenological parameters required for constructing a virtual tensile plot using the CPM. This method is not only straightforward but also seen effective in delivering reliable results, particularly when careful attention is paid to the selection of reference points. Furthermore, the virtual tensile plot, like any experimental uniaxial tensile plot can be utilized for the derivation of key tensile parameters, including yield stress, ultimate tensile stress, uniform elongation and tensile toughness. Furthermore, the study investigates ways to improve the model's versatility by enabling it to generate virtual tensile plot for any aging temperature based on two reference tensile behaviors linked to two aging temperatures for a specific aging duration, in comparison to an isochronal aging condition. These enhancements could significantly broaden the model's predictive power and provide a wider understanding of the uniaxial tensile behaviors of structural alloys under different aging conditions. The current invention facilitates a transition in reporting the mechanical behavior of an alloy, moving from an isolated aging condition to a more integrated representation of its aging behavior.

Keywords: Comprehensive phenomenological model; simulation; stress-strain behavior; virtual tensile plot.

# Engineering safe microstructure against hydrogen embrittlement in steels used for automotive applications

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## Abstract

Hydrogen Embrittlement of high strength steels is a great hindrance for the application of these steels in hydrogen storage systems. The clear understanding of how hydrogen reacts with the materials place a vital role in overcoming the embrittlement problems. A novel microstructure has been engineered to study the hydrogen trapping characteristics of retained austenite through thermomechanical treatment. In this study, an intrinsic approach of generating hydrogen traps in the microstructure to immobilize the atomic hydrogen within the microstructure. Efforts are made to stabilize nano-sized retained austenite laths in a bainite matrix by deforming the samples in the austenitic condition at elevated temperatures and then performing isothermal bainitic transformation in a thermomechanical physical simulator, Gleeble-3800. Detailed microstructural characterization is carried out using optical, scanning, and transmission electron microscopy. The volume fraction of retained austenite is measured using X-ray diffraction analysis, and Electron Back Scatter Diffraction (EBSD) is used to compare the phase fraction in the microstructure. The amount of atomic hydrogen diffused into the samples, as a function of size and volume fraction of retained austenite, is measured using a Bruker diffusible and total hydrogen analyzer. Atom probe tomography (APT) studies provide direct evidence of hydrogen localization, which helps in understanding hydrogen interactions with microstructural phases and developing hydrogen-resistant steels. The variation of the mechanical properties with and without hydrogen charging is studied using tensile testing. The results are analyzed to identify the optimum thermomechanical processing conditions to generate a nano-sized austenite containing bainitic microstructure that can store the maximum amount of atomic hydrogen without exhibiting embrittlement.

**Keywords**: Hydrogen Embrittlement, Retained austenite, thermomechanical treatment, hydrogen traps, hydrogen analyzer, Atom probe tomography

# Carbon reduction initiative in JSW Blast Furnaces

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## Abstract

JSW has taken major initiative to reduce CO2 emission in-line with country announce pledges. JSW have taken a bold step in line with our decarbonization commitments for 2030 resulting in reduction of 12 Mn T CO2. This gives us reduction of CO2 emission up to 30% from the baseline of FY22 and helping JSW to achieve less than 1.95tCO2/TCS

**Alternative Carbon Source:**

**Initiative (1) :** As part of our ongoing efforts to reduce carbon emissions, JSW has taken proactive measures to explore the utilization of biofuels such as biomass pellets and bio-charcoals as a partial replacement for coal and coke in our plant's SP and BF units. JSW sourced multiple alternate fuel samples (both biomass pellets and bio-charcoal samples) for qualifying chemical analysis. Required properties for trials include: fixed carbon content above 70%, ash content below 11%, volatile matter below 18%, and alkali content less than 4%.

**Initiative (2) :** Utilization of mixed-grade waste plastic as a partial replacement for coal and coke in our plant's BF units. The objective of this initiative is to demonstrate successful plastic injection by exploring conducting multiple trials utilizing plastic in different size. Over a period of 6 months, through multiple trials, we found that plastic granules of 3 to 5 mm size were more suitable for injection vs plastic chips, as we encountered issues with hopper choking when using chips which hampered discharge of plastic to lance. Additionally, we determined that a coaxial lance (temperature inside lance is regulated) was the ideal injection method as fusing was observed in the conventional lance caused by melting of plastic inside the lance. These findings paved way for two successful injection demonstrations. Using a coaxial lance, we injected plastic granules sized between 3 to 5 mm through one of the 36 tuyeres in the blast furnace without plastic in May'23. We also achieved injection using a similar mechanism with plastic and PCI in Jul'23 which further eased injection and discharge process. In addition to CO2 reduction, the use of waste plastic helps save costs associated with coke and the disposal or recycling of waste plastic. From a social standpoint, waste plastic injection provides an alternative use for plastic waste, contributing to the reduction of plastic pollution and the promotion of a circular economy.

**Initiative (3) :** Injection of COG in blast furnace is currently being pursued at JSW as a part of a decarbonization program across the plant. Through COG injection, we aim to reduce consumption of coke, which will effectively decrease both emissions and costs at Blast Furnace. To determine the COG-Coke replacement ratio, we completed simulations in collaboration with OEM to evaluate impact of COG injection on our 5 MTPA (Metric Tons Per Annum) blast furnace. Our simulations have shown that by injecting 50 Nm3/thm (Normal cubic meters per ton of hot metal), we can achieve a replacement ratio of 0.8 with a density of 0.45. This translates to an overall CO2 impact of COG injection at 17, encompassing Scope 1, and 2 and upstream emissions. Specifically, Scope 1 and upstream emissions decrease by 57, and 3 respectively, while Scope 2 increase by 43.

key words: Biomass, Waste Plastic Injection, Coke Oven Gas

# Microstructure Evolution in Inconel 718: A Phase-field Study

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## Abstract

This study provides an in-depth computational investigation into the microstructural evolution of Inconel 718, a nickel-based superalloy for high-temperature applications due to its remarkable strength and resistance to thermal degradation. Through computer simulations, this research delves into the effects of heat treatment, with a particular focus on double aging and temporal evolution of ordered precipitates. A novel phase-field model is developed which can take into account the coherency states of both $\gamma'$ and $\gamma''$ precipitates in a disordered $\gamma$ matrix. Using this model, we perform a comprehensive parametric study to predict the optimal heat treatment conditions. These conditions are essential for achieving the desired precipitate morphology and size distribution, which are critical factors in enhancing the mechanical properties of the alloy. The findings from this study are anticipated to make a significant contribution to the ongoing development and optimization of the processing condistions of Inconel 718, offering valuable insights that could lead to improved performance in high-temperature service condition.

Keywords: Inconel 718, heat treatment, microstructure evolution, phase-field model

# Effect of TMP Parameters on the Transformation Kinetics of Bainite During Isothermal Bainitic Transformation

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## Abstract

The effects of plastic deformation below the non-recrystallization temperature and varying cooling rates on the bainitic transformation have been examined using dilatometry, optical metallography, and electron microscopy. Plastic deformation below the non-recrystallization temperature inhibits the bainitic transformation by retarding bainite growth due to the presence of dislocation debris in the deformed austenite. The initial transformation rate is enhanced at low deformation levels because the deformed austenite provides additional nucleation sites. However, the final transformation rate is reduced due to the slower growth of bainite. The interaction between accelerated nucleation and retarded growth creates a complex relationship between phase transformation kinetics, applied strain, and cooling rates. The overall transformation kinetics are faster than non-deformed samples for small deformation strains at 900 °C. Conversely, extensive deformation accelerates the initial transformation rate but decreases the bainite fraction in the final microstructure. This phenomenon is attributed to the mechanical stabilization of the deformed austenite and the high transformation velocity, which results in increased impingement between bainite sub-units. This impingement inhibits bainite growth, leading to a higher volume fraction of martensite in the final microstructure. Without deformation, increasing the cooling rate and shortening the incubation period for isothermal transformation lead to refining the bainite packet size.

**Keywords:** bainitic ferrite; transformation kinetics; mechanical stabilization; nucleation; and non- recrystallization temperature

# An Innovative and Sustainable Approach to Enhance the Mechanical Properties of High-Strength Martensitic Spring Steels

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## Abstract

The pursuit of enhancing advanced high-strength steel's mechanical properties is unremitting. Heat treatment remains a cornerstone in this pursuit, wherein altering the austenitisation and tempering temperatures, plays a crucial role in modifying steel characteristics effectively. To address this challenge without increasing production costs, step tempering, a novel heat treatment method, emerges as a promising avenue. It involves controlled heating and cooling stages during tempering to optimise the steel's microstructure and properties. During this process, retained austenite decomposes, and the formation of transition or alloy carbides begins. Retained austenite, especially in the form of nanofilms, exhibits enhanced stability due to its fine morphology, being surrounded by harder phase martensite, and a higher percentage of carbon diffusion from the martensitic matrix during tempering. This retained austenite contributes to an increased strain hardening and improves the mechanical properties of the steel. Additionally, finely precipitated carbides throughout the steel matrix, further enhance its mechanical properties. This study employs step tempering to adjust the retained austenite content and fine carbide precipitation, effectively addressing the challenge of enhancing the toughness of high-strength martensitic spring steels while preserving their strength. Comparing this method with normal tempering highlights the advantages of this innovative approach. By examining the impact of step tempering on the microstructure and mechanical properties of martensitic spring steels, this research holds immense potential for advancing heat treatment processing and enhancing the performance of advanced materials in various applications.

Keywords: Step Tempering; Martensitic Spring Steels; Retained Austenite; Cementite carbides; Sustainable;

# Eliminating Hot Mill ICDP Work Roll Failures at Tata Steel India

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## Abstract

Understanding and investigating roll failures in the hot mill is a very complicated subject. Post-mortem analysis requires for precision insights and actual data of the rolling mill. It also requires deep technical knowledge of the subject of rolls and the rolling process.

The present paper captures the journey into the investigation of Tata Steel's Finishing Mill Work Roll (FMWR ) Failure at the conventional Hot Strip Mill (HSM) at Jamshedpur.

In this case of HSM FMWR failure, it was found that there was one failure mechanism on the work roll. This was a surface-initiated crack which traversed the roll shell through a ribbon fatigue path.

The other finding was the morphology of the graphite in the shell matrix which significantly influences the rate of crack propagation through the shell.

Detailed investigations in the case was done through visual examination of the fracture faces, metallographic investigations , rolling signals analysis and literature review.

The proposed corrective actions taken have helped us in preventing further roll failures till date.

The paper captures the journey of the Cross Functional Team to arrive at the correct root cause and prevent its recurrences.

Keywords-Hot Rolling Flat; Work Roll ; Finishing Mill ; Spalling , Failure

# Root Cause Analysis and elimination of stretcher strain defect in Bake hardened galvannealed flat steel

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## Abstract

Here in this paper we have studied the stretch mark defect having X shaped appearance on the bake hardening grade. The SEM characterization is done to analyse the defect and EDX analysis is performed to evaluate the chemical composition at defect and okay region. A root cause analysis is performed for the processing conditions at different process line. The impact of furnace line tension at the continuous galvanizing line is analysed and summarized in this paper.

Achieving optimal BH effects requires precious tension and temperature control during production. Variations in line tensions, and in addition of non-uniform stress distribution, can lead to localized yielding stretch marks on the material's surface during forming (Fig 1). Improper felt condition, high temperature and weight of the coil leads to non-uniform stress distribution and that results in the formation of Lüders band which usually makes a well-defined angle of 45-50º with the coil creating X like mark on the surface. Figure: 1 illustrates the influence of tension, strain and load of the coil from zinc pot to top roll. Addressing these challenges involves optimizing pot tension control systems, rigorously monitoring tension levels, and regularly changing the felt to enhance material flow and minimize localized yielding. Maintaining proper temperature before water cooling (WC) was crucial, so placement of pyrometer for continuous monitoring and good temperature control. Press forming every lot and thoroughly inspecting each coil has completely eliminated the possibility of supplying defective material that could lead to aesthetic flaws.

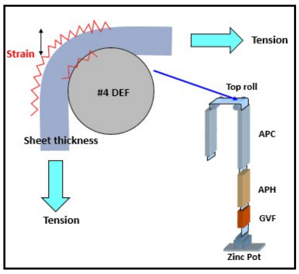


Figure 1: Effect of Tension on yielding

**Key words** : Bake hardening, localized yielding, Stretcher Strain

# Mitigation of Luders band or Stretcher Strains in formed components of FerriticStainless Steel Grade 430

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## Abstract

Stainless steel type 430 is currently the most used ferritic stainless steel grade in the world. The grade with high chromium (16-18%) has remarkable corrosion resistance for wide range application such as dishwasher, washing machine and aesthetic decorative applications. The formation of Cottrell atmospheres and propagation of Luders band during sheet metal forming process can leads to surface defects which is called stretcher strains in formed components. A schematic study on Luders band elimination in thinner gauge below 0.40mm thickness sheet of ferritic stainless steel grade 430. The results show that favourable mechanical properties and suppressed yield point can be achieved by the optimization of annealing temperature at bright annealing process.

This article presents a systematic study has been undertaken to investigate the causes behind the yield point phenomena. According to computational thermodynamic and phase diagram Thermo-Calc tool, the volume fraction of carbides and nitrides of the type MX & $M_{23}C_6$ precipitates drastically reduced in metal matrix when the annealing temperature go beyond 850°C which results discontinuous yielding and formation of Cottrell atmospheres. Hence, more efficient precipitation of such precipitates and in other words the amount of free C & N (Interstitial Atoms) must be controlled through modification of annealing parameters and decreasing cooling rate during post annealing treatment. In order to dimmish the Luders band issue, the soaking temperature freezes to 830°C at bright annealing process and further providing adequate cumulative elongation at skin pass mill to suppress the yield point along with desired mechanical properties which can be beneficial for forming application and which were optimized by extensive lab scale heat treatments. And, which can also help to avoid the multiple re-work at skin pass mill, reduces the internal diversion and customer complaints.

**Keywords:** Ferritic stainless steel type 430, Luders Band, Cottrell atmospheres, Thermo-Calc, MX & $M_{23}C_6$ precipitates

# Optimization of Heat Treatment Cycle to Prevent Quench Cracks in 5150 Grade Rolled Steel Shafts

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## Abstract

Quench cracking in 5150 grade rolled steel shafts is a significant issue affecting the structural integrity of these components. This study investigates the root causes of quench cracks and proposes an optimized heat treatment cycle to eliminate these defects. Metallurgical analysis of cracked samples revealed a grid-like pattern in the microstructure, linked to issues during the quenching process.

Induction heating, widely used in the surface hardening of 5150 grade steel, introduces complex local thermal cycles that lead to rapid heating and cooling, resulting in significant metallurgical changes. Our study identifies that martensite tempered at 600°C can become overaged, forming coarse carbides along lath boundaries, leading to the grid patterns observed. This is attributed to carbide precipitation rather than chemical inhomogeneity. While tempering aims to form fine carbides within the martensitic matrix, excessive heating beyond the optimal tempering range results in coarse carbide formation within the ferritic matrix, negatively impacting the material's mechanical properties.

An optimized heat treatment cycle, involving hardening at 850°C with a 2-hour soak followed by tempering at 550°C for 4 hours, was developed. This cycle successfully eliminates the undesirable grid patterns and enhances the mechanical properties of the steel shafts. The study details the microstructural analysis methods and experimental trials conducted to reach these conclusions.

The time- and temperature-dependent microstructural developments observed in this study are directly applicable to induction hardening processes, providing a practical solution for improving the quality and durability of 5150 grade steel shafts. These findings offer valuable insights for manufacturers addressing similar quench cracking challenges, ultimately contributing to the production of more reliable components for high-stress applications.

**Key words** **:** heating rate, induction heat treatment, steel, 5150

# Effect of section thickness and alloying element (Mo) on microstructure and mechanical properties of Austempered Ductile iron.

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**Abstract:** The objective of this study was to assess the effect of casting thickness and the alloying element (Mo) on the mechanical properties and microstructure of austempered ductile iron (ADI). The ASTM standard A-897-grade-1 was followed in the production of ductile iron, which was then cast into a Y-block and machined into sections with thicknesses of 15 mm, 20 mm, 25 mm, and 30 mm for molybdenum and without molybdenum. To create ADI, all plates are austenitized for 2hrs at 870˚C and then austempered for 2hrs at 370˚C. The microstructure and mechanical properties were then described. The microstructure was examined under an optical microscope, and XRD was used to determine the crystallite size and %RA. According to ASTM standard technique, their hardness and strength were also assessed. The microstructure of with moly plates were observed ausferrite but in without moly 30 mm plate pearlite patch observed. Due to microstructure difference without moly plates mechanical properties goes down drastically. The study concluded that the structure and mechanical properties of ADI strongly depends on casting thickness and chemical composition.

**Keywords**: Ausferrite, section thickness, Austempered ductile iron, tensile testing.

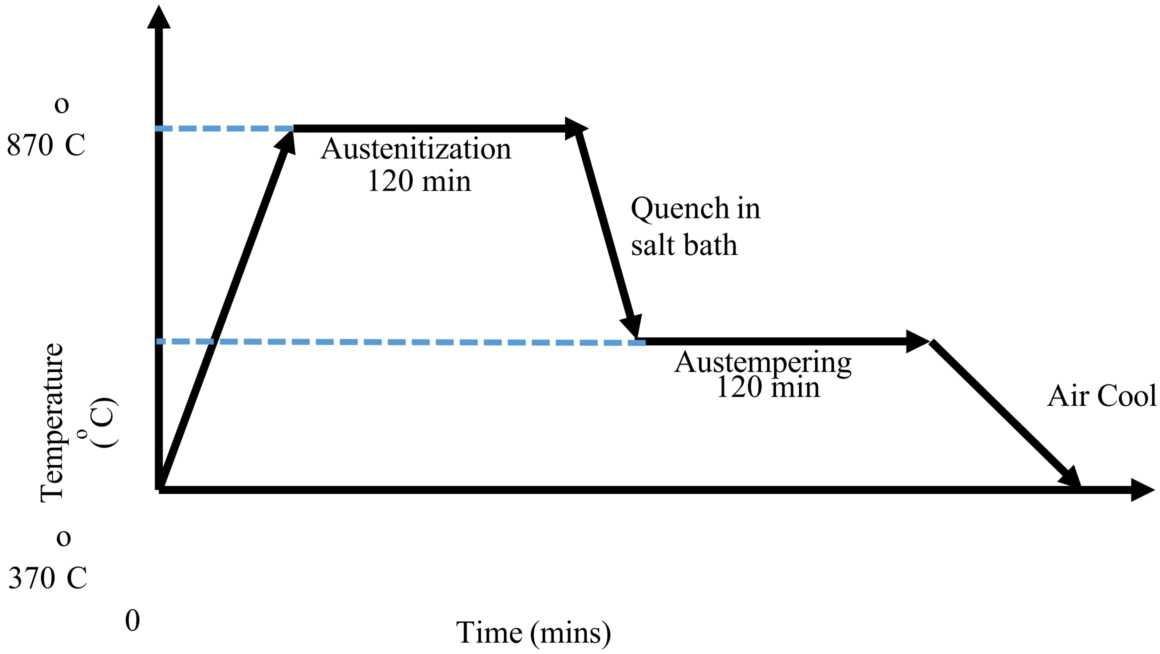


Fig.1 Heat treatment cyc

# Development of High Strength Thinner Gauge Hot Rolled Steel Coils for Lighter Domestic LPG Cylinders

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## Abstract

This work describes the development of a new high-strength steel for LPG cylinders by Steel Authority of India Limited (SAIL) to meet the needs of Oil Marketing Companies (OMCs) in India. The OMC design requirement called for lighter domestic cylinders (approximately 2.3 kg reduction) with thinner walls (2.2 mm) compared to the conventional cylinders while maintaining safety standards.

This was achieved by developing a high-strength steel grade (IS 15914 HS345) at SAIL's Rourkela Steel Plant (RSP) with a minimum yield strength of 450 MPa and ultimate tensile strength of 540 MPa. The steel's microstructure was optimized through precise control of the steel rolling process, employing a high soaking temperature of 1220°C, a targeted finish rolling range of 860-880°C and a coiling temperature of 620-640 °C. This ensured strong tensile properties in the HR coils, compensating for the decrease after the normalizing stage of the formed cylinder.

The thinner gauge HR coils made from this steel allowed for fabrication of LPG cylinders through deep drawing with a draw height of 250 mm and strict adherence to the maximum allowable thinning criterion (2 mm) for structural integrity. These cold-drawn and MIG-welded cylinders underwent normalizing heat treatment at 900°C.

The resulting cylinders, achieved with the thinner gauge, high-strength steel coils, exceeded the required safety standards for burst pressure (125 kg/cm²), volumetric expansion (24%) and tensile tests (YS: 380-410 MPa, UTS: 500-540 MPa, %Elong.: 19-23%). This development is expected to make India self-sufficient in high-strength, lightweight LPG cylinders and contribute to the "Atmanirbhar Bharat" initiative.

Keywords: LPG cylinders, lightweight

# Improvement of Stretch Flangeability of DP 980 Steel by microstructural modification of cut edge

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**Abstract**

The automobile industry uses dual-phase (DP) steels to achieve lightweighting and improve passenger safety. Among DP steels, DP 980 grade steel is gaining wide acceptance. However, DP steels fail easily during stamping operations due to their poor stretch flangeability. Stretch flangeability of a material is the resistance to through-thickness crack propagation during edge stretching operations. There are various conventional heat treatment methods available to improve the stretch flangeability of DP steel. The complete heat treatment of the entire DP sheet blank can reduce the strength of the entire sheet therefore it is not suitable for production of high load-carrying auto parts. Stretch flangeability is usually measured by a standardized test called hole expansion testing. In hole expansion testing, 90 mm x 90 mm sheet specimens with a central hole of 10 mm diameter are prepared and the central hole is expanded using a conical punch till onset of a through thickness crack. The percentage increase in the hole diameter is referred to as the hole expansion ratio.

In the current study, an attempt has been made to improve the stretch flangeability of DP 980 steel by locally modifying the microstructure and hardness at the hole edge using a micro-plasma heat source. Standard HET specimens 90 mm x 90 mm square with a 10 mm diameter central hole were prepared and a micro-plasma torch with a controlled heat input was used to locally heat treat the edge of the hole. This ensures local softening around the circumference of the circle resulting in decrease in hardness and change in microstructure. The hole expansion test (as per standard ISO 16630) was carried out to identify the stretch flangeability of DP 980 steel. Local heat treatments with varying heat inputs from the microplasma were investigated and the corresponding hole expansion ratios were measured. Optimum heat inputs for improving hole expansion ratios have been identified. This has been correlated with local changes in microstructure and hardness.

Keywords: Dual Phase steel; Hole expansion ratio; hole expansion testing, Micro-plasma torch

# Improving Evaporator Economy Promoting Lower Carbon Footprint

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## 1. ABSTRACT

Evaporation process is an important section in alumina production by Bayer process. It consumes a large amount of thermal energy and helps to manage water balance in refinery. To produce alumina from bauxite ore, the weak aluminate liquor has to be concentrated through evaporators, so that it can be recycled back to the digestion.

Reducing energy consumption in alumina production is always an important research topic in the field of alumina refinery, having some of the oldest technology evaporation units in plant, it has always been a challenge to achieve benchmark energy norms.

Renukoot Alumina Refinery is one of the oldest refineries in the world. Being the oldest refinery, various evaporation technologies are installed in Renukoot alumina plant, i.e., Multistage Flash Evaporation, Multistage Falling Film Evaporation and Multistage Rising Film Evaporation. A comprehensive analysis was carried out considering drawbacks in existing system and consequently actionable points were identified for attaining the objective. In this case we described the stepwise approach on the successful journey of steam economy improvement of one of the oldest technology evaporation units through process re-engineering, refinement in process control and improved operational practices.

**Keywords: Evaporation Technology, Steam Economy, Process re-engineering, Energy Reduction, Lower Carbon Footprint.**

## 2. Background

Alumina cost of production was increasing significantly, and Steam was the major cost driving factor for Alumina production, The total impact of steam consumption is approx. 17% in cost of production of Alumina. **Fig.1**

Renukoot alumina refinery is operating with 3 Nos of Evaporator with average steam economy of ~ 2.8-2.9 t/t. However, there have been some instances wherein the evaporator has achieved ~ 3.0 t/t steam economy, but it is not sustained on a continuous basis. So, there is a need to arrive at a set of process conditions, which can be implemented in the refinery so that an overall steam economy of evaporators can be consistently achieved in the range of 3.5 t/t.

In this Paper we described a stepwise approach on the successful journey of Steam Economy improvement through Process Re-engineering, Refinement in process control improved operational practices and data analysis.

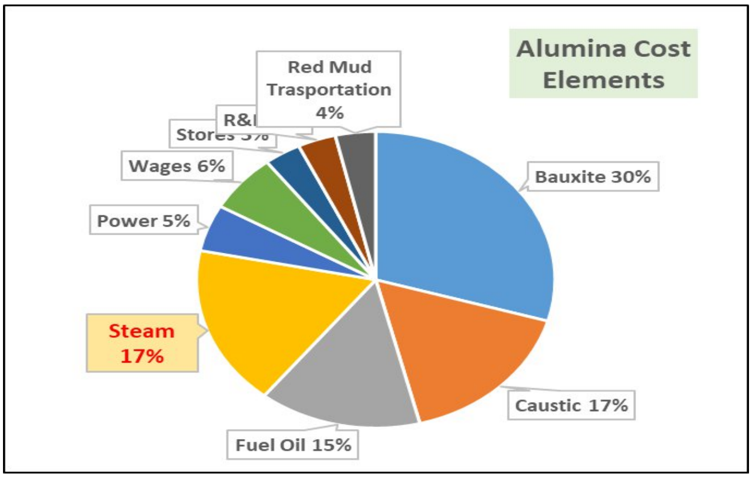



**Fig. 1**

## 3. Process:

A comprehensive analysis was carried out by team considering drawbacks in existing system and consequently following actionable points were identified for attainment of objective:

- Increase in hot spent temperature feeding to Evaporators.
- Optimization of feed flow, vacuum and other process parameters impacting steam economy thru data analytics.
- Utilization of Feed flash vapor enthalpy as Evaporation feed.
- Process re-engineering by installing vacuum pump in place of steam ejector.

## 4. Methodology adopted:

- Process Re-engineering
- Refinement in process control
- Improved operational practices.
- Data Analytics.

## 5. Actions Taken

### 5.1 Improvement in Hot Spent Temperature.

Temperature of Hot spent liquor plays a major role in reducing steam consumption and thereby achieving higher steam economy of Evaporators. In house process modification was done to increase hot spent temperature with the help of old PHE, good condensate of digestion-2 area, which is at the temp. of ~130C is utilized to increase hot spent liquor temp from 67C to 75C. **Fig.2**

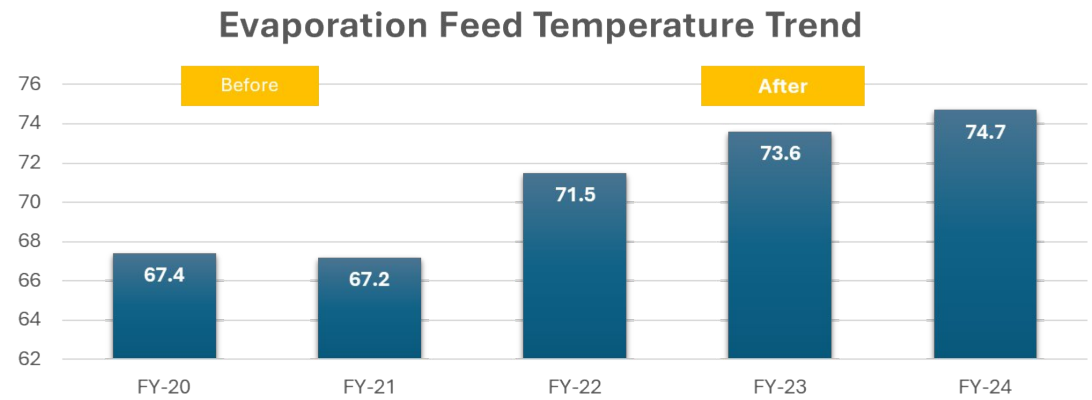



Fig. 2

## 5.2 Process refinement using Data Analytics

Past data was analysed thru Data analytics with detail brainstorming amongst the team member to arrive a set of operating parameters for better steam economy and higher evaporation rate.

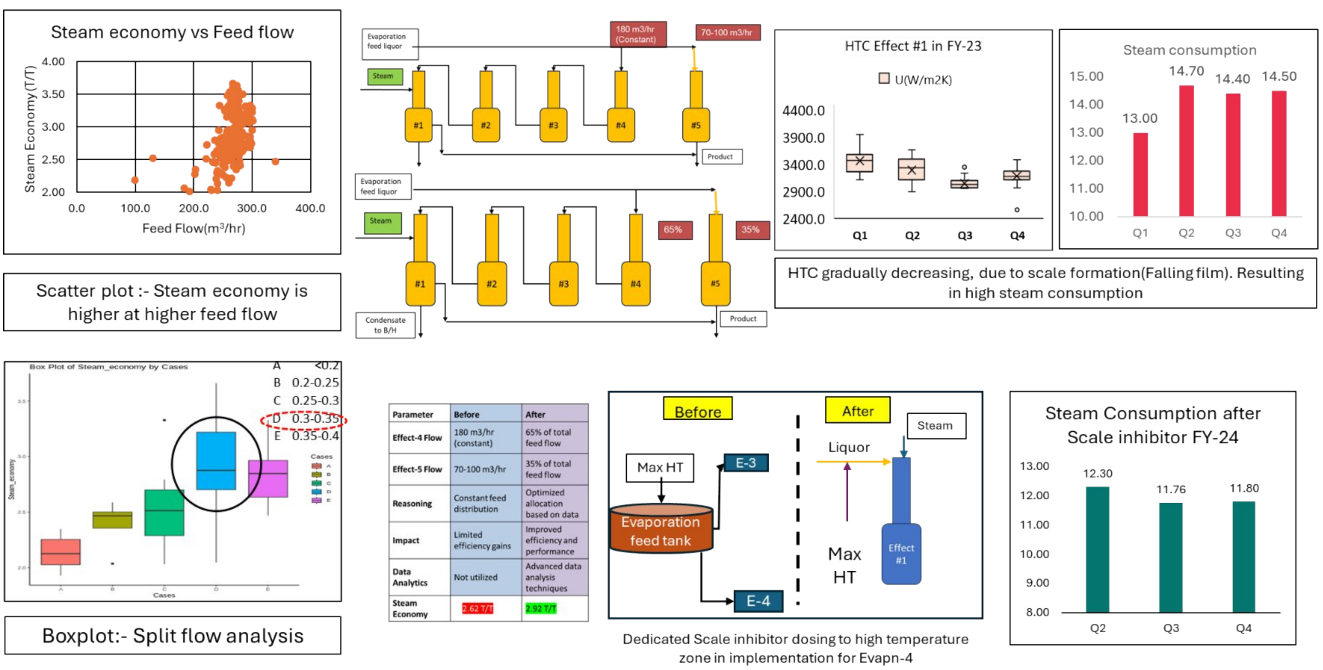



Fig. 3

### 5.3 Utilization of Feed flash vapor enthalpy as Evaporation feed:

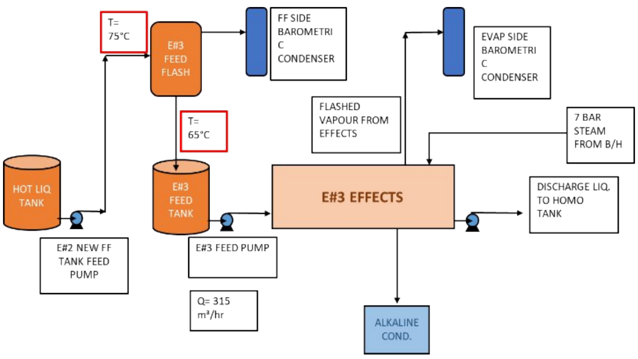
It was observed that, there is a temperature drop due Evaporation feed flash tank is in line, So the Operational philosophy changed from traditional to innovative way by bypassing the feed flash and feeding the high temperature spent liquor to evaporation circuit which reduced the steam consumption.

**Before:**

- When E#3 Feed flash tank is in line with vacuum of 585 mm Hg, it gives 6TPH evaporation against 10°C temperature drop. **Fig. 4**

**After:**

- When E#3 Feed flash tank is in line with no vacuum, evaporation feed temperature is same as hot spent liquor temperature.
- LSH inlet temperature increases by 5°C(earlier 104 °C vs now 110 °C) **Fig. 5 & Fig.6**



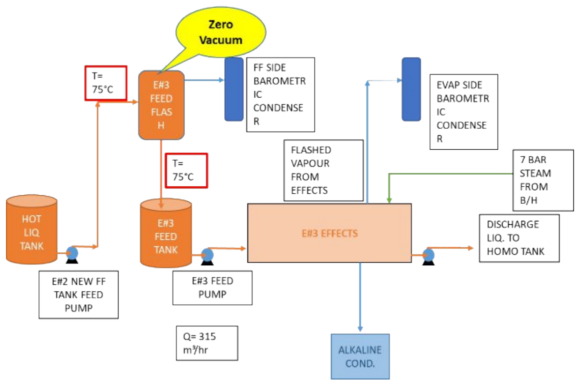




**Fig. 4** **Fig. 5**

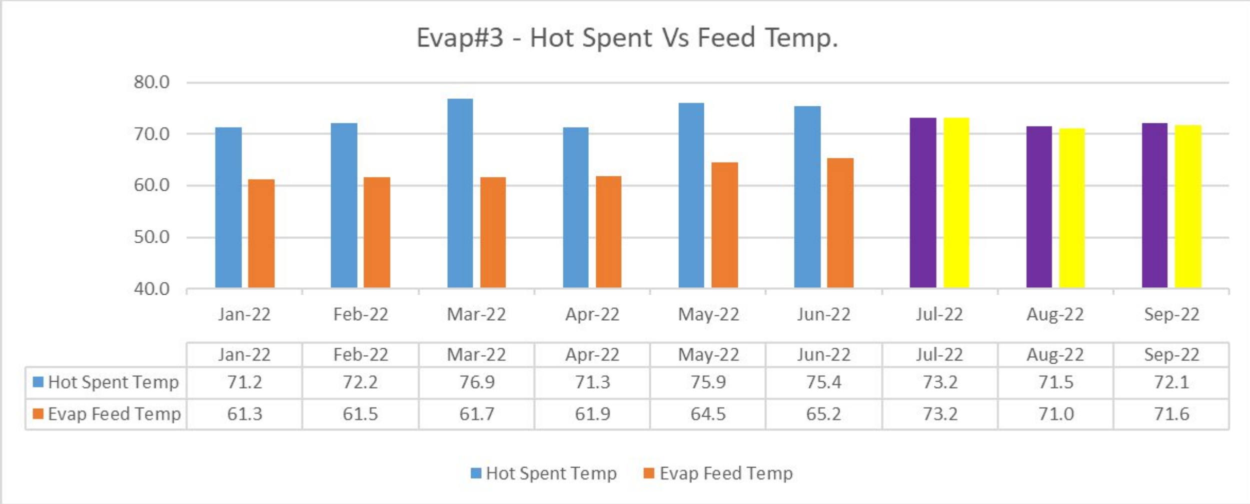
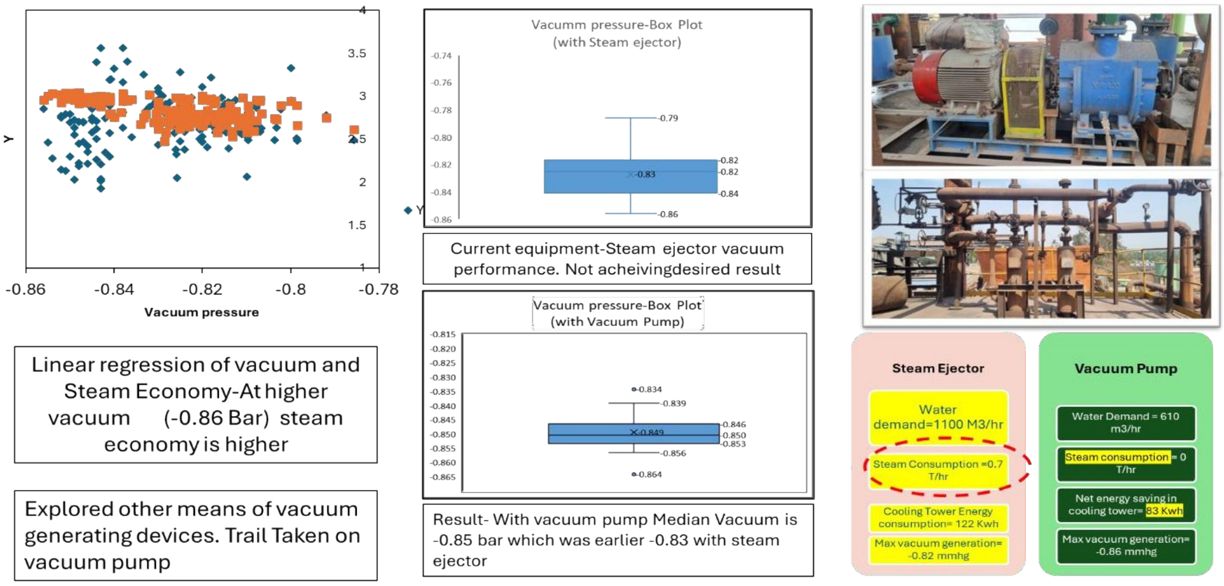



**Fig. 6**

## 5.4 Process Re-engineering

Installation of vacuum pump in place of steam jet ejector

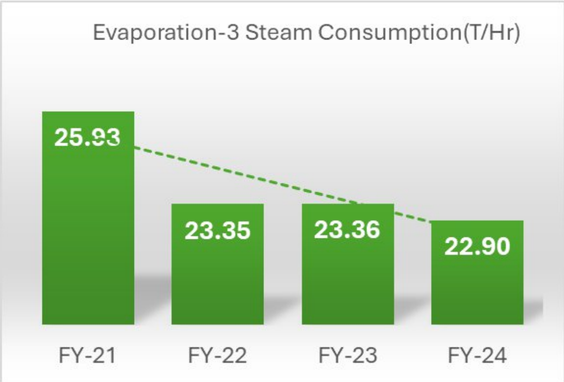


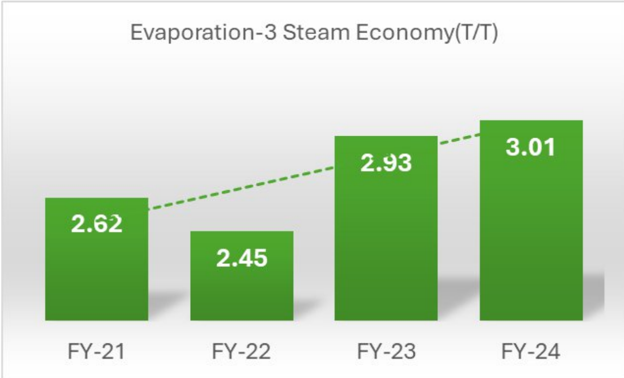

## 6. Major Challenges:

- Dependency of Hot Spent Liquor Temperature on precipitation process Control.
- Soda carryover in flash vapours hampering hot well conductivity.
- Optimization of Evaporation feed flow without impacting plant performance.

7. **Final Outcome/Deliverables:**

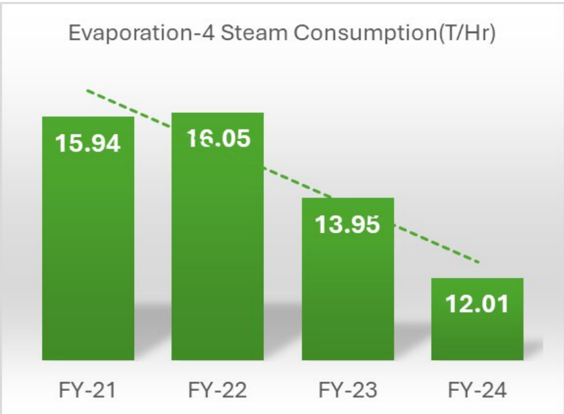
The steam economy of Evap-III achieved from 2.6 t/t to 3.0 t/t with an overall steam saving of 3.01 TPH.

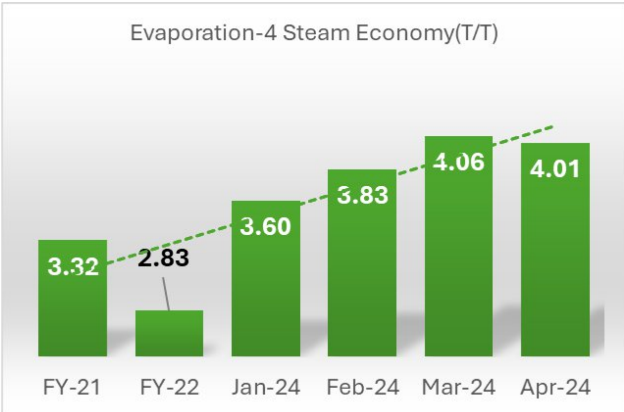



Net Steam Saving of 3.01 T/Hr saving in Evaporation-3

The steam economy of Evap-IV achieved from 3.32 t/t to 4.0 t/t with an overall steam saving of 3.02 TPH.




Net Steam Saving of 4.02 T/Hr saving in Evaporation-4

Fig. 7

# Effect of section thickness on Grade 3 175-125-04 Austempered ductile iron (ADI) casting.

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## Abstract

Austempered ductile iron (ADI) is an alloyed ductile iron that is heat treated by an austempering process. This austempering process includes heating the casting to a fully ferritic, homogenous condition and then cooling it to a controlled temperature above the martensitic start temperature. This isothermally transforms the matrix structure to achieve the desired properties. ASTM A897 175-125-04 is one of 6 grades of ADI. It can be used as an alternative to steel forgings, providing cost savings with high strength and abrasion resistance.
Heat treatment carried out for two different section thickness (25 mm & 50 mm Y-Block). both the specimens were subsequently austenitized at 900$^0$C for 150 mints. and austempered in a salt bath for constant austempering temperature at 310ºC for fixed time period of 150 mints. microstructure analysis was done through optical microscopy and retain austenite percentage through X-ray diffraction. Tensile properties were determined and same were correlated with the microstructure. The results reveals that there is no much effect of section thickness on mechanical properties, ductility austenitized at 910°C and austempered at 310$^0$C for 150 mints. respectively.

Keywords: ADI, Austenising temperature, Austempering temperature, retain austenite, un-notched impact energy.

**Referances**

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# Experimental and first-principles investigation of diffusivity in bond-coat and Ni-based superalloy

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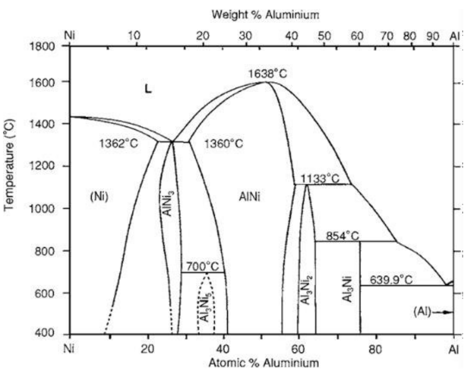
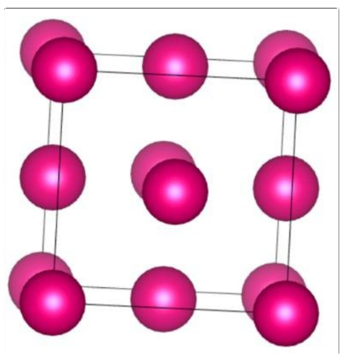
## Abstract

In this work, we are going to perform the following experiments and DFT calculations for better understanding of diffusion mechanisms in different phases and to develop a reliable mobility database. The diffusivities have been determined in the gamma phase for the binary system where Ni-Ni5X have been coupled at different temperatures and activation energy of diffusion has been estimated. At the cross of Ni5Al/Ni5X and Ni/Ni5Al5X using experimental methods, we have then estimated diffusion parameters in ternary system. Moreover, the density functional theory (DFT) calculations were performed to calculate activation energy in Ni-X (FCC) systems using VASP code. The elements considered as impurities are Cr, Mo, Re, Ta, and W. After that, it is shown that adding Al influences the migration of these impurity elements. In gamma phase, irrespective of binary or ternary system, Ta diffuses fastest in comparison to other elements. In γ' phase, Ni3Al/Ni3(Al-X) pseudo-binary diffusion couples have been prepared for same set of "X" atoms at different temperatures. Using the known Hall method, we have calculated impurity diffusion coefficients of X-atoms in γ' phase. The trend for diffusion coefficients of solute elements in Ni3Al is explained by DFT calculations. In gamma-prime, it's the Cr which diffuse the fastest of all other elements. It is concluded that the electronic configuration of solute and host elements are responsible for the observed trend of diffusivity.

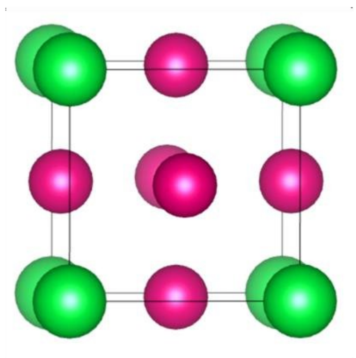
Key words: Solid-solution phase, γ' phases, DFT, Ternary, Hall Method




**Ni-Al phase diagram**



**Ni crystal structure**



**$Ni_3Al$ crystal structure**

# Effect of Austmepring Temperature On Microstructure And Mechanical Properties Austempered Ductile Cast Iron

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## Abstract

Owing to their exceptional physical, mechanical, and technological properties, ductile cast irons have been increasingly used, especially in automotive industries. Heat treatment process can alter strength of ductile cast iron. This work is aimed at study the effect of austempering temperature on microstructure and mechanical properties of austempered ductile cast iron. Y blocks of 25 mm were used in this study. The austenitizing was carried out at constant temperature of 870 °C for 180 Minutes. During austmepring samples were heat treated in salt bath at different asutempering temperature of 310 °C, 340 °C, 370 °C for 180 Minutes. Optical metallography was used for microstructure analysis. Mechanical properties were obtained by tensile test, hardness test. Retained austenite phase fraction was evaluated by XRD method. Results shows that as austempering temperature is increased, yield strength, tensile strength and hardness lowered, while elongation is increased. Also retained austenite phase fraction is increased with increasing austempering temperature. Highest mechanical properties except elongation obtained at austempering temperature of 310 °C. At 310 °C austempering temperature very fine ausferrite structure obtained as compared 370 °C austempering temperature.

key words : Ductile cast iron, austempering, ausferrite, retained austenite

# Development of magnetic quality texture in warm-rolled carbon free Fe-3.78%Si (Wt. %) alloy for non-oriented electrical steel (NOES) applications.

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## Abstract

This study focuses on developing a magnetic quality texture for non-oriented electrical steel (NOES) in a carbon-free Fe-Si alloy. The effects of heat treatment on the microstructure, texture, magnetic properties, and mechanical properties of warm-rolled Fe-3.78%Si were investigated. Iron-silicon alloys were prepared through vacuum arc melting, homogenization, and warm rolling at 600°C. Warm-rolled samples underwent heat treatment at 900, 1000, and 1100°C for 1 hour. Microstructure and texture were analysed using SEM-EBSD, magnetic properties were evaluated with a Vibrating Sample Magnetometer (VSM), and mechanical properties were assessed through Vickers hardness testing. The warm-rolled microstructure exhibited grains elongated along the rolling direction with evidence of dynamic recrystallization. Increasing the annealing temperature led to grain growth from 36 to 95 micrometres. SEM-EBSD results indicated that higher annealing temperatures promoted the development of Cube and Goss textures (partially), likely attributed to deformation characteristics and increased grain size. No significant changes in hardness were observed between warm-rolled and heat-treated samples. The relationship between texture and magnetic properties was explained, and potential mechanisms were identified [1-4].

Key words

: FeSi alloy; Microstructure; Texture evolution; Magnetic and mechanical properties.

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# Influence of solution treatment on mechanical properties and fracture behaviour of aluminium 7068 alloy

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**Abstract**:

The impact of solution heat treatment on the generation of secondary phases and mechanical properties of 7068 Al alloy has been studied in this research work with the help of electron microscope (EM) scanning electron microscopy (SEM), energy dispersive X-ray spectrometry (EDS), hardness, tensile and fractography tests at solution temperature secondary phase particles start to dissolve which leads to single phase formation. Secondary phase particles while $MgZn_2$ $Al_2Cu_2$mg and $Al_7Cu_2$Fe were randomly distributed on as rolled sample. Solution treatment Sudden quenching leads to dissolution of secondary phases in α al matrix and precipitate doesn't get enough time to evenly distribute along the grain boundary. Microhardness and tensile strength of as rolled al 7068 were 180 HV and 670 Mpa while for solution treated sample it was observed 140 Hv and 525 Mpa respectively. Compared to the as-rolled alloy, the microhardness and tensile strength of solution treated sample has decreased by 28.57% and 21.64% and elongation of the sample under solution heat treatment at 470 °C for 2 h are increased by 101.1%, respectively This is due to complete dissolution of the eutectic $Mg (Zn, Cu, Al)_2$ phases in α Al matrix which leads to single phase formation and consequently improve ductility of materials .As rolled sample has been further processed using friction stir processing (FSP) technique to enhance localised mechanical property. Friction stir processed (FSP) sample has shown 'W' shape pattern in hardness testing which indicate the hardness of the nugget zone is higher compare to other zone due to direct contact of FSP tool which leads to heating and grain refinement. The hardness of nugget zone in FSP processed sample has been observed 116 HV compare to 140 HV of base metal the heating of nugget zone leads to averaging Fractography analysis has been done to analyse the fracture behaviour of al 7068 In solutionised Al 7068 sample. The cracks and dimple were shallower, uniformly distributed and cup shape which indicates slower crack propagation, necking formation and ductile cup and cone failure while in as rolled sample the dimples were non-uniformly distributed apart from that presence of micro cracks and cleavage plane reduce the plastic deformation.

Keywords: solution treatment, friction stir processing, microstructure evolution, secondary phases, mechanical properties, grain boundary, 7068 Al alloy.

# Effect of variation of weight percentage of Zinc in 6061AA

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## Abstract

In the present work, a new Al alloy was developed in billet form by adding the 1wt.% - 4wt.% Zinc in 6061AA alloy through the stir casting process and all these alloys are compared with the billet of 6061AA alloy. All the alloys underwent 180°C ageing temperatures. The findings demonstrate that adding 1- 3 wt% Zinc to 6061AA alloy does not alter the sequence of precipitates in the alloy i.e. with the formation of supersaturated solid solution (SSSS), Mg-Si atomic clusters zones, and subsequent precipitation of β'', β', and β phases, and no η′ is formed while the addition of 4wt.% Zn in 6061Al alloy lead to the formation of η′ i.e. the sequence has been interrupted. After the ageing treatment, all the alloy's hardness, tensile and Fatigue test strength compared to base 6061AA Al alloy. In addition, 1wt.%, 2wt.%, 3wt.% and 4wt.% in 6061AA Al alloy after ageing at 180°C for 10 hr, 8hr, 8hr, and 6hr maximum strength of 385MPa, 390MPa, 395MPa and 405MPa, percentage elongation 13.8%, 12.6%, 12% and 9% and hardness of 138HV, 140HV, 142HV and 145HV were achieved. Whereas in base 6061AA alloy after ageing at 180°C for 8hr maximum strength of 348MPa, percentage elongation of 12.6% and hardness of 115HV were achieved. The hardness and strength in Zn-added alloys from (1wt.% to 3wt.%) were increased due increased formation of mirror symmetries and 2-fold symmetries of β″ precipitates, which boosts their strength and hardness, and as well Zn has an affinity for occupying Mg1/Al, Si1, Si2, and Si3/Al sites in the β″ unit cell which increase the volume fraction of β″. While the 4wt.% of Zn in 6061AA Al alloy the strength and hardness are increased due to formation η′ in 6061AA Al alloy.

Key Words: 6061AA alloy; 6061AA+Zn1wt% alloy; 6061AA+Zn2wt% alloy; 6061AA+Zn3wt% alloy; 6061AA+Zn4wt% alloy; β″-Precipitates; TEM;

# Multi-Axial Forging of Low wt.% Samarium-Modified AA5083 Alloy: Microstructural and Mechanical Improvements

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## Abstract

The increasing importance of aluminum (Al) alloys in contemporary industries has led to a demand for improved properties through micro alloying. This study explores the impact of adding Samarium (Sm) to AA5083 alloy processed via Multi-Axial Forging (MAF). In the current study, 0.5 wt. % of samarium was added to the AA5083 alloy and fabricated through direct casting. AA5083-0.5 wt. % Sm alloy subjected to solution treatment at 475 °C for 12 h and processed with MAF process with a strain of 0.63 per cycle at room temperature. The research involved analyzing the microstructure using X-ray diffraction (XRD), optical microscopy, and field emission scanning electron microscopy (FESEM). The mechanical properties, such as hardness, tensile strength, and compression test, were assessed using micro-Vickers hardness tests and a universal tensile testing machine. Following MAF, the results showed a maximum hardness of 127 Hv and tensile strength of 328 MPa after two cycles, with significant microstructural refinement being observed.

Keywords: AA5083 alloy, Samarium, Microalloying, Multiaxial forging, MAF, Grain refinement.

# ELECTRON BEAM WELDING OF IN-718 TO AISI-316L SHEETS: MECHANICAL PROPERTIES AND MICROSTRUCTURE ANALYSIS

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## Abstract

IN-718 and AISI-316 stainless steel (SS) are widely used in the fields of petrochemical, nuclear, aerospace, automotive, and power generation industries. In many such industries, dissimilar joints of Inconel to austenitic SS find potential applications that provide cost-cutting and weight reduction and meet the required design flexibilities. During their fabrication, welding is often used as a joining technique. Fabrication of dissimilar joints using high heat input conventional fusion welding processes has various drawbacks like higher distortion, residual stresses, and risk of contamination in the fusion zone (FZ) and heat-affected zone (HAZ). Wider HAZ and FZ, shallow penetration depth, porosity, poor mechanical properties, etc., are some added weldment problems. Owing to various advantages like contamination-free weld, low heat input, high aspect ratio, narrow weld zone, etc., electron beam welding (EBW) is one of the most sophisticated welding techniques that find applications for various dissimilar metal/alloy combinations. Though earlier researchers have studied welding of Inconel to SS by EBW, investigation on the effect of different processing conditions such as varying welding speed, multi-pass joining, and beam oscillation on microstructure and mechanical properties is still missing. Accordingly, the present work is focused on analyzing the mechanical and metallurgical properties of IN-718 and AISI316 dissimilar butt joints made with different EBW processing conditions. The beam oscillation has the advantage of churning liquid action in the weld pool that restricts the segregation of elements, lowers residual stress, and provides more uniform properties. This is in contrast to the weld pool created without beam oscillation, where directed liquid flow due to Marangoni convection brings in directional properties. Similarly, double-side beam pass and higher welding speed conditions provide various benefits to the EBW butt joints, such as low porosity, narrow weldment region, etc. For this study, all joints were prepared using the same heat input rate condition so that the effect of EBW processing conditions on weld attributes could be effectively analyzed. The prepared joints were characterized through optical and scanning electron microscopy. The mechanical properties were evaluated using micro-hardness, tensile, and impact tests in accordance with the respective ASTM standards. It has been observed that for specific optimized EBW parameters, the mechanical properties of the weldments were enhanced significantly. Residual stress, grain size, and weld zone microstructures were also found to have been influenced by the EBW processing condition, which will be discussed in the presentation.

**Keywords:** Electron beam welding; AISI-316L; Inconel-718; Mechanical Propertie

# Effect of initial dislocation density on the steady-state creep behavior of Al 6061

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## Abstract

Material undergoes recovery with an increase in temperatures due to dislocation arrangements, leading to its softening. The arrangement of dislocations also gives rise to substructure formation, which significantly influences the material's behavior, particularly during dislocation creep. However, the impact of dislocation density on the steady-state creep rate of the material is still an area that requires further exploration.

In present work, the steady state creep behavior of Al-6061 is being reported for various orders of dislocation density. We introduced different dislocation density via cold rolling, ensuring uniform dislocation density distribution within the specimen. The quantification of dislocation density was done using X-ray diffraction (Williamson-Hall plot) analysis. Creep experiments were performed on the samples with different dislocation densities at various temperatures ranging from 200°C – 350°C and at initial tensile stress in the range of 100 – 200 MPa. Stress jump test was also performed to evaluate the stress exponent along with apparent activation energy to investigate creep mechanism being operated.

Keywords: Dislocation-density; Creep; X-ray diffraction; Stress jump

# Influence of microstructure on fatigue life of cryogenically treated aisi h13 steel

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## Abstract:

Cryogenic treatment is widely utilized for tool as well as die steels in order to enhance the performance of these materials. AISI H13 die steel is widely used in forging industries wherein fatigue loading conditions are frequently encountered leading to failure of the forging dies. This work involves heating AISI H13 specimens to 1020$^0$C for 20 minutes thereafter quenching in oil followed by double tempering at 525$^0$C. The specimens were subjected to cryogenic treatment at -185$^0$C for 16 hours cryosoaking period. Rotating bending fatigue test was performed at room temperature at constant amplitude loading conditions. Precipitation of fine carbides in the matrix of tempered martensite assists in refining the grain structure by inhibiting the grain growth. The fatigue life was noted to be enhanced by 17% on account of obstruction to the crack propagation due to fine grained structure in case of 16 hours cryogenically treated specimens.

**Keywords:** AISI H13; fatigue; cryogenic treatment; carbides; crack; tempering

# Effect of Ce and La on structure and mechanical properties of squeeze cast aluminium alloys

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**Abstract**

Rapid coarsening of precipitates, second phases, and grains at a temperature ≥200 °C is one of the major drawbacks of commercial aluminium alloys. The addition of rare earth elements in aluminum alloys forms thermally stable precipitates, modifies the phase morphology, and imparts excellent high-temperature strength. Rare earth-added (Ce and La) aluminium alloys are used in industrial heat exchangers, cryogenic tanks, and automobiles, among other applications. The eutectic reaction in Al-Ce alloy occurs at 640 °C and at a Ce composition of 9.35 wt%. Similarly, the eutectic reaction in Al-La alloy occurs at 638 °C and La composition of 10.87 wt%. The diffusivity and solid solubility of Ce and La in aluminium are limited and thereby reducing the diffusion-controlled microstructure coarsening. Moreover, the reduced solid solubility of La and Ce promotes the formation of strengthening phases such as $Al_{11}La_3$ and $Al_{11}Ce_3$, respectively. Al-Ce and Al-La alloy have been produced using gravity die casting and squeeze casting. Structural and microstructural studies were done using x-ray diffraction and scanning electron microscopy. The microstructure consists of α-Al (FCC) and $Al_{11}Ce_3$ and $Al_{11}La_3$, respectively. Thermo-calc studies show the $Al_{11}Ce_3$ is the most stable phase as compared to the other strengthening phases (such as $Al_2Cu$, Si, $Al_3Mg_2$) in commercial aluminium alloys. The mechanical, tribological and corrosion studies of the Al-Ce and Al-La alloys were also investigated in the present studies. The effect of Ce and La elements in the development of high-performance squeeze cast aluminum alloys, paving the way for their potential applications in aerospace, automotive, and other engineering industries.

**Keywords:** Rare earths, Rare-earth added Al alloys,Eutectic, Precipitates, Thermo-calc

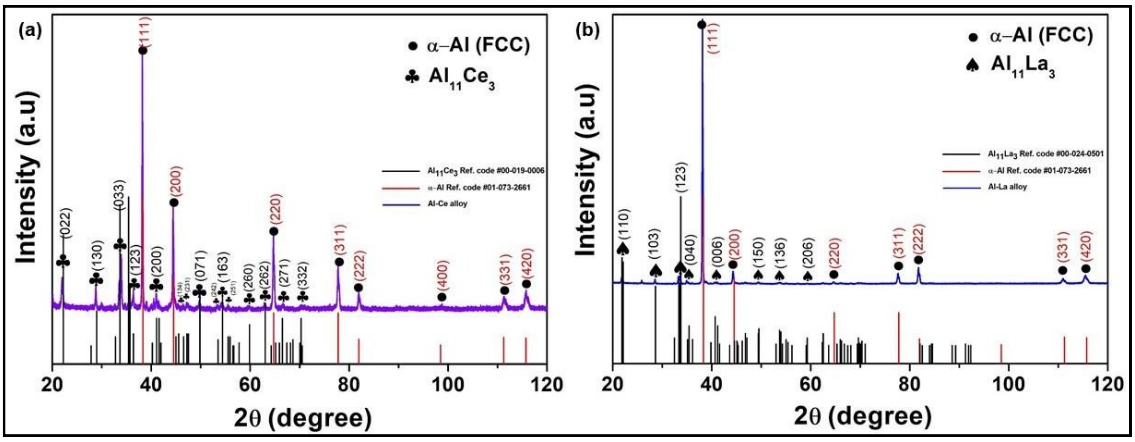


Fig. 1: (a) X-ray diffraction pattern of Al-Ce alloy and (b) X-ray diffraction pattern of Al-La alloy

Reference:

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# Effect of Cr addition in molten Zn to improve galvanised coating quality

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The zero spangle (ZS) galvanised steel sheet is the preferred choice of steel material over spangle galvanised steel for application in appliances & automotive for better formability and paint ability characteristics of ZS galvanised steel material. Now a days the fine grain ZS galvanised steel sheet with its grain size less than 100 µm is the most preferred coated steel sheet for different application where surface lustre is also an important factor along with formability and paint ability. The grain size of the galvanised coating is generally refined by costly auxiliary cooling step (ACS) technology. Normal, ZS galvanised steel sheet with grain size in the range of 400-500 µm is generally failed where surface lustre is a critical aspect. Our thought process is to refine grain size of ZS galvanised steel by addition of traces of nucleating element in GI bath. Cr can be used as a potential nucleating element as per the spherical cap & Q model of nucleation theory. A series of hot dip experiments were conducted using National Metallurgical Laboratory and Swansea University hot dip process simulator under variable process conditions like addition of traces of Cr in normal galvanised bath and variable wiping pressure. The coating characterization findings indicate that the grain size was refined after addition of Cr in GI bath. The targeted grain size of less than 100 micron was obtain after addition of only 0.02wt% Cr in molten normal galvanised bath. The spherical cap method as well as independent Q model have explained how heterogeneous nucleation process leads to refinement of grain size by incorporation of some inoculant like chromium in the galvanising bath. The corrosion resistance of Cr added ZS galvanised coated steel shows performance improvement by 50%, improvement in surface gloss and improved the paint ability characteristics significantly. This excellent performance was obtained due to adhered and compact layered double hydrozincite phase is formed in the coating.

key words: Zero spangle, galvanised, grain, corrosion, paint ability

# Assessment of Physico Mechanical and Microstructural Properties of Fire Bricks Refractory Matrix Reinforced with Calcined Petroleum Coke(CPC)

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## Abstract

Demands of firebricks across various pyro-industries are increasing day by day. Technological advancements and innovations have resulted new types of firebricks such as lightweight, precast, dimensionally stable type etc. In this investigation, an attempt has been performed to synthesize firebrick matrix incorporated with calcined petroleum coke, a new type of carbon based refractory rationale with non-wettability phenomenon and also verified most of the physico-mechanical properties like permanent linear shrinkage, Porosity, Bulk Density, CCS and thermal spalling. The experimented results among the samples as designated RC-1 to RC-10 and found RC-6 performs the best suit due to its physical properties like permanent linear shrinkage (7.69%), Porosity (21.78%), Bulk Density (1.83 gm/cc), CCS (17.82 MPa) and thermal spalling cycle features up to 5$^{th}$ Cycle accomplishments. Phases are identified by X-ray diffraction analysis. SEM study has been used to analyze the integrated matrix of the synthesized refractories. Investigation found that the sample RC-6 performs best among all these samples. Further physical interactions with molten alumina have been investigated for all synthesized briquettes to know non-wettability phenomenon. This finding could be applicable for heat resistance refractory especially for aluminium, foundry or cupola furnace domains within a temperature range of 1200$^0$C.

**Fig.-1 RC-6**
(CPC assisted Firebrick Refractory)

**Fig.-1 RC-6**
(One of the Thermal Spalling Results)

key words: New type; physico-mechanical properties; best suit; heat resistance refractory, non-wettability phenomenon

# Proton irradiation effects of Co21.5Cr21.5Fe21.5Mn21.5Ni14 multi-principal elemental alloy

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## Abstract

To investigate the irradiation behavior of MPEAs, experiments were conducted on a low stacking fault energy (SFE) variant of the Cantor alloy ($Co_{21.5}Cr_{21.5}Fe_{21.5}Mn_{21.5}Ni_{14}$). Proton irradiation was carried out with a 6.5 MeV beam energy at a dose of 5E17 p/cm², both at room temperature and 200°C. SRIM (Stopping and Range of Ions in Matter) simulations for room temperature conditions indicated a peak damage of approximately 0.16 dpa, located around 135 μm from the surface. Nanoindentation tests on the cross-section of the room temperature irradiated sample showed an increase in hardness from 3.55 GPa in the unirradiated alloy to
4.43 GPa at a depth of 50 μm and 5.41 GPa at a depth of 130 μm, highlighting depth-dependent irradiation-induced hardening. TEM analysis further revealed a higher density of dislocation loops at depths of 115-130 μm compared to 30-50 μm, contributing to this hardening effect at room temperature. In contrast, irradiation at 200°C resulted in depth-independent hardening, with the underlying reasons currently under investigation.

**Keywords:** MPEAs; Proton irradiation; Nanoindentation; Irradiation hardening; TEM

# Electronic indicator of mechanical properties in metals and alloys

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**Abstract**

Ab-initio calculations are commonly used for correlating the crystal structure of a material to its mechanical, electronic, magnetic, optical and other properties. Electronic, optical and magnetic properties of materials are generally explained in terms of electronic band structure and density of states, a routine job for modern density functional theory calculation based packages. On the other hand, mechanical properties are generally described in terms of inter-atomic bonding, calculated using strain-energy relationship. Although metals and alloys bond via delocalization of the valence electrons, mechanical properties of metals are rarely described in terms its electronic band structure. In this work, we uncover a deep correlation between the electronic band structure of a metal and its mechanical properties. We are able to predict certain mechanical properties directly from electronic band structure. Such an approach will change the conventional way of first principles calculation based mechanical property prediction.

key words : Ab-initio calculations, electronic structure, electronic bonding

# Overcoming Strength Limitations in Interstitial-Free Steel: A Study of Deformation and Crack Propagation

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## Abstract:

Interstitial-free (IF) steel is known for its exceptional formability and is widely used in applications such as automotive body panels due to its low carbon and nitrogen content. However, its limited strength poses challenges for structural applications. This study explores the microstructural evolution and mechanical behaviour of as-received IF steel through uniaxial interrupted tensile testing to address these limitations. By interrupting the tensile tests between the yield strength (YS) and ultimate tensile strength (UTS) points at various stages, we aim to examine the development of dislocations and grain boundary movements during deformation. This approach also sheds light on crack initiation and propagation mechanisms, which are crucial for enhancing the steel's reliability. Additionally, the work investigates the progression of work hardening and strain localization to optimize material processing techniques. Further analysis using hardness testing, electron microscopy, EBSD scans and X-ray diffraction on interrupted samples will provide a comprehensive understanding of the material's properties and pave the way for improving its mechanical performance.

# Laser Shock Peening

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Keywords: Laser shock peening, titanium, residual stress, corrosion, tribo-corrosion

## Abstract:

Laser shock peening (LSP) is an emerging and advanced surface treatment technique primarily aims at introducing compressive residual stress on the surface by irradiating the surface of finished component with a pulsed laser with sufficient energy density to generate plasma followed by its expansion causing introduction of compressive residual stress on the surface. The residual stress also propagates along the depth. The advantages of laser shock peening over conventional shot peening process are environment cleanliness, development of surface with no visible discontinuity, accurate control of the depth of penetration and improvement of other properties line corrosion and tribo-corrosion properties. In the present contribution, followed by a brief introduction of laser shock peening process, its effect on the microstructures of ferrous and non-ferrous materials would be discussed. The effect of laser shock peening on the mechanical and electrochemical properties of ferrous and non-ferrous materials would be discussed. The scope of application of laser shock peening for structural parts would also be discussed at length. Finally, the future scope of research in this direction would be presented.

# Development of high strength and toughness steels

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## Abstract

Microstructural refinement enhances the strength of materials and alloys. However, not many methods exist that can make nanostructured materials in bulk. Casting followed by appropriate thermo-mechanical treatment can be used to make nano-structured steels if the composition of steel is carefully chosen. Nano-structured bainite as well as pearlite can show exceptional strength while possessing reasonable ductility and toughness. The predominant mechanisms of deformation changes in these steels with a decrease in the microstructural length scale and the same has been shown by in-situ microscopy studies. Their corrosion and wear response are also dependent on the lamellar spacing/lath thickness. This talk will discuss the various parameters that can be varied to achieve the specific properties required in nano-structured steels.

key words:nano-bainite, nano-pearlite, strength, toughness, ductility

# Hot deformation behaviour of pure Molybdenum

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**Abstract**

Molybdenum (Mo) is a transition metal having melting point of 2610 $^0$C with BCC crystal structure. Mo finds potential applications in missiles, nuclear, aerospace and mining due to its outstanding physical, electrical and mechanical properties at higher temperatures. This study aimed at understanding the deformation behaviour of Mo during hot working and correlating to microstructure evolution. Hot uniaxial compression tests were carried out on the forged Mo rod in the temperature range 900-1200°C at an interval of 75°C and at strain-rate range $10^{-3}$-$10^{2}$ $s^{-1}$ at an interval of 10 $s^{-1}$ in Gleeble 3800. Microstructure characterisation was carried out on post deformation samples through Optical as well as EBSD techniques. Three types of stress-strain curves including work hardening, steady state and softening behaviour were observed depending upon the deformation condition. It exhibits work-hardening behaviour at higher strain rates (>$10^{-1}$ $s^{-1}$) and at lower strain rates initial work-hardening followed by flow softening behaviour was observed. It was also seen that at lower strain-rates the rate of work-hardening index (n = log(σ)/ log(ε)) is independent of strain-rate and at higher strain-rate condition especially the curves corresponding to 1200°C show significant increase in work-hardening rate. The values of strain-rate sensitivity index (m) are almost similar at temperatures below 1050°C. However, at higher temperatures (1125 & 1200°C), the slopes 'm' are different for lower and higher strain-rates and the corresponding change in slope occurs at strain -rate $10^{-1}$ $s^{-1}$. Vickers hardness of each sample deformed at different temperature and strain -rate conditions were recorded. The hardness value decreases with increasing temperature. However, the hardness value decreases steeply for strain – rate below $10^{-2}$ $s^{-1}$. EBSD analysis shows that the deformation condition 975°C- $10^{-3}$ $s^{-1}$exhibit complete recrystallization with fine grain structure and random texture. The microstructure exhibits partial recovery at lower temperature (900°C) whereas abnormal grain growth at higher temperature (1125°C). At higher strain-rate ($10^{2}$ $s^{-1}$) irrespective of temperature non-uniform banded structure were observed in the microstructure.

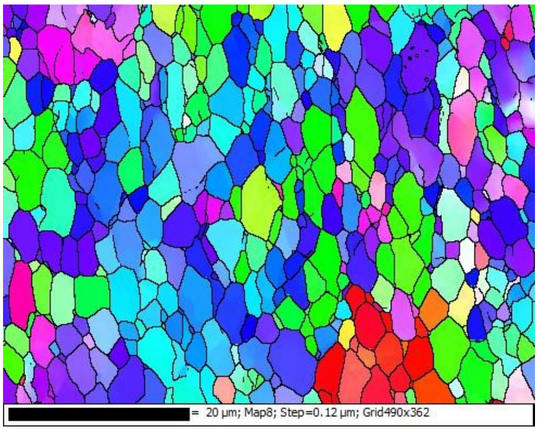


Fig. 1: Inverse Pole Figure (IPF) image of compressed samples at 975°C- $10^{-3}$ $s^{-1}$

key words: Hot deformation, Work hardening, Strain-rate sensitivity, Texture and Hardness

# Improvement in mechanical properties in ferritic stainless steel Grade - 430 coils in hot rolled thickness of 6-10 mm

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## Abstract

Dual-phase 430 ferritic stainless steels, treated by traditional bell furnace annealing, have a wide range of applications. 430 ferritic stainless steels (FSSs) offer better application prospects compared to austenitic stainless steels due to their lower cost, smaller thermal expansion coefficient, and superior pitting and stress corrosion resistance. They are commonly used where corrosion resistance is required, such as in kitchen appliances, automotive trim, architectural trim, and industrial equipment. They are also used in some cookware and utensils but are not suitable for highly corrosive environments.

Shear cracking is a well-known issue with 430 stainless steel ferritic grade, particularly in critical bending applications, often due to non-uniform microstructure. The probable reason of the nonuniformity is inadequate grain growth during annealing in Bell annealing furnace (BAF). Microstructure analysis reveals the elongation grain, especially in the longitudinal direction of the annealed sample. After studying the phase diagram and considering the AC1 temperature. Muffle heat treatment trials were performed at different temperatures to identify the optimal bell annealing cycle. The initial trial involved increasing the bell cycle soaking temperature near the AC1 temperature. However, non-recrystallized and elongated grains were observed in the longitudinal direction. This means soaking below AC1 temperature is not enough for grain growth. The cycle was then modified to include two soaking temperatures. First, AC1+30 for grain recrystallization, and second, AC1-30 to prevent austenite transformation to martensite. This resolution solved the problem of non-uniform, elongated microstructure in longitudinal directions.

**Keywords**: Bell Annealing Furnace, Ferritic Stainless Steels, Recrystallization, Soaking Temperature, Phase Diagram

# Significance of 'Ar' Value in Thermo Mechanical Treated Bar for better property correlation

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## Abstract:

The bond strength of concrete depends up on the strength of the concrete, diameter of the bar and bond stress between the reinforcement and the concrete which prevents slipping between these two material. For smooth bars the bond is mainly due to chemical adhesion between the cement paste and the bar whereas for ribbed bar the bond strength increased (slipping resistance) in addition to chemical bond, the surface irregularities. In case of ribbed bars the slipping resistance mainly due to the pressure exercised by the ribs i.e the mechanical action between the concrete and geometry of the ribs. In this study Ar (Mean projected rib area per unit length) for Tata Steel of different diameter has been compared along with different competitor and also different teat has been carried out to find the significance of Ar value with the Bond strength.

Key words: Bond strength; Concrete; Ribs; Slipping Resistance

# Microstructural Refinement and Strength Improvement in Medium Carbon Bainitic Steel via Electropulsing

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**Abstract**

In the quest for superior mechanical properties, unlike the conventional low temperature bainitic transformation method that relies on higher carbon content, this study utilizes electropulsing to achieve a refined microstructure, resulting in enhanced strength. The treatment led to uniform distribution of retained austenite and an increase in its content, the formation of martensite, and partial dissolution of cementite. Through X-ray diffraction and electron microscopy, the presence of cementite precipitates, bainite, retained austenite, and martensite were confirmed. The emergence of martensite is due to thermal effects and an increased dislocation density are attributed to the electron wind force-induced deformation. The electropulsed sample exhibited remarkable tensile properties, with a yield strength (YS) of 1532 MPa, an ultimate tensile strength (UTS) of 1768 MPa, and a total elongation (TE) of 9.56% surpasses the bainitic structure's YS of 1385 MPa, UTS of 1721 MPa, and TE of 9.43%.

Keywords: Bainite; electropulsing; electron microscopy; tensile properties

# Influence of Annealing Parameters on Mechanical Properties of High Strength Dual Phase Steel

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**Abstract**

Automotive application demands robustness and shape versatility. These properties are critical for ensuring automotive structural integrity, crashworthiness & fuel efficiency. The ability of dual phase steel to maintain high strength while allowing significant formability makes it indispensable for automotive body structures, safety components, and chassis elements.

This study emphasizes on the influence of process parameter optimization to achieve the optimal set of mechanical properties using the Gleeble-3800 thermo-mechanical simulator. Cold-rolled full hard (CRFH) samples of high strength (980MPa) dual phase steel , with dimensions of 260 mm in length, 50 mm in width, and three different thicknesses, were subjected to a series of controlled thermal cycles to simulate the continuous annealing process. The study details the execution of 10 distinct annealing cycles, The process parameters, including heating rates, soaking temperatures, and cooling rates, were meticulously monitored and controlled using K-type thermocouples spot-welded onto the specimen surfaces. The soaking section temperature (SS) was maintained in the range of 760-820°C. The slow cooling section (SCS) , rapid cooling section temperature (RCS) & line speed were maintained such that the cooling rates achieved were between 30-50°C/s. Post-annealing, tensile tests were conducted to measure the yield strength (YS), ultimate tensile strength (UTS), and elongation (%EL) of the samples followed by phase analysis & SEM. The microstructure reveals martensite % in the range of 30 – 50%. The results of the CAL simulation show three cycles with minimum strength of 1000MPa owing high cooling rate (>35°C/s) at the rapid cooling section. However, the overall mechanical properties obtained from various combinations of soaking temperatures and cooling rates demonstrate the potential for a range of properties catering to requirements for different part criticalities, thereby facilitating its application in advanced automotive designs and performance-driven engineering solutions.

**Key words** : Dual Phase, CRFH, CAL, Gleeble Simulation P

# Understanding Yield Strength Variability in 850 LA Grade Steel: The Role of Soaking Temperature and Microstructural Evolution

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## Abstract

The demand for high-strength steel in the automotive sector is rapidly rising to achieve weight reduction goals. Micro alloyed steel, characterized by a yield strength (YS) exceeding 850 MPa (850LA) and a high YS/TS ratio, has demonstrated significant potential for use in automotive seat track manufacturing. However, the presence of high levels of micro alloying elements such as Nb and Ti necessitates precise processing and control, particularly during the hot-rolling phase, to manage variations in yield strength.

This study examines more than one hundred coils of 850LA grade steel to investigate YS variability. Findings indicate that coils subjected to lower soaking temperatures and shorter times during the hot strip mill stage exhibit YS values below 850 MPa, whereas those exposed to higher soaking temperatures achieve YS values above this threshold.

To elucidate the influence of soaking temperature on the final microstructure, both low-YS and high-YS samples underwent comprehensive analysis. Electron Back Scattered Diffraction (EBSD) revealed three main features: ultrafine grains, micron-sized grains indicating grain growth, and deformed regions with high strain and no recrystallization. Moreover, high-YS samples exhibited higher strain and dislocation density, determined through EBSD-kernel average misorientation maps and modified Williamson-Hall method from X-ray diffraction.

The study concludes that lower dislocation density and larger grain size contribute to reduced strain hardening and lower YS. Additionally, the precipitation of carbides and carbo-nitrides significantly impacts the recrystallization temperature. Samples with fewer carbides precipitated during hot rolling did not experience an increase in recrystallization temperature, resulting in grain growth and lower YS at identical CAL temperatures.

**Key words** : Micro alloyed steel, Electron back scattered diffraction (EBSD) Recrystallization, X-ray Diffraction, Dislocation density,

# Hole Expansion and Microstructure Study of Various automotive grade Steels

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## Abstract

Hole expandability is a critical parameter in the formability assessment of automobile body parts subjected to deep drawing conditions. Hole Expansion Ratio which is the measurable of sheared edge stretchability or hole expansion property is influenced by the microstructure, composition, strain hardening, and elongation of automotive steel grades. Proper control of these microstructural constituents is essential for achieving favourable strength and ductility properties necessary for automotive applications. The hole expansion test is commonly used to evaluate stretch flangeability and sheared-edge stretching, which are crucial for forming operations.

This study aimed to analyze the effect of microstructure on HER across various steel grades and establish correlations between microstructural features, tensile properties, and sheared-edge formability. Hole expansion tests conducted with commercial grade, interstitial-free (IF) steel, dual phase (DP), and C-Mn grades along with tensile testing, and microstructural analysis, with a particular emphasis on DP steels. Microstructures were evaluated quantitatively and qualitatively using light optical microscopy (LOM), scanning electron microscopy (SEM), and x-ray diffraction (XRD). Results indicated that microstructural characteristics which includes various microstructural phase such as ferrite, martensite and bainite significantly influenced sheared-edge formability in various grade of steels. Key findings include the influence of secondary alloying elements, particularly manganese and niobium and their reaction products on HER due to their presence in steel compositions. In dual-phase C-Mn steels, a stronger soft matrix enhances HER, while significant strength disparities between dissimilar phases can reduce HER. Additionally, carbon content was identified as detrimental to HER, highlighting its adverse effect on formability.

**Key words : Hole expansion ratio; Formability; Dual phase steel; Martensite**

# Processing, Microstructures and Mechanical Properties of Hot dip Galvannealed DP780 & DP980 Ultra-high Strength Steel with high ductility

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**Abstract**

Recent trends of using thinner gauge materials in automotive steel for weight reduction with intention of reducing CO2 emissions thus protecting the global environment. Usage of high strength materials will prevent deformation of formed component during a collision so it is demanded in automotive cabin structural parts for passenger's safety.

Dual Phase steels offer a good combination of strength and stampability as a result of their microstructure, in which a hard martensitic phase is dispersed in a ductile ferritic matrix. These steels have high strain hardenability and superior formability, such as stretch-formability, stretch-flangeability and bendability. Yield strength of Dual Phase steels is further increased by the paint baking process. Suitable spot-weldability and corrosion resistance after painting will be added advantages to use in automotive structural parts like center piller outer, side sill outer, cross members etc.

JSW steel is developed galvannealed (GA) high strength steel with optimum product design and process design with precise process control in various production facilities. Intermediate product simulation being carried out for deciding the annealing cycles. Material is processed with highly protective furnace environment to achieve the better surface and optimum Galvanneal furnace parameter to achieve desired phases in coating layer.

The effect of continuous annealing parameters for mechanical properties and galvanneal furnace parameters are optimized by confirming the desired phases in coating layer through characterization study.

Product mechanical properties, metallography study, SEM analysis for coated layer phase analysis, X-ray diffraction study for phase confirmation, Hole expansion ratio, Spot weldability study, Paintability study being carried out to launch the product into the market.

GA780DP & GA980DP microstructure results revels using latest Continuous Annealing technology a uniformly distributed martensite in ferrite matrix and required fraction of delta phase in GA coating layer by optimizing the Galvanneal furnace and cooling parameters.

Conventional AHSS (GA DP780 & GA DP980) were simulated in PAMSTAMP software for typical B-Pillar (Safety component) to study Spring-back phenomenon. Coated AHSS is future solution for automotive industry to reduce vehicle weight, improving safety of passenger with excellent corrosion resistance.

**Key words : Galvanneal High Strength, DP780, DP980,**

# Comparison between mechanical property of Niobium based and Titanium + Niobium added HSLA flat galvanized steel

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## Abstract

In this paper we have done a comparative study of microstructure and mechanical property between the Niobium added HSLA steel and Niobium with Titanium added HSLA steel. We have characterized the precipitation by SEM EDX analysis to establish the composition and size of Titanium and Niobium precipitates. This research explores how varying Nitrogen levels affect the size and distribution of Titanium Nitride precipitates, and how these changes influence the subsequent formation of Titanium Carbide during the hot rolling process or later cooling stages. The impact of Titanium Nitride on Niobium precipitates are examined in the SEM characterization and its impact on mechanical property are correlated.

In the production of HSLA (High-Strength Low-Alloy) steel, small quantities of elements such as Titanium, Niobium, and Vanadium are added to achieve high strength levels. This enhancement in strength is primarily due to precipitation hardening and grain refinement resulting from the formation of various precipitates. Carbon and Nitrogen react with these micro alloying elements to form precipitates, and the size and distribution of these precipitates are crucial for achieving the desired strength properties. It is inferred that Niobium forms fine, stable precipitates that contribute to both precipitation hardening and grain refinement. It is well-documented that Titanium forms very stable precipitates with Nitrogen, specifically Titanium Nitride.

The product analysed in this study is a galvanized coated flat steel with a yield strength range of 300-600 MPa. We also propose a containment strategy for different Nitrogen levels in the heat, aiming to achieve the desired mechanical properties. Finally the benefit of Niobium only micro alloyed steel on the variation of mechanical property is explained.

**Key words** : **HSLA (High-Strength Low-Alloy) steel, Titanium, Niobium**

# Improvised methodology of thickness consideration during Tensile Testing of Zinc Aluminium coated steel

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## Abstract

Here in this study, we have envisaged upon the idea to reduce the step involving the zinc coating removal of tensile sample in Zinc and Zinc-Aluminum coated grades for the mechanical property evaluation. The testing evaluation requires the cross section of sample where the margin of error for the thickness measurement is high. The error comes due to the added thickness by zinc or passivation coating over the substrate. The added thickness does not contribute to the strength of the material but is reflected in the yield strength and tensile strength calculation. Zinc being much softer than Iron can give error in the actual property value when the coating is not removed before testing. The mechanical strength values hence obtained are less than the actual property. In this study we have calculated the correction in coating thickness required for different coating weight and specimen thickness that can be used for direct tensile testing of sample without zinc stripping. By this method the acid used for zinc stripping is eliminated which has reduced the environmental, health and cost impact during testing process. The adoption of this method is a step towards inculcation of sustainable methods in manufacturing.

**Key words:** Tensile test, sustainability, cost saving

# Controlled modulation of coating morphology, Mechanical Properties And Anti-Tarnishing Response Of Nanocrystalline Au-Cu Alloy Coatings Electrodeposited From A Thiourea (TU)-Based Non-Toxic Cyanide-Free Bath: Effect of Current Density Variation

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## Abstract

In the present work, Au-Cu alloy coatings are prepared by pulse galvanostatic electrodeposition from a novel thiourea (TU)-based bath by varying the current density from 5 to 25 mA/cm$^2$. The effect of the applied current density on the surface morphology, mechanical properties, and anti-tarnishing performance of the developed Au-Cu coatings is investigated. Linear sweep voltammetry (LSV) experiments from different bath compositions are carried out to explore the electroanalytical behaviour of Au and Cu in the system. The SEM and EDS investigations show a wide variation in the surface morphology and Cu content of the deposited coatings as the applied current density changes from 5 to 25 mA/cm$^2$. As the current density increases, the hardness of the coatings escalates from 173 to 279 VHN. The electrochemical impedance spectroscopy (EIS) studies suggest that the severity of tarnishing decreases with the increase in the current density.

**Keywords:** Electrodeposition; Au-Cu coatings; anti-tarnishing; cyanide-free; Pulse Galvanostatic.

# Influence of cooling strategies on the microstructural development of 600-780 MPa dual-phase steels

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Abstract

Dual-Phase (DP) steels are widely used in the automotive industry due to its excellent combination of strength and plasticity, low yield ratio, and high initial work-hardening rate. The excellent mechanical behaviour of DP steels is attributed to its microstructure which composed of two phases; normally a ferrite matrix and a dispersed second phase of martensite, retained austenite and/or bainite. There is renewed interest in development of hot rolled DP steels with advancement of hot rolling equipment and manufacturing technology enabling mass production of thin gauge strip with desired shape, surface quality and consistent microstructure.

The present investigation involves a laboratory-cast low carbon manganese steel, alloyed with chromium and niobium to produce hot-rolled DP steel with tensile strengths ranging from 600 to 780 MPa. The two-step cooling strategy implemented on the run-out table (ROT) control the austenite transformation kinetics resulting in desired DP structure in the hot strip mill. A continuous cooling transformation (CCT) diagram was generated for investigated steels using the DIL805A/D thermo-mechanical simulator to determine an appropriate ROT cooling profile. ROT simulations (Fig.1) are conducted using initial cooling rates of 35°C/s and 60°C/s, paired with intermediate cooling rates of 4-8°C/s to achieve a range of intermediate stop temperatures ($T^e_{im}$), from 660°C to 620°C, followed by rapid cooling at 100°C/s to CT of 250°C. A constant intermediate start temperature ( ) of 700°C and a hold duration ($t_{im}$) of 10 seconds were employed in the present study. The resulting dilatation curves were analysed to determine start and end of desired phase transformations temperatures.

The results of controlled cooling simulations indicate that a two-step cooling strategy is necessary to achieve desired distribution of hard martensite islands dispersed in a soft ferrite matrix. The findings point out that the initial cooling rate along with $T^e_{im}$ plays a crucial role in achieving desired ferrite-martensite phase balance and mechanical properties in DP steel. An initial cooling rate of 35°C/s, an intermediate rate of 8°C/s and $T^e_{im}$: 620°C, resulted in phase fractions of 82% ferrite, 8% bainite, and 10% martensite with UTS of approximately 640 MPa (Fig. 2a). In contrast, a higher initial cooling rate of 60°C/s, intermediate rate of 4°C/s and $T^e_{im}$: 660°C produced a phase distribution of 38% ferrite, 22% bainite, and 40% martensite with a UTS around 780 MPa (Fig. 2b). It is important to keep $T^e_{im}$: 620°C, approximately 20°C above the bainite start ($B_s$) temperature, for achieving 80% ferrite and 20% martensite phase balance for DP600 grade. This study identifies optimal cooling strategies that enhance mechanical properties, improve production efficiency and enhance cost effectiveness to produce DP steels.

**Key Words**: Dual phase, hot strip mill, run out table, CCT, intermediate start temperature($T^s_{im}$), intermediate stop temperature ($T^e_{im}$), UTS.

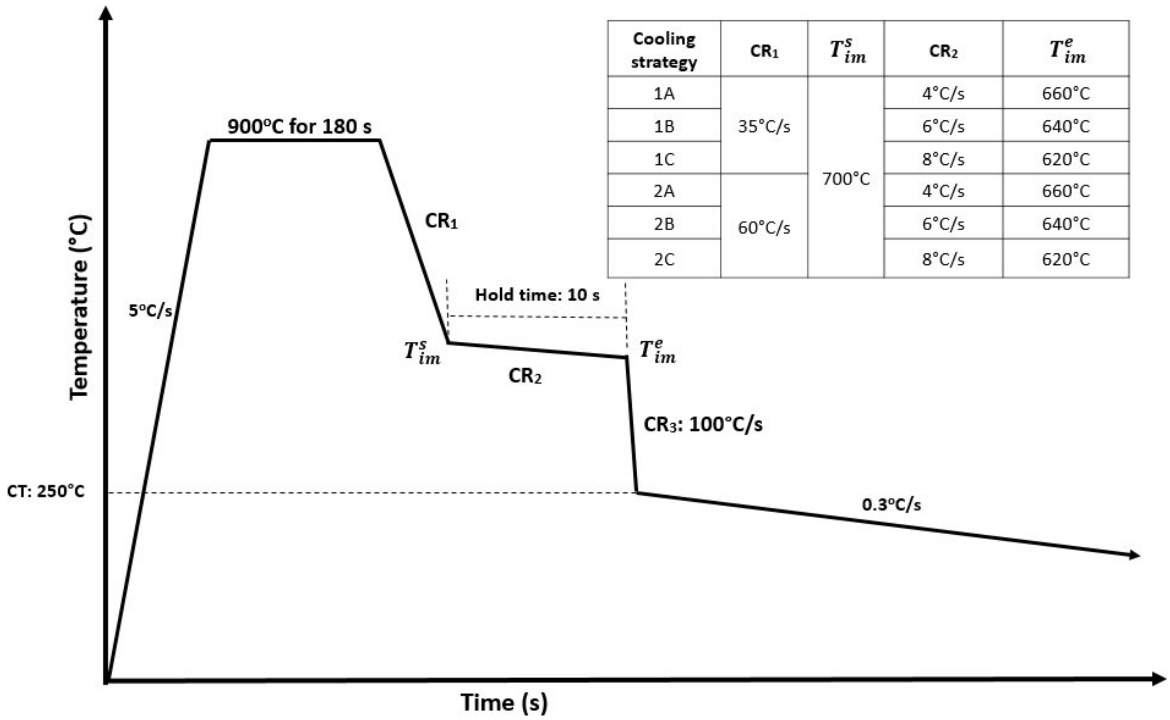


Fig. 1: Schematic representation of two-step ROT simulation performed on DIL 805A/D thermomechanical simulator to produce hot rolled-DP steel

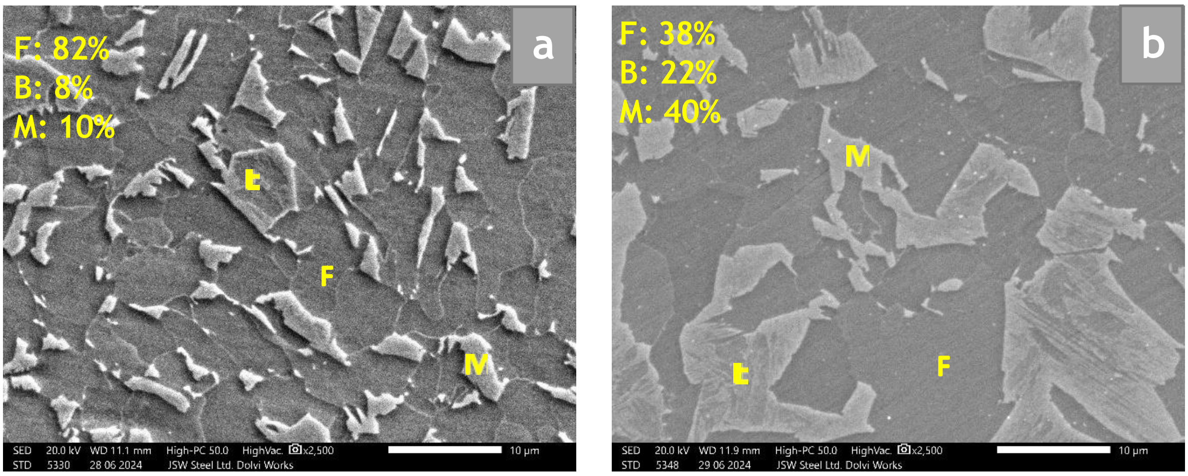


Fig. 2: Effect of cooling strategy on the developed microstructure in DP steels: a) Strategy 1A [CR1:35°C/s, CR2:8°C/s ( $_{im}$:620°C)] b) Strategy 2A [CR1:60°C/s, CR2:4°C/s ($_{im}$:660°C)]

# Development of Third generation AHSS using Quenching & Partitioning technique through CR-CAL route for manufacturing of structural components of automobiles.

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**Abstract**

For the past few years, significant attention has been given for the development of third generation advanced high strength steel (3rd Gen AHSS) especially for the automotive applications. Behind this, the major reason is to reduce weight coupled with enhanced fuel efficiency without compromising the passenger safety. Novel alloying addition and innovative processing routes are being implemented to develop steels which possess high strength with impressive ductility. The approaches concerned with third-generation AHSS requires unique alloy- microstructure combination to achieve desired mechanical properties. The third generation of advanced high strength steel comprises of the multiphase microstructure that has the characteristics of both first and second-generation AHSS . The new microstructure involves both the presence of ultra-fine grained ferrite/non-carbide bainite/martensite and stabilization of austenite phase. Like the microstructure, the mechanical property of third- generation AHSS also lies within first and second-generation

In this connection, quenching-partitioning (Q&P) grade steel is one of the most promising candidates, where the microstructure consists of carbon depleted martensite and retained austenite. The martensite matrix provides the requisite strength whereas the retained austenite improves the ductility of the steel by transformation induced plasticity (TRIP) effect. The best combination of strength and ductility is obtained when the matrix contains relatively high-volume fraction of retained austenite. In this process, after heating the steel at a high temperature, it is being quenched to a predetermined temperature which lies in between the martensite start ($M_S$) and martensite finish ($M_f$) temperatures. This is followed by the subsequent partitioning step where the as-quenched steel is again heated to a temperature (above/below the $M_S$ temperature) which results in carbon partitioning between martensite and austenite.

Key Words: AHSS, Q-P, Martensite, Bainite, Retained Austenite, TRIP.

# Development of Nb-Mo Microalloyed "Fire Resistance" Construction Steels

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Abstract

The development of fire-resistant (FR) steels has been predominantly driven by research in Japan, with significant contributions from Europe, China, Korea, and the USA. These FR steels are typically modified version of high-strength microalloyed construction steels, with molybdenum additions to improve their performance at elevated temperatures. Literature reports various alloy designs, particularly focusing on low-carbon-microalloyed steels containing molybdenum (Mo), niobium (Nb) and/or vanadium (V). FR steels can reduce the need for passive fire protection and, if such protection is compromised by a blast, they can prevent or delay structural collapse, providing critical additional time for occupants and emergency responders during high-rise fires.

Japanese FR steels guarantee a minimum yield strength at 600°C that is two-thirds of the room temperature yield strength, which has led to their adoption in niche applications. This study evaluates important classes of Nb and Ti microalloyed construction steels for their fire-resistance properties, with and without Mo additions. The selected steels were produced in thickness ranging from 6-10 mm at industrial scale in a hot strip mill. Tensile tests were conducted at elevated temperatures (100-800°C) with a minimum 25 minute holding period for thermal equilibration prior to testing, in accordance with the IS15103:2002 standard, to determine the yield strength, tensile strength, and elongation of selected steels.

The results demonstrate that microalloyed grades exhibit greater room-temperature strengths and higher yield and tensile strengths at elevated temperatures over base steel. Yield strength being particularly significant in these construction steels, the Nb+Mo grade maintains higher yield strengths above approximately 500°C and shows notable strength increases at intermediate temperatures around 350°C, likely due to dynamic strain aging. The Nb+Mo alloy meets the IS15103:2002 standard's minimum criteria, demonstrating enhanced yield strength retention at elevated temperatures (600°C) compared to other alloying strategies.

The overall increase in strength with elevated test temperature in microalloyed steels is attributed to the retention of substructure, ferrite grain refinement, and precipitation strengthening. The Nb+Mo additions result in finer Nb(CN) precipitates after high-temperature exposure, likely due to Mo segregation to the precipitate/matrix interface, which suppresses Nb(CN) precipitate coarsening. This mechanism, as hypothesized by earlier researchers, demonstrates a significant synergy between Mo and Nb in FR steels. Additionally, Mo contributes to microstructural refinement by promoting bainitic microstructures in as-rolled strip over range of cooling rates as applicable in an industrial production.

Key Words: Fire-Resistant Steel (FRS), Microalloying, Construction, Fire Protection

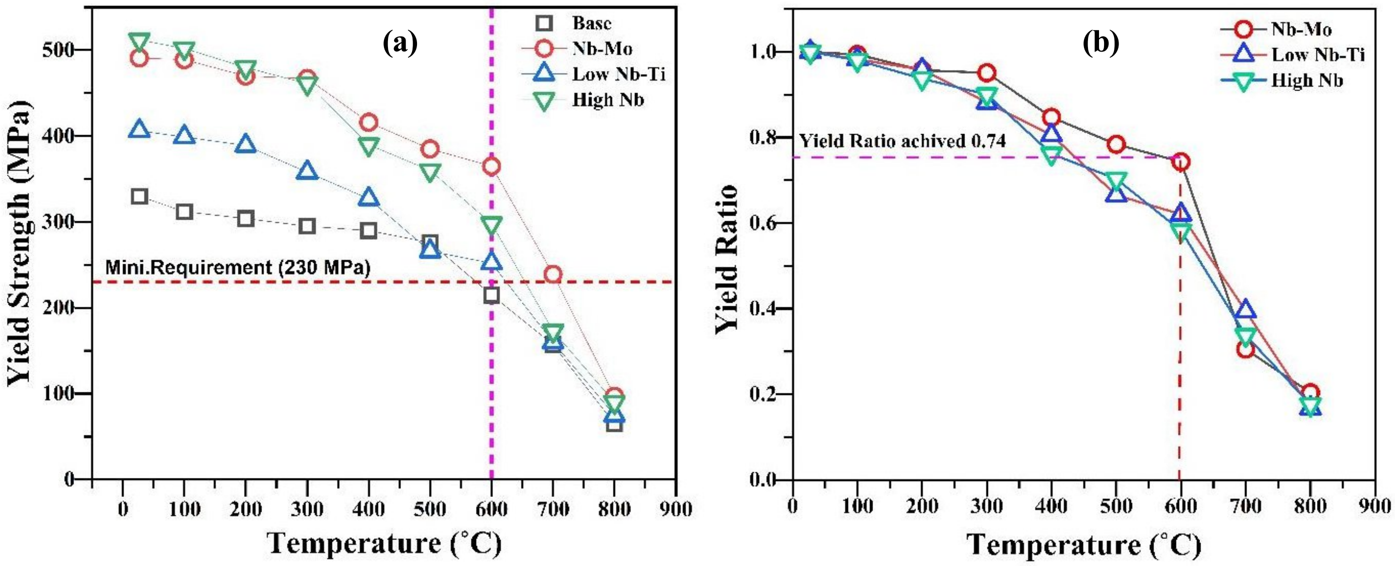


Fig. 1: Elevated temperature properties of four alloys (a) Yield Strength (b) Yield Strength Ratio

# Does the nanoindentation strain rate truly affect the mechanical properties of viscous materials?

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**Abstract**

In this study, the nanoindentation strain rate ($\dot{P}/P$) and depth dependence of nano-mechanical properties (elastic modulus ($E_N$) and hardness (H)) for viscous materials are examined in detail by following a wide range of $\dot{P}/P$ and applied load ($P_m$). We have indented polycarbonate (PC) and poly (methyl methacrylate) (PMMA) samples at various $\dot{P}/P$ values, ranging from 0.05 /s to 50.0 /s. Indentations were carried out to different $P_m$ values from 1000 μN to 9000 μN. It has been noticed that higher amounts of deformation occur during loading by indenting at low $\dot{P}/P$ while a significantly higher amount of creep occurs during holding at higher $\dot{P}/P$. As a result, the maximum penetration depth is higher for high $\dot{P}/P$ for the same $P_m$. Additionally, it is seen from scanning probe microscopy (SPM) images that the residual depth is also higher for high $\dot{P}/P$ (for the same $P_m$) due to a greater extent of viscoplastic and plastic deformation. We have calculated the stiffness (S) values from the upper range (95-70% of $P_m$) of unloading data fitted with the power law equation. For contact area ($A_c$) estimation, SPM images are employed with pile-up and tilt corrections. It is seen that the estimated S and $A_c$ values do not vary with $\dot{P}/P$ and $P_m$ for both samples. Hence, the $E_N$ and H values are not affected by $\dot{P}/P$ and $P_m$. This happens if the hold time is sufficient to allow the viscous deformation to saturate. Thus, it can be concluded that for accurate estimation of $E_N$ and H values for viscous materials it is essential to use an appropriate load function, which allows for the viscous deformation to saturate before unloading.

**Keywords:** Viscous materials; Nanoindentation; Strain Rate; Scanning Probe Microscopy; Mechanical properties.

# Cryogenic toughness and strength optimization in 7% Ni Steel for LNG tankers

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## Abstract

7wt.%Ni alloy steel was prepared, hot rolled, and heat treated according to popular quenching, lamellarization, and tempering treatments. Tempered martensite with blocky and lamellar morphology, along with retained austenite and ɛ-martensite, were observed in the microstructures after the above-mentioned heat treatment. The lamellarization at 700℃ leads to a more uniform distribution of alloying elements and, therefore, promotes the formation of finer retained austenite with uniform distribution, compared to 650°C lamellarization temperature. The presence of lower matrix strain and uniformly distributed fine retained austenite provides the highest toughness with moderate strength in the 700°C samples. ɛ-martensite is expected to provide the necessary strength to balance the softening arising due to tempered martensite and retained austenite. Moreover, the uniformly distributed fine and filmy-shaped retained austenite provides thermal stability and arrests crack propagation, enhancing toughness. The XRD results after impact toughness show that the γ-ε-α transformation takes place during the -196°C temperature, and during impact toughness testing, ε-α transformations also provide the toughening in the Ni-700+590 sample.

Key words: Ni steel, ε-martensite, retained austenite, cryogenic Impact toughness, intercritical tempering

# Upliftment of tensile response via tuning the alloy chemistry in low-carbon cerium- modified steels

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## Abstract:

This study investigates four cerium-modified low carbon steels, named as S1, S2, M1, and M2, with cerium (Ce) content in the proportions of 0.03 wt.%, 0.6 wt.%, 0.1 wt.%, and 0.3 wt.%, respectively. All the investigated steels exhibit predominantly polygonal ferrite microstructure, with pearlite as the secondary phase along with the cerium-containing precipitates, mainly oxides and oxysulphides. The presence of moderate amount of Widmanstätten and acicular type of ferritic structures are evidenced in S1, M1, and M2 steel, which is absent in S2 steel. However, the presence of minute amounts of MnS compounds in M1 steel cannot be overlooked. Evolution of the Ce rich intermetallic phases, specifically $Ce_2Fe_{17}$ and $Ce_2C_3$, are feasible in S2 steel, while the inter-particle spacing of the precipitates being much lower in the case of M2 steel. All the steels exhibit distinctive responses to uniaxial tensile tests, as depicted by typical Yield Strength (YS), Ultimate Tensile Strength (UTS), and Total Elongation (TE) values. Damage and failure mechanisms have been elucidated for all the steels through advanced characterization techniques, strain hardening plots, and fractographic analysis. The strain hardening response is excellent in M2 steel, attributed to its overall refined structure, consisting of finer inter-lamellar spacing in the pearlite and higher amount of acicular ferrite.

**Keywords**: Cerium modified steel, Uniaxial tensile deformation, intragranular ferrite, strain hardening behavior.

# High Strength Hot-rolled Steel Sheet with Improved Stretch Flangeability for Automotive Application

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## Abstract

Hot-rolled steel sheets used for automotive applications, such as wheel disc, lower control arm and chassis parts requires a combination of improved stretch flangeability and very high strength. Stretch flangeability is measured in terms of hole expansion ratio (HER), which is an important product attribute to assess the local formability of the material. However, as the strength increases, the formability and HER of steel sheet deteriorates.

Present work demonstrates the effect of chemical composition, hot rolling parameters, controlled cooling in run out table (ROT) and resulted microstructure on formability and HER of TS 590 MPa steel grades. Different chemical composition of TS 590 steel, such as Nb+Ti microalloyed, only Ti microalloyed design is described in terms of microstructure and mechanical property. The developed hot rolled steel grades have improved strength and HER combination as compared to DP/TRIP or any conventional HSLA steel. It was attributed to supressed cementite precipitation at the grain boundaries, ferrite + bainite or bainitic ferrite microstructure through controlled cooling, and appropriate inclusion control during steel making, resulting in excellent hole expansion ratio (HER > 100%).

Formation and propagation of microcracks during hole expansion was suppressed by ferrite-bainite duplex microstructure due to reduced harness ratio between ferrite matrix and second phase. It was also observed that formation of large textural colonies in Nb added steel deteriorates the stretch flangeability. Reduction in of void nucleating sites (inclusion, large TiN precipitate, cementite etc.) results in improved HER. In case of Ti only microalloyed design, precipitation strengthening with nano-metric homogeneously distributed precipitate in ferrite/ or low carbon bainitic ferrite single phase matrix can enhance strength and HER combination.

Keywords: Hot Rolling, high strength steel, stretch flangeability, HER, controlled cooling, automotive steel

# Microstructure-Property correlation in Al and Si added Medium-Mn Steels

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## Abstract

The global demand for high performance materials across industrial sectors has driven the continuous development of different steel grades. Due to exploration in the scientific research over the years, steels have undergone numerous advancements from conventional steels to different generations of the advanced high strength steels (AHSS) having good combination of mechanical properties. There's also a growing need for materials with high specific strength to facilitate substantial weight reduction, contributing positively to a sustainable future. While traditional methods focused on increasing steel strength, recent attention has shifted towards producing steels by incorporating lightweight elements like Al or Si. These steels, often referred to as "Low density steels" (LDS) are based on the Fe-Mn-C system with Al or Si additions.

This study focuses on incorporating 3% Al and 3% Al-1% Si into an Fe-8Mn-0.2C medium-Mn steel system, classified as a third-generation AHSS, to achieve a better combination of strength and ductility. The addition of Al and/or Si broadens the intercritical annealing (IA) window, allowing for flexible selection of IA temperatures. Si-free steel, after IA, demonstrated a superior product of strength and ductility (PSE) value of 61 GPa%, compared to 41 GPa% for Si-containing steel. Microstructural analysis showed the presence of α-ferrite and austenite, with negligible martensite in both steels. However, the retained austenite fraction was 45% in Si-free steel and 19% in Si-containing steel. The better mechanical performance of Si-free steel is attributed to its higher retained austenite fraction and slower TRIP effect. The role of IA temperature in determining austenite stability and retention at room temperature was investigated using thermodynamic equilibrium predictions and the Koistinen-Marburger model for martensite calculations. Factors such as element partitioning and local microstructural heterogeneities were discussed in relation to austenite stability at IA temperature. Finally, the mechanical response of the microstructural constituents was analysed, highlighting the mechanical stability of retained austenite. The transformation kinetics of retained austenite showed a lower mechanical stability parameter for Si-free steel, explaining its slower TRIP effect.

Keywords: Advanced high strength steels (AHSS), Low density steels (LDS), Intercritical Annealing (IA), Product of strength and ductility (PSE), Transformation induced plasticity (TRIP)

**Structure-property correlations of the over-aged AA7075T7352 alloy**

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## Abstract

The structure-property relationship of the AA7075T7352 alloy is reported in this work. The evolution of Metastable precipitates of $MgZn_2$ (GPzone, η' and η (hP12)), as well as $Al_2Cu$ (tI12), and $Al_2CuMg$ (oS16) intermetallic, are observed. The precipitates are randomly distributed. The η and η follow the separated nucleation and in-situ nucleation mechanisms. The η contributes higher strengthening than the η' and dispersoids phases. The significant strengthening in such alloy arises due to the Orowan strengthening mechanisms, following the Ludwigson flow behaviour. The alloy failed due to mixed modes of ductile and brittle failures. The measured YS value (450 MPa) is closely aligned with the experimental YS value of 425 MPa. The coarse but discontinuous grain boundary precipitates of η results in the severity of corrosion ($I_{SCC}$) value of 0.14.

**Keywords:** AA7075T7352 alloy, Orowan strengthening, Dislocation loops, Tensile properties, Ludwigson flow behavior.

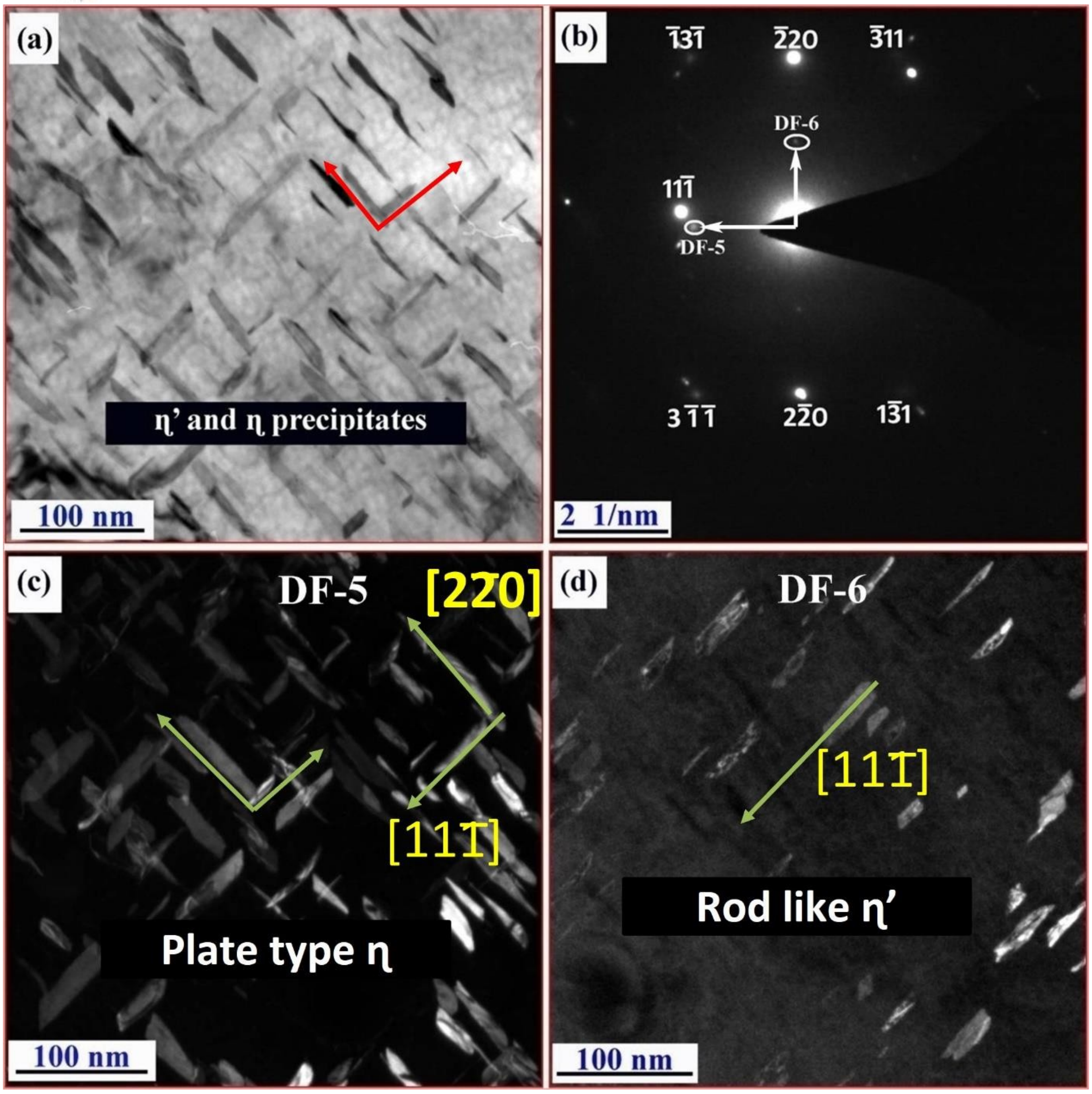


**Fig. 1a-d** Precipitation behaviour: (a) bright-field TEM micrograph, (b) corresponding SAEDPs, (c) dark-field TEM micrograph from DF-5, (d) dark-field TEM micrograph from DF-6.

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# Structure-Property Process Parameters Correlation of Laser Composite Surfaced Titanium Based Alloy (Ti13Nb13Zr)

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## Abstract

The present study concerns the development of a carbide dispersed surface on β titanium alloy (Ti-13Nb-13Zr) by preplacement of graphite and subsequent melting using a 6 kW continuous wave fibre laser. Laser processing has been carried out using a diode laser (LDF 6000-40, Laserline Germany) with a Gaussian beam profile under varied laser power ranging from 1000-1400 W and scan speed ranging from 10-20 mm/s in an argon shroud. Followed by laser composite surfacing, a detailed measurement of the surface roughness of the processed surface has been carried out using a surface profilometer. The microstructure, composition and phases present in the processed zone have been analyzed by optical/scanning electron microscope, energy dispersive spectroscopy and x-ray diffraction study. The mechanical properties of the surface in terms of micro/nano hardness and wear resistance against the WC ball in fretting mode have been carried out. Finally, a detailed structure-property process parameter correlation has been undertaken to optimize the process parameters corresponding to maximum improvement in hardness and wear resistance properties. A grey relational-based optimization tool has been applied to statistically derive the process parameter and compare it with the experimentally derived one.

Keywords: Laser Composite Surfacing, Ti-13Nb-13Zr, TiC, Hardness, Wear.

# Synergistic Effects of Titanium and Runout Table Cooling Strategy on Mechanical Properties of Micro-Alloyed Steel

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## Abstract

Micro-alloying of steels is a critical process that significantly enhances the mechanical properties and performance of the material. Titanium is an effective microalloying element due to its high affinity for carbon and nitrogen, forming stable carbides and nitrides. These precipitates act as pinning sites, inhibiting grain growth during hot working and subsequent heat treatments, resulting in a refined grain structure. The fine-grained microstructure significantly contributes to the strength and toughness of the steel, meeting the stringent requirements for HSLA steels.

The present study aims to provide insights into tailoring cooling strategies at hot strip mill to leverage titanium's benefits, ultimately improving the mechanical properties. The runout table cooling strategy plays a pivotal role in optimizing the benefits of titanium microalloying. By controlling the cooling rate on the runout table, the precipitation behavior and phase transformation kinetics of the steel can be precisely managed. Experimental results indicate that an optimized runout table cooling strategy, tailored to the specific titanium microalloyed steel composition, can lead to significant improvements in tensile strength (>700 MPa) in titanium microalloyed steels. The interplay between the titanium content and the cooling rate determines the size and distribution of precipitates, directly influencing the strength of steel. With no significant differences in phase evolution or grain size, precipitation strengthening appears to be the primary contributor to the net increase in strength.

In conclusion, the synergistic effects of titanium microalloying and runout table cooling strategies significantly enhance the mechanical properties of titanium-based microalloyed steels. The findings suggest that by fine-tuning the chemical composition and meticulously implemented cooling strategy, manufacturers can produce cost effective high-performance HSLA steels tailored for specific demands. Further research and industrial trials are recommended to refine these processes and explore their full potential in various applications to reap the maximum benefits of titanium micro-alloying.

Keywords: Steel, Micro-alloying, Microstructure, runout table cooling strategy, Precipitation

# Effect of pass rolling of the parent austenite on martensite variant, texture, and mechanical properties of Nb-V low carbon Steel

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## Abstract

Research is currently being conducted on microalloyed or high strength low alloy (HSLA) steel to achieve a balance between strength and ductility through the utilization of rolling reduction and low transformation products. The investigation focuses on the influence of step rolling reduction (20% and 40%, with 10% intervals) on non-recrystallization temperature to achieve the specific variant selection during martensite transformation and the rolling reduction impacts on parent austenite grain (PAG), texture, and mechanical characteristics. Findings suggest that an increased rolling strain initiates the activation of the secondary slip plane {-111}γ, (γ denoted as a austenite phase) subsequently variant selection influencing in the martensite formation grains. Increase the rolling reduction leads to a shift in texture from (111) [1-10]α to (332) [-1- 13]α, (α denoted as a ferrite phase) which confirms the brass component in the austenite region and leading to a significant improvement in the mechanical properties. The average PAG size undergoes an increase at a rolling reduction of 40%, influencing the packet and block sizes. The rise in rolling strain contributes to an elevation in yield and ultimate tensile strength by 27.9% and 19.32%, respectively, while causing a reduction in elongation by 1.625%. Analysis of the grain boundary characteristic distribution reveals that the change in rolling reduction increases the plane distribution from (111) to (110) plane, thereby preserving the ductility in a 40% pass rolling reduction. It has been observed that the enhancement in strength primarily arises from the strengthening effects of dislocations and grain boundaries.

**Keywords:** Thermomechanical processing; Variant selection; Martensite crystallography; Quasi cleavage; grain boundary characteristic distribution.

# On the B induced phase transformation and mechanical behavior in Fe-Mn-Al-Ni-C high-specific strength steels

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## Abstract

The rising demand for energy-efficient, lightweight structural materials has stimulated significant interest in high-Al containing Fe-Mn-C steels, particularly for automotive applications such as crash-resistant car body frames. These steels exhibit excellent mechanical properties, especially high specific strength (170-220 MPa $g^{-1}$ $cm^3$) and good ductility (20-30%), making them ideal candidates for enhanced fuel efficiency and mitigating greenhouse gas emissions [1]. Ni-alloyed Fe-Mn-Al-C steels, featuring a distinct microstructure comprising of intermetallic phases dispersed in a disordered solid solution matrix, demonstrate improved mechanical properties and a significant density reduction of ~13% compared to conventional steels. To further augment these materials, interface engineering by solute decoration at grain boundaries is employed. In this study, a particular grain boundary cohesion enhancer namely, Boron (B) was alloyed at varying concentrations between 30-100 ppm, to bolster the interfacial load-bearing capability of Fe-16Mn-9Al-5Ni-0.9C (wt%) steel. The addition of B resulted in substantial improvements in high-temperature stability and strength compared to the B-free steel.

XRD and EBSD analysis indicated the presence of a single phase FCC structure in the hot rolled (HR) condition of the B-alloyed Fe-16Mn-9Al-5Ni-0.77C (wt.%) steel. After annealing at 600℃ for 30 min, the BCC phase formed along the high angle FCC grain boundaries. A multi-scale correlative microscopy analysis involving TEM-TKD-APT enabled in unearthing the unique microstructural aspects, especially the localization of B2 nanoprecipitates strengthening the grain boundary decorating BCC phase, which appears to be strengthening the steel at elevated temperatures.

This comprehensive analysis demonstrates that B alloying significantly enhances the interfacial load-bearing capability, high-temperature stability, and strength of Fe-Mn-Al-Ni-C steels. The presentation will focus on the role of B in influencing intermetallic phase formation and its effect on the mechanical response of the material, highlighting its potential for advanced automotive applications.

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**Keywords:** Boron; High specific strength steel; Ferrite nucleation; B2 precipitation; Correlative Microscopy

# Warm rolling-based microstructural engineering to overcome the strength-ductility trade-off in a medium manganese steel

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**Abstract**

Advanced high-strength steels (AHSS) are the forefront structural material for applications requiring the combination of strength and ductility. Medium manganese steels are one of the emerging 3rd generation AHSS which can be processed suitably to impart such properties. However, any metallurgical approach to enhance strength is associated with a loss in ductility and vice-versa, a phenomenon commonly referred to as strength-ductility trade-off. Microstructural modification via thermomechanical processing optimization is one of the promising metallurgical solutions to this enduring problem of strength-ductility trade-off.

In the present work, we modified the microstructure of a medium manganese steel via a novel low-temperature warm rolling (WR) treatment to overcome the strength-ductility trade-off. Controlled generation of dislocations in the constituent austenite and ferrite phases along with the introduction of twins in the austenite phase, both induced by WR fetched an improvement in the yield strength compared to the steel conventionally treated by intercritical annealing. Additionally, austenite stability regulation via deformation above the $M_d$ temperature during WR led to simultaneous improvement in ultimate tensile strength (UTS) and ductility as compared to the steel treated with IA. The achieved combination of yield strength and tensile toughness (product of UTS and total elongation) in the steel treated with this novel WR technique was significantly superior in comparison to the medium manganese steels with similar composition processed through different other innovative techniques reported to date. The present study demonstrates an approach to tailor the defect microstructure for escaping the near-ubiquitous strength-ductility paradox in metastable FCC alloys such as stainless steel, HEAs, TWIP steels etc.

**Keywords**: Strength-ductility trade-off, Austenite stability, Warm rolling, TRIP-TWIP, Medium manganese steel

# Development of high strength and ductile Fe49Mn30Co10Cr10C1 medium entropy alloy by cryo-rolling

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## Abstract

Interstitial alloying has become a practical and economical approach to improve the mechanical properties of high-entropy alloys (HEAs). In this work, a fascinating medium-entropy (MEA) Fe49Mn30Co10Cr10C1 alloy with a dual-phase structure, phase transformation-induced plasticity (TRIP) was prepared by vacuum arc melting and cryo-rolling followed by annealing. The samples were characterized using x-ray diffraction (XRD), scanning electron microscopy (SEM), and electron backscattered diffraction (EBSD). The mechanical properties such as hardness and tensile properties were evaluated.

Fig. 1 shows stress-strain curves for the Fe49Mn30Co10Cr10C1 MEA in different conditions. The CR sample heat-treated at 650 ℃ for 10min shows the best combination of strength and ductility with 1.1GPa of yield strength, 31% elongation among all the samples studied. The microstructural results revealed that the enhanced strength and ductility is mainly due to reduction in dislocation densities and grain refinement.

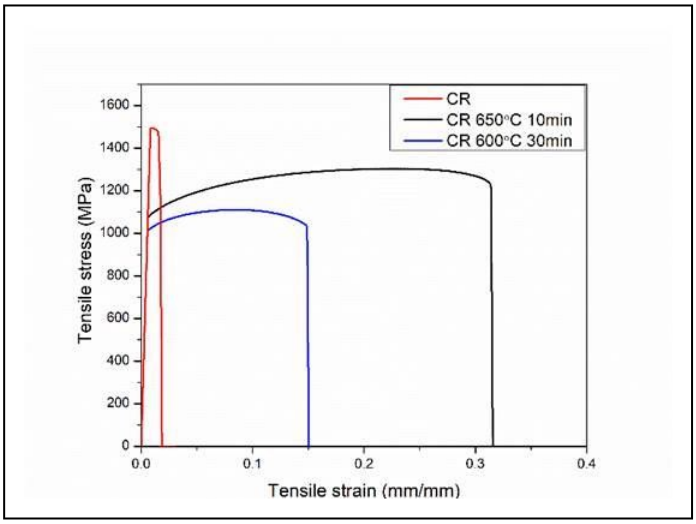


**Fig. 1:** Tensile stress-strain curves of the Fe49Mn30Co10Cr10C1 MEA in different condition.

**Key words:** Medium-entropy alloy, Carbon, Interstitial alloying, cryo-rolling, Transformation-induced plasticity.

# Effect of Heat Treatment on Cast Microstructure of 410L Stainless Steel

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## Abstract

Ferrite-martensite stainless steel grade has become a potential candidate for structural application near the coastal areas due to its inherent corrosion resistance. One of the major applications of this grade is reinforcement bar. To achieve desired properties for the application, it is important to study cast microstructure and effect of homogenization heat treatment on it. In this study, a detailed microstructural analysis of as-cast and heat-treated samples was conducted. A laboratory-scale experimental heat treatment was performed on the as-cast 410L sample at various temperatures ranging from 950 to 1100ºC for different holding time (1 to 5h). Heat treatment temperature was determined using Thermo-Calc software and selection was done in such a manner that temperature falls in both single-phase (γ) and two-phase (γ+δ) regions. In the as-cast structure, the δ-ferrite, Widmanstatten ferrite and martensite were observed. It is known that fraction and distribution of δ-ferrite influence the mechanical properties during hot rolling, while the Widmanstatten ferrite phase is said to be detrimental to toughness. Therefore, adequate re-heating prior to hot rolling is necessary in order to achieve good combination of strength and ductility. Various characterization techniques, including optical microscope (OM), scanning electron microscope (SEM), and electron backscatter diffraction (EBSD), were used to analyze the progressive changes in the morphology and fraction of ferrite. This study demonstrates that reheating the sample in the single-phase (γ) region and holding it for an adequate duration disrupts the δ-ferrite network, significantly impacting the mechanical properties. The heat treatment in the two-phase (γ+δ) region disrupts the network of δ-ferrite, while the fraction of δ-ferrite increases with extended holding time.

Key words: Ferrite-Martensite Stainless Steel; Homogenization; Microstructure; Thermo-Calc; Heat Treatment

# Role of nitrogen and deposition temperature on the structure and mechanical properties of the (AlCrNbSiTi)N films

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**Abstract:**

Multi-principle elemental nitride thin films are a class of advanced ceramic materials that have attracted significant interest due to their exceptional mechanical and tribological properties. The structural and mechanical properties of these films can be tailored by varying the deposition parameters, a combination of nitride-forming elements, and their elemental composition. The present study deals with understanding the structural and mechanical properties of the (AlCrNbSiTi)N films deposited at different nitrogen flow ratios (0-20%) and deposition temperatures (upto 500°C). These films were deposited on Si (1 0 0) substrates using the D.C. Magnetron Sputtering system. The microstructural studies revealed that the films showed granular morphology with columnar growth. From the XRD, it is observed that the films transitioned from amorphous to FCC crystal structure with varied nitrogen flow ratio and showed better crystallinity at higher deposition temperatures. XPS analysis confirmed the formation of the binary nitrides in these films. The hardness and modulus of the films improved from 8 GPa to 18 GPa, and 161 GPa to 250 GPa with the addition of nitrogen and substrate temperature.

**Key words:** (AlCrNbSiTi)N thin films, Deposition parameters, XPS analysis, Mechanical properties, and Fracture behaviour.

# Deformation and microstructural evolution in Advanced High Strength Steel (AHSS)

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**Abstract**

In the present study, a thermomechanical treatment was developed to produce a mixed morphology of austenite, primarily a combination of globular and lath-type reverted austenite. The effect of this treatment on yield point elongation (YPE) during uniaxial tensile loading was investigated. This approach aims to optimize the balance between strength and ductility. The research methodology includes warm rolling and intercritical annealing, followed by comprehensive microstructural and mechanical characterization. The study focuses on the mechanical response of these steels, particularly the transformation-induced plasticity (TRIP) effect, where austenite transforms into martensite during deformation, enhancing work-hardening behaviour. This research investigates the effect of mixed (lath and globular) morphology on the mechanical response of medium Mn steels, with the composition Fe-4.98Mn-0.2C-0.89Si-0.34Al. Studies indicate that hot rolling results in a lath-shaped microstructure, cold rolling results in a globular microstructure, while warm rolling produces a mixed morphology of globular and lath-shaped structures. X-ray diffraction (XRD) and electron backscatter diffraction (EBSD) analyses after warm rolling revealed a limited austenite fraction, which was significantly increased through intercritical annealing at 660°C for 3 hours. This process yielded a mixed microstructure, enhancing mechanical properties compared to the hot-rolled, cold-rolled, and intercritical annealed samples. However, variations in the stress-strain response among the four tested samples highlight the need for further detailed investigation into microstructural differences.

Keywords: Medium manganese steels, transformation-induced plasticity, deformation, mixed morphology, intercritical annealing.

# Corrosion Characteristics of Phosphorus Bearing Steel

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## Abstract

Different alloying elements have varied effects on the properties of steel. It is the combined effect of all the alloying elements, process parameters and the impurities that determine the characteristic property of a certain steel grade. Majorly, Mn, Ni, W, Cu, B, Si, Al, Cr, Mo, V are added to obtain some positive effects that leads to improvement in properties of carbon steels like hardness, strength, toughness, corrosion and oxidation resistance etc. All these alloying elements basically generate a point defect that creates a stress field in the crystallographic structure of steel which reduces dislocation mobility and in turn improves properties of carbon steels. This report enumerates the effect of Phosphorus (P) added as micro-alloying element in weather resistant steel in comparison to other commercial grades and strategic application steel. The result of various test like salt spray test, XRD of the oxide films scrapped from samples after salt spray test, impact tests for determination of DBTT, metallography of the steel samples under consideration, show the variation in performance of microalloyed and plan carbon steel in comparison to P-added steel. The experimental evidences are discussed in comparison with published literature and simulation values to understand the corrosion characteristics of Phosphorus bearing steel.

Key words : Corrosion, Phosphorus bearing steel, characterization

**Tempering resistance behaviour of carbide-free bainitic steel at 400°C**

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## ABSTRACT

In the pursuit of steel development, microstructure control for optimum mechanical properties without using high amount of costly alloying elements is always fascinating. In this direction extensive research on the development of carbide-free bainitic steel structure is being carried out around the globe. Apparently simple but complex microstructure of this variety of steel consisting of bainitic ferrite lath, film and blocky austenite and martensite provides wonderful combination of tensile properties with high strength and considerable ductility. The thermal and/or mechanical stabilization of retained austenite, film type or blocky, in the carbide-free bainite steel is a major concern for understanding the microstructure-property relationship of this steel variety.

The present study looks into the tempering resistance behaviour of a carbide-free bainitic steel of simple composition received from TATA Steel, The Netherlands in the form of 3 mm thick hot-rolled sheet. The chemistry of the steel is: 0.35C-2.07Mn-1.65Si-1.07Cr-0.06Ti (wt%). The bainite start temperature ($B_s$) of the steel is estimated as 452°C and martensite start temperature ($M_s$) as 287°C. In this investigation tempering resistance of the steel has been studied at 400°C for different lengths of time to know the decomposition of retained austenite and to understand the effect of tempering on microstructure and mechanical properties of the steel. Optical microscopy, Scanning Electron Microscopy, Transmission electron microscopy, X-Ray diffraction, Tensile testing, Hardness testing have been done to understand the phase transformations occurring during tempering and the corresponding evolution of mechanical properties.

Optical microscopy of the steel reveals that microstructure of the steel consists of bainite, austenite and martensite. The amount of retained austenite in wt pct is found as 20 ± 2 pct as determined by X-ray diffraction analysis. Vickers hardness (HV) of the steel under 30 kg load and 15 second loading duration is found as 455 kg/mm$^2$. Specimens for tensile tests, both in the as-received condition and after tempering have been fabricated with long axis of specimens parallel to the rolling direction. Tempering has been done in a salt bath furnace for a time duration of 1 to 24 hrs and the temperature of the salt bath has been controlled within ± 2°. Tensile strength/ductility combination of the steel in the as-received condition steel is found as 1470 MPa and total elongation is 22% at a strain rate of $10^{-4}$ s$^{-1}$. In this investigation, it is found that hardness after tempering monotonically decreases up to a tempering time of 12 hrs and then increases after tempering for 24 hrs reaching almost close to the hardness in the untempered condition. On the other hand, highest level of both strength and ductility has been obtained after 4-hr tempering. The results are discussed in terms of phase transormations occurring during tempering.

Key words: Banite, Tempering, Austenite, Hardness, Tensile.

# Non-Metallic Inclusion Rating of Different Alloys by metallographic methods

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## Abstract:

Non-metallic inclusions are a critical factor influencing the quality, performance, and reliability of steel alloys. Their presence can significantly impact the mechanical properties, corrosion resistance, and overall durability of the material. This comprehensive study investigates the non-metallic inclusion rating of various alloys produced at Mishra Dhatu Nigam Limited (MIDHANI), Hyderabad, using the standardized ASTM E45 methods. This analysis meticulously employs methods A, B, C, D, and E to assess and rate the inclusions such as sulfides, aliman type inclsuions, silicates and oxides, providing a detailed understanding of their type, size, distribution, morphology and severity.

The findings of this study will be thoroughly discussed with experts in the field, providing valuable insights into the alloy's quality, potential applications, and areas for improvement. This rating contributes significantly to the understanding of non-metallic inclusions in alloys, ultimately enhancing the manufacturing process, product reliability, and performance in critical applications.

The results of this study will be presented in detail, including the methodology, results, and implications for future research and industrial applications. The discussion will also explore the potential for optimizing alloy composition, improving manufacturing processes, and developing more effective quality control measures to minimize the presence of detrimental non-metallic inclusions. By sharing the outcomes of this analysis by metallographic methods, we aim to facilitate knowledge sharing, collaboration, and innovation in the field of metallography.

Key words: Inclusions, sulfides, Oxides, Silicates, alumina inclusions.

# Structure – Property Correlations in CaO – doped Zirconia ceramics sintered in vacuum

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## Abstract

A vacuum environment is usually preferred for reducing the dwell time and sintering temperature for doped zirconia ceramics. Traditional approaches predominantly employ vacuum sintering for well-established yttria-doped zirconia systems (i.e, 3YSZ and 8YSZ) to fabricate transparent/translucent ceramics with superior mechanical properties for desired applications. Herein, our focus is to refine and tailor the sintering parameters specifically for CaO-doped zirconia systems (≥10 mol.% CaO) in its cubic range within a vacuum environment. CaO-doped zirconia nanoparticles were synthesized (10, 15, and 20 mol.% CaO) via a modified co-precipitation method, followed by calcination at 550 °C and subsequent sintering in a high-temperature vacuum hot-press unit at 1500 °C, utilizing hot-pressing (with 20 MPa uniaxial pressure). However, the 10 mol. % (10CaSZ) and 15 mol.% (15CaSZ) hot-pressed ceramics showed results in contrast with that of 20 mol.% (20CaSZ) in terms of phase evolution (monoclinic phase) and densification (open porosity).

To investigate the monoclinic phase evolution and non-densification, a detailed study on 10 mol.% CaO-doped zirconia ceramics sintered via vacuum hot-pressing, vacuum sintering and conventional sintering was conducted. Unlike conventionally sintered 10CaSZ ceramics, which exhibit mixture of cubic and tetragonal (in 5:1 ratio), both hot-pressed and vacuum sintered 10CaSZ ceramics portrayed a maximum density of ~ 93% and monoclinic phase (> 50%). Consistent vacuum-induced monoclinic phase formation was confirmed in heat-treated 10CaSZ nanoparticles. Grain size distribution, EPR (Electron Paramagnetic Resonance) analysis and compositional analysis revealed substantial CaO dopant loss, causing non-densification, and influencing the monoclinic phase transformation. Despite this, XRD (via shift to left side due to loss of $Ca^{2+}$) and calcium elemental mapping suggested dopant segregation at grain boundaries [1].

In contrary to the results of 10CaSZ hot-pressed ceramics, 20CaSZ hot-pressed ceramics were monoclinic free and fully densified. The 20CaSZ hot-pressed ceramics depicted a maximum transmittance value of ~73% for a 1.5 mm thick pellet at 600 nm with an average grain size of ~2 μm, hardness of ~ 14.5 GPa, and indentation toughness of ~1.9 $MPa.m^{1/2}$. The vacuum environment likely functions as a reducing atmosphere in the graphite chamber, lowering the oxygen partial pressure and significantly influencing as well as altering the sintering mechanisms for CaO-doped zirconia ceramics. Traditional sintering mechanisms may not be feasible in vacuum environment for CaO-doped zirconia ceramics. The challenges faced in terms of phase evolution and densification in vacuum environment are unique to CaO-doped zirconia ceramics and intrinsic to the amount of doping used.

key words: zirconia, hot-pressing, vacuum, monoclinic, densification

References: J.A. Reddy, A.K. Lakshya, A. Chowdhury, J. Am. Ceram. Soc. (2024). https://doi.org/10.1111/jace.19831.

TITLE: Quaternary Interdiffusion in BCC Al-Ni-Co-Fe System at 1100 °C. Authors:

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## Abstract

AlNiCo magnets are a popular class of permanent magnets used in electric motors, sensors, microphones, and aerospace applications. The monopoly in the distribution of rare-earth elements and their being critical materials has renewed interest in AlNiCo magnets. The quaternary AlNiCo alloy containing iron exhibits a single phase (BCC) above 1100°C and at lower temperatures, it exhibits spinodal decomposition into Fe-Co-rich ferromagnetic $\alpha_1$ (BCC-1) and Al-Ni-rich paramagnetic $\alpha_2$ (BCC-2) phases. The low-temperature aging treatment where atomic migration occurs for the splitting of the single α-phase into $\alpha_1$ and $\alpha_2$ phases is diffusion controlled and hence understanding interdiffusion in these alloys is of technological importance. Interdiffusion studies in this quaternary system were conducted by choosing alloy compositions in the single-phase region at 1100°C. Quaternary diffusion couples were assembled with these single-phase alloys, and they were diffusion annealed at 1100 °C for 96 hrs in an inert atmosphere. Body diagonal diffusion couple approach was utilized to design the couples. The composition analysis of the diffusion zone was done using EPMA (Electron probe micro-analyser). The Boltzmann Matano analysis was extended here for quaternary system. Assessment of the concentration profiles for interdiffusion fluxes developed in the diffusion zone and evaluation of the quaternary interdiffusion coefficients will be discussed in detail in this talk.

# Effect of Reduction Ratio and Coiling Temperature on Mechanical Properties of Low Alloy Steel

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## Abstract

The microstructure and mechanical properties of steels depend on chemical composition and processing parameter. While C and Mn increase strength through solid solution strengthening effect, the micro alloying element like Nb, V and T increase strength of steel through grain refining effect. For light weight application and even for cost effective purpose, it is essential to optimize the process parameter with minimum micro alloying addition. In view of this, different coils were hot rolled with different effective reduction ratio vis-à-vis different Mn, Nb and V content. For this, heats were made through BOF-SMS-CC route and hot rolled to 10 mm x 1500 mm, 120 mm x 1500 mm, 16 mm x 1500 mm. Reheating and soaking of the CC slabs were carried out at 1240-1250$^0$C in reheating furnace for 3 hours. The hot rolling was carried out through 4 nos. of roughing stands and 7 nos. of finishing stands. The transfer bar thickness after roughing was maintained within 35-36 mm. Hot rolling was carried out above Tnr, i.e., above no recrystallization region. In addition to this, effect of coiling temperature on mechanical properties was also studied. Keeping Mn content at 1.20%, Nb content 0.012% and V content 0.025-0.03%, the achieved yield strength was 440-450 MPa and tensile strength was more than 550 MPa. On decreasing Mn content to 1.1% and without V, the yield strength decreased to 400-410 MPa and tensile strength 540-545 MPa. Further decreasing Mn content to 0.95% and keeping initial stand in finishing mill dummy, i.e. without any load, the yield strength almost remained unchanged as 395-410 MPa while tensile strength decreased to 525-530 MPa. The similar yield strength with lower Mn content is attributed the grain refinement effect, which was correlated with microstructural study. When coiling temperature decreased from 680-685$^0$C to 640-650$^0$C, both yield strength and tensile strength increased by 20-30MPa. While making initial stand of finishing mill resulted in increase in effective reduction ratio among six numbers of remaining stands and this lead to increase in mechanical properties, the effect of different reduction ratio of final stand did not lead to substantial changes in final properties. The grain refining effect was also correlated with charpy impact energy. Thus, it was possible to optimize process parameter as well as alloying element contents to achieve desired mechanical properties.

key words: Low Alloy Steel, Microstructure, Mechancial Properties, Grain Refinement

# Unique Characterization Techniques for Zn-Al-Mg Coated Steel

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Abstract

Hot-dip galvanizing with zinc–aluminium–magnesium (Zn–Al–Mg) alloy coatings is new generations of coatings developed for very long life, cut edge protection and high corrosion resistance applications. Zn-Al-Mg coated steel have been now extensively being utilized in solar panel, exposed ducts and structures and C4 or C5 environmental conditions. This is a unique alloy composition and results in formation of multiple phases in the coated layer than compared to galvanised or galvalume coatings. These alloy coatings consist of a combination of four primary phases: Zn, Al, $MgZn_2$, and $Mg_2Zn_{11}$, which together form a fine-grained structure. The distinct hardness, higher thickness and reactivity, sensitivity to cooling rate and properties of these phases pose challenges for metallographic sample preparation. To address these challenges, unique practices and analysis procedures have been developed to prepare and characterize such samples for meaningful conclusions. Surface grain morphology was highly inconsistent and hence was not utilized for any analysis. For cross-sectional analysis, a 45-degree inclined polishing technique is employed, using 1000 grit paper followed by cloth polishing. The polishing process progresses from 6 microns to 1 microns using water-free solutions, and etching is performed with 0.1% Nital. For surface analysis, cloth polishing alone is practiced to remove the oxidized layer and reveal a representative surface. Surface hardness and XRD was carried out after removing few microns layers based on the cross-section imaging. GDOES was used to understand the depth profiling of elemental composition. SST and CCT test were used to compare the corrosion behaviour. Bend samples were also characterised to study the cut edge protection tendency. Corrosion product analysis was carried out using intermediate samples of the corrosion tests. Grain size distribution and $MgZn_2$ phase was found to have better relation to its corrosion resistance behaviour. These innovative preparation techniques ensure accurate and reliable characterization of Zn–Al–Mg alloy coatings, facilitating advancements in their application and performance in demanding industrial environments.

Keywords: Zn-Al-Mg Coating, Characterization, $MgZn_2$

# Development of S960QL Grade Plate for Ultra High Strength Structural Applications and Rockhard 500 Grade Plate for Abrasion Resistance Applications

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**Abstract**

S960QL grade steel is primarily used in the high strength structural applications such as load bearing members in trucks, and chassis parts for the Self-Propelled Modular Transporter (SPMT) trailers, while Rockhard 500 (RH500) provides guarantee surface hardness 470 BHN minimum. These steel grades are produced for abrasion resistance applications e.g. ore crushing, grinding mill lining etc. Manufacturing these plate-grades with 80 mm and 100 mm thicknesses is quite a challenge in terms of achieving the required hardenability up to the inner core of the plate. These grades have been successfully developed at such higher thicknesses for the first time in India at Jindal Steel and Power, Angul Plate Mill through suitable alloy design, thermomechanical controlled rolling and subsequent heat treatment process. A detailed microstructural characterisation has been carried out and correlated with the mechanical properties. Achieving desired mechanical properties with sufficient strength and toughness throughout the thickness in the relatively thicker plates (>70 mm) is an industrial challenge due to the insufficient strain penetration to the core during hot rolling and as a consequence, inadequate grain refinement in the subsequent processing. The heat treatment process parameters were carefully optimised to achieve YS ~1000 MPa, UTS ~1050 MPa, and Charpy Impact Toughness more than 100 Joule (at -40°C) in S960QL grade for 80 mm thick plates. On the other hand, in RH500 grade plate the mechanical properties achieved as YS ~1300 MPa, UTS ~1600 MPa, Impact Toughness ~30 Joule (at -60°C). The core hardness of ~400 BHN in a 100 mm thick plates achieved which also complies to the clients requirement of core hardness >90% of the minimum surface hardness. The methodology, manufacturing processes and the modeling capabilities adopted for this development will be presented.

**Keywords**: High strength steels, thermomechanical processing, tensile properties, impact toughness, core hardness.

# Insights into thermomechanical processing of Al added low density medium Mn steel

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## Abstract

In this study, the Al (~3 wt%) added low density medium Mn steel has been developed by melting-casting route in an open-air induction furnace. The cast ingot has been hot forged and hot rolled to 50% thickness reduction in temperature range of 1100-800℃ after soaking at 1100 ℃ for 2 hrs. After hot rolling, two different cooling mediums, still air and water quenching has been chosen to cool to room temperature. Subsequently, the rolled samples has been intercritical annealed at 720℃ for 1 hr and then air cooled to room temperature. The phase fraction of specimen after every thermomechanical processing has been analyzed by rietveld refinement using X-ray diffraction (XRD) peaks. The microstructure characterization has been carried out by using optical microscopy, scanning electron microscopy, electron back scattered diffraction and transmission electron microscopy, and 3D atom probe microscope. The microstructural analysis shows the formation of multiphase microstructure of elongated ferrite and lamellar structure of martensite + austenite in hot rolled as well as annealed condition. The xrd analysis reveal that the austenite fraction in intercritical annealed sample has significantly increased compare to hot forging and rolling due to elemental partitioning during annealing. However, the highest fraction of austenite has been found in the annealed sample that is water quenched compare to air cooled after hot rolling. Therefore, it shows the highest total elongation of 40±2.5% with yield strength and ultimate tensile strength of 593±10 and 854±20 MPa respectively due to the presence of high fraction of reversed austenite with suitable mechanical stability. The annealed sample that is air cooled after hot rolling possesses the ultimate tensile strength, yield strength and ductility of 1000±20 MPa,700±10 MPa and 18.5 ± 0.5, respectively. Interestingly, it also reveals the precipitation of kappa (k) carbide in intergranular region may be due to segregation of C and Al. The xrd analysis of annealed sample (before tensile test) shows both ferrite/martensite and austenite peaks, whereas after tensile test, it represents mainly ferrite/martensite peaks. This shows the enhanced transformation-induced plasticity (TRIP) effect during tensile test. The TEM analysis of annealed sample (before tensile test) and after tensile test also confirm the occurrence of TRIP effect during tensile loading. Moreover, the stacking fault energy (SFE) of the steel has been found to be ∼16 mJ $m^{-2}$, calculated by the modified Olson and Cohen method too concludes TRIP is the preferred deformation mechanism in the developed steel.

Key words: Al added low density medium Mn steel; Thermomechanical processing; Kappa (k) carbide; Microstructural evolution; Tensile properties

# Development of low-fluoride flux for electroslag remelting: Effect of reduced CaF2 concentration on the structure of ESR slag

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## Abstract

The process of Electro-Slag Remelting (ESR) is well established for refining special steels as well as other critical alloys like Ni-based and Co-based superalloys. Conventional ESR slags consist primarily of $CaF_2$ along with varying proportions of $Al_2O_3$ and CaO. Fluoride vapour is prone to evaporation from the molten slag at the operating temperature, causing several environmental and health problems. The presence of fluoride in the ESR slag helps to maintain its melting, flow and electrical properties in an optimal combination that allows efficient operation of the ESR process. So any reduction in $CaF_2$ concentration in the ESR flux, notwithstanding the environmental benefits, needs to satisfy the requirement of these properties. Thermo-physical properties like viscosity and electrical conductivity are dependent on the structure of the molten slag at the operating temperature. This study investigates the effect of reduced $CaF_2$ concentration on the structural characteristics of the ESR slag, in order to estimate the feasibility of using low-$CaF_2$ fluxes in ESR.

In the present work, Raman and FT-IR Spectroscopy techniques were employed to analyze the silicate and aluminate polymerisation behaviour in fluxes having varying $CaF_2$ concentrations. The experimental results were compared with simulations carried out using FactSage™ software. This comparison provides useful information about the suitability of the low-$CaF_2$ fluxes for application in electro-slag remelting.

Keywords: slag, flux, $CaF_2$, structure, ESR, electro-slag

# Control of UTS and Microstructural Inhomogeneity in 10B35 Grade Wire Rods for Cold Heading Applications

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## Abstract

Cold Heading Quality (CHQ) steel wire rods include various low and medium carbon grades as well as alloyed steels, which are commonly used to produce several small parts like fasteners, chain links, studs, rivets etc. The Wire Rod Mill at JSP, Patratu produces several CHQ grades. The present study aims to control the ultimate tensile strength (UTS <620 MPa) and microstructure inhomogeneity, while assuring a minimum core quench hardness through the selection of suitable chemistry and optimisation of rolling process parameters for CHQ grade 10B35 wire rods manufactured at JSP, Patratu. Optical and scanning electron microscopes were used to observe the microstructural constituents whereas, Rockwell Hardness and tensile testing were performed to evaluate the mechanical properties. It has been found that alloying elements like C and Mn play significant role on controlling the UTS whereas, Cr influences the hardenability. A series of experimental studies for different diameters of wire rods were performed to optimise the soaking temperature and the soaking time required prior to the quenching process during the core quench hardness testing and the required core hardness value of 47 HRC was ensured. The variation of microstructural constituents as well as the UTS values in the wire rod at different locations of Stelmor-Conveyor were optimised by modifying the rolling process parameters and the cooling process parameters on the conveyor. It has been established that low laying head temperature (LHT) and modified cooling regime by air blowers in the conveyor system were crucial to decrease the UTS and possibilities of grain coarsening. The optimised chemistry along with the modified conveyor process parameters played a vital role in obtaining microstructural homogeneity and UTS level below 620 MPa for all diameters of wire rods.

Keywords: CHQ, Wire rods, Microstructure, UTS, Quench hardness. :

# Oxysulphide Inoculation to achieve improved Mechanical properties, reduced specific consumption of Magnesium and Inoculants during Ductile Iron pipe making

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**Abstract**

Inoculation is one of the most important metallurgical treatments applied to the molten cast iron immediately prior to casting. It promotes solidification according to the Iron Carbon phase transformation system by preventing undercooling below the metastable eutectic temperature. It provides sufficient nucleation sites for the dissolved carbon to precipitate as Graphite rather than primary carbides. Additionally, inoculation improves mechanical properties of the cast iron. According to literature, complex compounds act as potential sites as per a three-stage model for graphite nucleation in Ductile Iron, see Fig. 1.

As per the current practice at TSMD, Calcium based Ferrosilicon alloys are added as late inoculation during casting, which yields good mechanical properties. Studies have suggested that inoculation effect is not a result of the creation of new particles in the melt, but by activation of the inclusions already present in the melt. With an intent to improve the results further and to reduce the specific consumption of Mg and inoculants, the current research was carried out and has been bifurcated into two approaches. The first one is based on the discovery that pre-treating the iron with the inoculant as a preconditioner prior to nodulariser addition results in several significant and surprising advantages. The said preconditioner are basically ferrosilicon alloys having Si and a group IIA element other than Mg, preferably Ba, along with some other elements such as Al, Ca and Mn/Zr. The second one is a product-based approach highlighting the advantages of separate addition and/or partial replacement of an inoculant enhancer alloy with the conventional FeSi inoculant. This alloy provides active S and O in the melt forming oxysulphides which act as potent nucleation sites. Even a 0.03% addition of the oxysulfide inoculant produced similar or better results in comparison with additions of 0.2% to 0.3% calcium bearing foundry-grade FeSi75 in low-Sulphur late inoculated ductile irons. The initial set of trials have given positive results. Apart from the improved uniformity of nodule count and chill protection, the integration and successful implementation of both the approaches will reduce the specific consumption of Mg by 20% as well as inoculants by 30%.

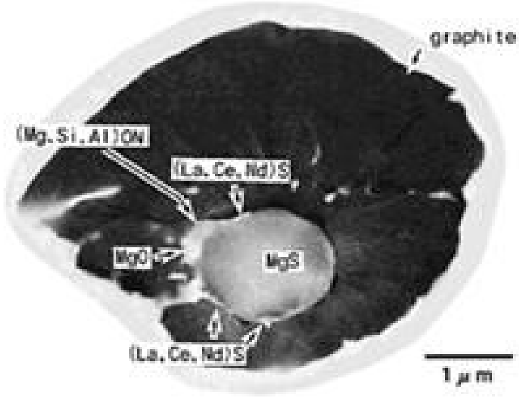


Fig. 1: SEM image showing graphite nucleation (https://doi.org/10.3390/met10020221)

key words: Oxysulphide, Inoculation, Noduliser, Graphite nucleation, Preconditioner

# On the Microstructure, Mechanical, and Electrochemical properties of heat-treated Ti- 6Al-4V alloy

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Abstract

The present research findings provide an important insight for tailoring the microstructure, mechanical, and electrochemical properties of the Ti-6Al-4V alloy by employing four types of heat treatment (HT). The HTs involve above and below the beta transus (Tβ) followed by ageing at 650 ℃. The results demonstrate that alterations in microstructure, resulting from variations in HT temperature and cooling rate, have an effect on mechanical and electrochemical properties. The Beta quenched HT (Type 1) displayed the maximum tensile strength (1166 MPa), which is attributed to the development of acicular α' phase. In contrast, the microstructure obtained from Beta annealed HT (Type 2) consists of Widmanstatten α/β phase, which leads to lower strength but increased ductility compared to Type 1. The microstructure of the solution treated and aged sample (Type 3) consists of globular primary $\alpha_p$ and acicular α', which led to well-balanced mechanical properties having tensile strength of 1124 MPa and 18% elongation. The duplex annealed sample (Type 4) shows the presence of globular $\alpha_p$ and Widmanstatten α/β phases. Among heat-treated samples, the best corrosion resistance was observed for the Type 1 sample.

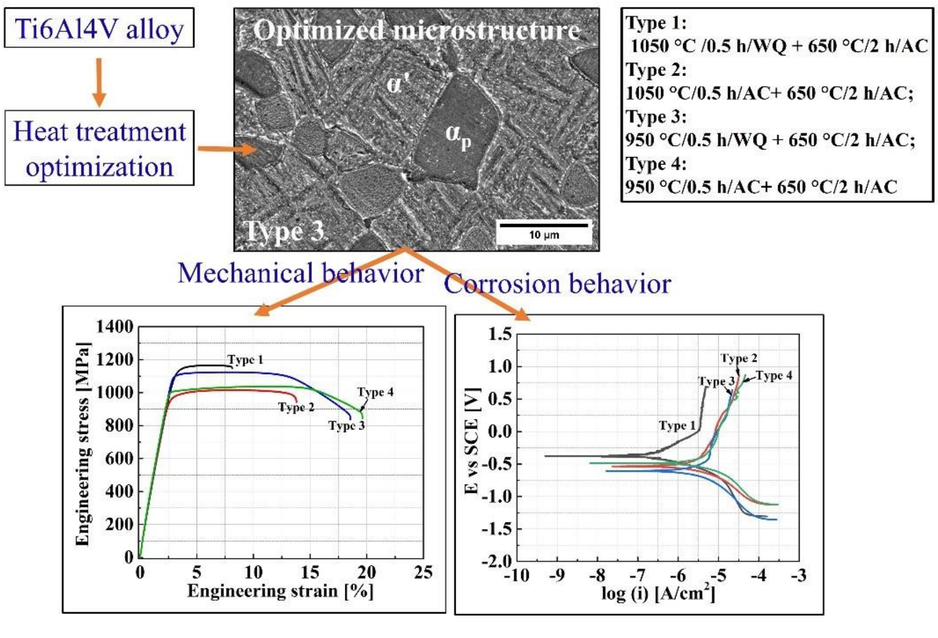


Fig. Illustration of present work

Keywords: Ti-6Al-4V alloy; Heat treatment; Microstructure; Mechanical properties; Corrosion

# Optimization of ferroalloy, process parameter and mechanical property for cost saving in pre painted Galvalume hard and soft grade

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**Abstract**

Here in this study, the production of pre-painted Galvalume flat steel product in hard and soft grade is envisaged to optimize the ferroalloy and process parameter so as to reduce the cost of production of the grade. Since the grade has high production volume, ideation for reducing cost of the grade itself serves huge EBIDTA improvement opportunity. In the next step the possibilities of cost saving in different units from steel melting to continuous galvanizing are investigated and identified. The ferroalloy cost and the continuous galvanizing line processing conditions were optimized so as to achieve required mechanical properties and surface characteristics. For the hard grade the minimum YS requirement stood at 550MPa and for soft grade it is 250MPa. Given the bath temperature of 610°C, achieving the given mechanical property in CQ substrate became challenging in full hard grade and the material would soften in the zinc pot, hence the substrate was micro-alloyed with Ti. In this study we aimed for the removal of micro-alloy and modification of processing parameter (Annealing Temperature, Line Speed & Snout Dipping Temperature) So as to achieve mechanical property just fulfilling the customer requirement. Reducing the ferroalloy usage and improvising the productivity will enhance the environmental sustainability of the grade. The reduction in overall carbon footprint is summarized in this paper.

**Key words** : pre painted Galvalume, cost saving

# Tensile property prediction model based on the Hardness measurement of zinc coated steel grades for quick validation during continuous production

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**Abstract**

In this study, a relationship between Hardness and Tensile Properties of Zinc and Zinc-Aluminum coated steel are established so as to quickly give feedback to the production line for quick validation of the process parameters. A predictive model (Machine learning polynomial regression model) is made for the calculation of mechanical property for different grade having different coating weight. The customer requirement generally is tensile property instead of hardness. Hence evaluation of tensile property is necessary. Using hardness to tensile property prediction model we can immediately predict the mechanical property by checking hardness value. This method helps in minimizing the mechanical property feedback time which is a crucial parameter for the manufacturing line operator to validate their processing parameters. The galvanizing line is continuous line hence immediate feedback is required. The tensile testing requires significant time for sample preparation and testing which can affect the production coils. Adopting this method has improved the compliance of mechanical property during mass production by quick modification in process parameters after mechanical property feedback. The tensile testing is done as per ISO 6892-1:2019 and Harness testing is done on HRB scale as per ISO 6508-1:2015.

**Key words** : Galvalume, Tensile test, cost saving, sustainability

# Microstructure and texture evolution of tailor welded blanks of AISI304

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## Abstract

Tailor welded blanks (TWB) are the emerging materials in manufacturing industry because of their weldability, formality and light weight blend. Austenitic stainless steels (AISI 304) are promising materials for their formability and corrosion resistance. Tailor welded blanks of austenitic stainless steels are best suitable material for automobile and aerospace parts like chassis, door panels, B pillars for high end automobile vehicles, fuselage parts in aircraft. In the present work tailor welded blanks of austenitic stainless sheets of thickness 1.2 mm were prepared by TIG welding, then their formability was evaluated through limit dome height test (LDH). Microstructure, texture features of deformed sheets was evaluated and corelated with formability. It was noticed that microstructure features like grainsize (GS), grain average miss orientation (GAM), grain orientation spread (GOS), twinning fraction (TF), phase fractions (PF) and intensity of texture components like, Copper, Brass, Goss texture was highly influenced by strain level and strain patch chosen for forming during LDH test.

**Keywords:** TWB, LDH, AISI304, Microstructure and texture.

# Plastic response of the heat-treated Fe-Mn-C steels after the profilometry-based indentation plastometry (PIP) tests

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## Abstract

Fe-Mn-C steels proves to be promising in the field of automotive, structural and mining industry owing to their remarkable strength, toughness, work hardening, corrosion resistance and wear resistance behavior. The present work focuses on the structure-property relationships of high manganese (Mn) steel subjected to heat treatment (HT) within 300˚C to 500˚C. The formation of carbides with the increasing temperature and the emergence of deformation bands during PIP test resulted in a monotonous increase in the strength and hardness of the steel. However, the localized presence of these carbides became the potential site for the initiation of cracks, adversely affecting the overall tensile properties. The post-EBSD characterization revealed a severity in strain localization within evolving deformation bands, resulting in the gradual decrease in uniform strain and the corresponding increase in the tensile strength of 500˚C-HT specimen. The lower specific wear rate and lesser wear volume also specify the better wear resistance properties in the above-mentioned condition.

**Keywords:** High Mn steel; Intermetallic carbides; Tensile properties; Strain partitioning; Deformation bands.

# Optimization and Performance Analysis of Brake Disc Chemistry and Microstructure under Extensive Braking Conditions

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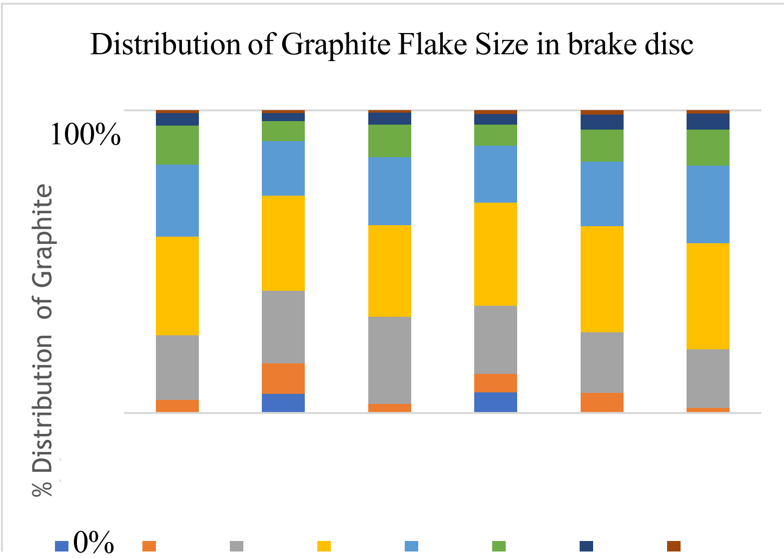
## Abstract

The effectiveness of braking systems under extensive applications is crucial for the safety of passengers. Thermal distribution in Brake Disc is one of the key factors to be considered in designing effective brake system, particularly during high-speed deceleration and frequent braking in hilly terrains. This study involves simulated braking conditions tested as part of the design validation plan.

A notable phenomenon observed was deep scoring marks on the brake disc and material pickup on the brake pad, which were examined under different microstructural conditions to determine the optimal structure. Additionally, the alloying tendencies of brake discs were benchmarked across different regions globally for passenger car applications. The study provided substantial evidence linking hardness, microstructure, flake distribution, and chemistry. The flake size distribution and type of flake microstructure were taken into consideration for optimization to improve targeted braking cycle performance without scoring and material pickup. Various brake disc chemistries were analyzed to understand their impact on mechanical and flake size distribution.

This research also explored the impact of different brake pad applications on physical properties and braking performance. The trend of graphite flake size relative to carbon equivalent was studied to comprehend its effect. Furthermore, the distribution of flake size on the braking surface from inner diameter (ID) to outer diameter (OD) was investigated to understand the influences of manufacturing processes and braking applications. Finally, the optimized target flake size (Fig. 1) and flake type 'A' provided an 80% improvement in braking cycle performance without scoring on the brake disc and material pickup/chip off on the pad.


Inboard ID Inboard Inboa rd Outboard Outboard Outboard

Center OD ID Center OD

Brake Disc Location

Size 1 Size 2 Size 3 Size 4 Size 5 Size 6 Size 7 Size

# Microstructure evolution and mechanical behaviour of as- cast chromium-contained ductile cast iron

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**Abstract**

The utilization and versatility of ductile iron (DI) extend across diverse sectors, from automotive to construction, owing to its exceptional blend of robustness and malleability, enabling the fabrication of complex and resilient parts that enhance the spatial effectiveness and dependability of contemporary engineering setups. This study investigates how adding chromium carbide to DI affects its mechanical properties. The authors examined the role of iron-chromium-carbides (Fe-Cr-C) formed by adding 4 and 8 wt.% $Cr_3C_2$ in DI. Compositions of alloys were selected using the DI-$Cr_3C_2$ phase diagram, which indicated the formation of ferrite, graphite, $M_3C$, and $M_7C_3$ phases on equilibrium cooling below $A_1$ temperature. Microstructural characterization reveals the increasing pearlite fraction and reducing graphite nodule size on increasing the $Cr_3C_2$ fractions in DI due to the formation of the $M_3C$ and $M_7C_3$ phases in DI during cooling. Alloy with 8 wt.% $Cr_3C_2$ showed a better combination of hardness, longitudinal elastic constant values, specific wear rate and flexural strength of 480 $HV_{30}$, 256 GPa, $2.61 \times 10^{-5}$ $mm^3/mN$ and 705 MPa, respectively, than other $Cr_3C_2$ concentrations. The findings highlight the significant role of $Cr_3C_2$ in enhancing the wear resistance and mechanical properties of DI, making chromium-alloyed cast irons a promising avenue for improving material performance in various industrial applications.

**Keywords:** Ductile iron, iron-chromium-carbides, three-point bending test, ultrasonic phase spectroscopy, and wear

# Development of Titanium Stabilized 409L grade with excellent R-Bar (Plastic Strain Ratio) & Improved Microstructure through Batch annealing Route for Deep Draw Applications

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Jindal Stainless Limited produces cost effective Ti-stabilized ferritic stainless steel 409L grade which exhibits excellent deep drawability, resistance to elevated temperature and good weldability. Hence, this grade is a promising material for the automotive industry which comprises complex critical drawn components.

This article presents a systematic study has been undertaken to accomplish the excellent combination of above 35% elongation, improved R-bar of 1.50 (Plastic Strain Ratio or Plastic Anisotropy) and uniformly equiaxed recrystallized grains. In order to fulfil the requirements of critical deep drawing applications, by using EMS to ensure 50% minimum equiaxed cast structure, low finishing temperature of 750°C during hot rolling, soaking temperature of 850°C for 5 hours & minimum 70% cold reduction in 20-Hi Sendzimir Mill followed by soaking temperature of 970°C and efficient soaking time at annealing & pickling line which were optimized by extensive lab scale heat treatments. And, which can help to develop uniform equiaxed recrystallized grains and increased fraction of γ-fibre texture on final microstructure of cold rolled annealed & pickled products. The properties of ferritic stainless steel are influenced by the volume fraction of grains with ND//<111> texture components which is more favourable for superior deep drawing characteristics.

**Keywords:** Ti-Stabilized Ferritic Stainless Steel, Automotive, Deep Drawing, Plastic Strain Ratio (R-Bar), Elongation

# Insights into the nano-scale mechanical property and random pop-in behavior in a Ni added lightweight steel

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**Abstract**

The current study aims to understand the effect of different microstructural features on nano-mechanical properties and random pop-in behavior in a Ni containing duplex lightweight steel. Towards this, the nano-indentation tests have been extensively performed at room temperature in undeformed condition (UC) and deformed condition (DC). The nano-hardness of various regions in the microstructure such as grain boundaries (GB), interphase boundaries (IB), and constituent phases are evaluated in both the specimens. It has been observed that the nano-hardness is higher in the matrix phases of the UC as compared to the DC, indicating the significant influence of nano-sized precipitates on the nano-hardness. Conversely, the GB and IB regions in the DC showed higher nano-hardness than in the UC due to the presence of coarse precipitates along the GB and IB regions. Further, the elastic modulus ($E_s$) of the individual phases is calculated from the nano-indentation data for both specimens and correlated with the microstructural features. The $E_s$ values in both specimens are observed to be higher than those in the conventional Fe-Al-Mn-C system, suggesting the influence of various precipitation phenomena. Additionally, the variation in random pop-in behavior in the plastic regime of the P-h curve is investigated in detail. This behavior is found to be associated with the factors such as the interaction between precipitates and dislocations, the presence of pre-existing dislocations, the strain field generated by dislocations and precipitates during the nano-indentation etc.

# Alloy design of low carbon low alloy carbide free bainitic steel

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**Abstract**

In this study, an effort has been made to replace the traditional heat treatment cycle, which typically involves quenching from the austenitization temperature followed by tempering, straightening, and stress relieving, with a single-step air cooling process. This alternative heat treatment method aims to reduce production and labour costs. The study began with the design of an alloy based on five parameters: hardenability, strength, restriction of $Fe_3C$ precipitation based on critical temperature (TC) and To composition (Co), weldability, and the combination of alloying elements. The designed low carbon low alloys resulted in a microstructure of granular-like carbide-free bainitic ferrite with a small amount of retained austenite which is formed during continuously cooling (air-cooling). Developed steel yields uniform microstructure obtained during various cooling rate which is important for industry where complex shapes are fabricated. The continuously cooled steel developed through this approach exhibited superior properties compared to ferritic-pearlitic and tempered martensite steels. Detailed characterization and quantification of microstructural constituents were conducted and correlated with tensile properties.

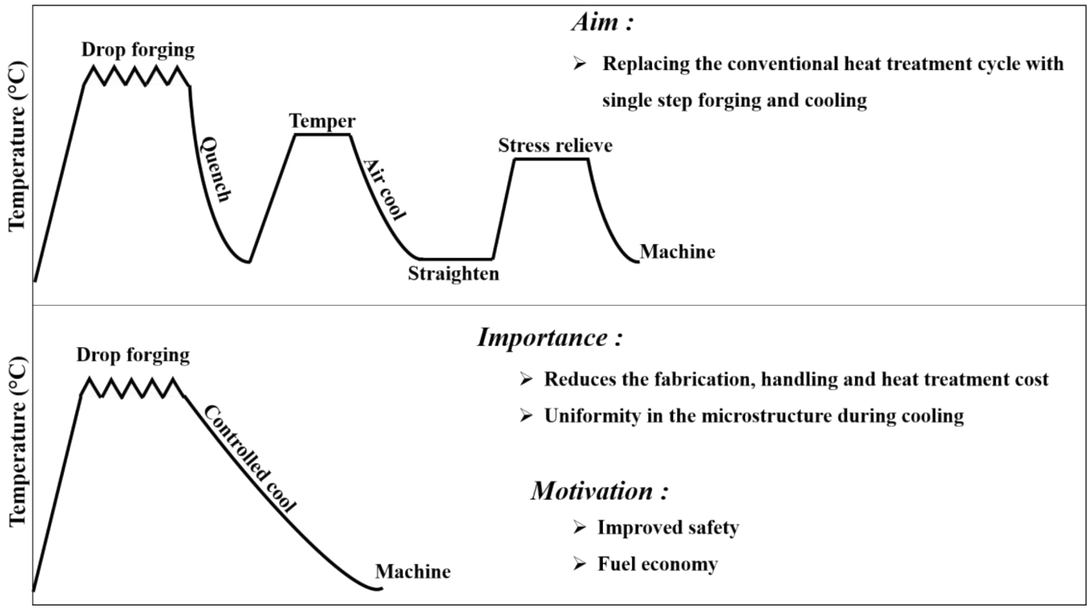


Fig. 1: Replacing the conventional heat treatment cycle with single step forging and cooling

key words: Carbide free bainite, tensile strength

# Structure-property correlation in a Ni-modified advanced high strength steel: Effect of hot rolling and subsequent annealing

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**Abstract**

The present study investigates the influence of microstructural features on the mechanical properties of a newly developed nickel-modified austenitic-based steel. This steel is produced by a melting casting route, followed by hot-forging, and hot-rolling. The microstructure of the hot rolled (HR) and annealed (at 973 K) specimens consists of BCC, FCC, B2, and κ-carbide precipitates. However, the specimen annealed at 1173 K contains the presence of BCC, FCC, and B2 precipitates. At an annealing temperature of 1373 K, the dissolution of κ-carbide and B2 precipitates occurs, resulting in the stabilization of the BCC and FCC phases. The HR specimen demonstrates an exceptional combination of strength and ductility, with an ultimate tensile strength (UTS) of approximately 900 MPa and total elongation (TE) of about 70%. In comparison, the specimen annealed at 1173 K exhibits the highest tensile strength (UTS ~ 1103 MPa) along with good ductility (TE ~ 45%) among the specimens studied. The superior ductility observed in the HR specimen is attributed to the synergistic effects of optimal grain size, a reduced quantity of B2 precipitates, a higher fraction of deformation twins, and enhanced strain hardening. Conversely, the higher tensile strength of the specimen annealed at 1173 K is due to the increased presence of B2 precipitates and finer grain structure.

Key words: Hot-rolled, B2 precipitates, tensile strength, Deformation twins, Strain hardening

# Evaluation Of Strain-Induced Precipitation in HSLA Steel Through Stress Relaxation Testing

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**Abstract**

A low carbon microalloyed HSLA steel was studied for its strain induced precipitation behaviour through stress relaxation testing, emphasizing the interplay between recrystallisation behaviour and precipitation strengthening.

Among the different methods available for studying precipitation behaviour, the stress relaxation test is extensively employed, chosen for its notable advantages over alternative techniques. Stress relaxation tests were conducted on cylindrical compression specimens of a low carbon microalloyed HSLA steel, of 15 mm x 10mm size, using Gleeble thermomechanical simulator system following a double deformation pass with first pass at a fixed temperature and second deformation pass at various temperatures. Both deformation passes were imposed for 20% reduction.

This work showcases the understanding developed for identifying the precipitation from stress-time data and its interpretation and also highlights the challenges faced in this study. ThermoCalc was used to assess the precipitation behaviour. Fractional softening values were derived from the experimentally recorded data and a temperature-time plot was made which indicates the shift of time taken for completing the static recrystallisation. This retardation to finish static recrystallisation is attributed to occurrence of precipitation.

# Light weighting of Automotive structures made of High strength Boron steel by heat treatment

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**Abstract**

The increasing need to enhance fuel efficiency and control greenhouse gas emissions is driving automakers to develop lighter vehicles. Since alternative fuels like batteries, hydrogen fuel cells, and LNG are heavier than conventional fuels, there is a strong push towards reducing vehicle weight. Various methods exist to achieve this, such as using lighter materials like aluminum or composites, or employing advanced high-strength steel (AHSS). However, aluminum, composites, and AHSS can be cost-prohibitive for the commercial vehicle sector. An alternative approach to weight reduction involves using heat-treated boron steel, which can be made thinner while maintaining strength. Boron enhances the hardenability of steel by influencing grain-boundary segregation, which helps in reducing nucleation of ferrite and maintains growth rates. Boron-alloyed quenched and tempered steels are extensively utilized in hot stamping in the automotive industry due to their favorable properties like good wear resistance and strength, owing to their lower carbon content. Structural components such as frames, cross members, and load bodies contribute significantly to vehicle weight. In this study, we utilized 28MnB5 steel, shaping it as needed. For heat treatment, induction hardening is selected for its rapid and even heating. After forming the sample, induction hardening is employed to heat the sample to 850°C, followed by pretreatment of direct quenching in proprietary water+polymer mixture, and subsequent tempering at 550°C. By replacing the current steel with this heat-treated variant and reducing its thickness, we can achieve a weight reduction of 25%. Below Fig 1 shows the stress strain behavior of boron steel before and after heat treatment. From the figure heat treated boron steel shows superior properties (UTS -1700 MPa) then non heat treated steel (UTS – 700 MPa).

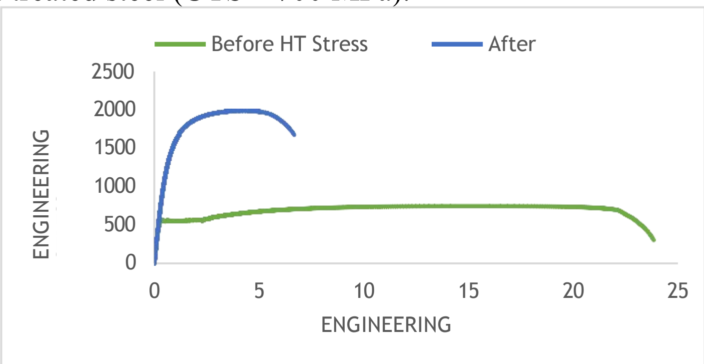


Fig 1: Stress strain curve of 28MnB5 steel before and after heat treatment

key words : HSLA, Stress Relaxation test, Gleeble, Strain induced precipitation, Static recrystallisation
Key words: Light weighting, induction hardening, direct quenching, High UTS, Boron steel

# Differential Scanning Calorimetric Studies on Aluminium Alloy conforming to AA7049 specification

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## Abstract

High strength Aluminium alloys are used extensively as aircraft structural components. These alloys are susceptible to corrosion in the peak-aged T6 temper. The susceptibility of this temper to corrosion is alleviated through the use of over-aged T73 temper, that provides improved corrosion resistance, but with a 10-15% loss in mechanical properties compared to the T6 temper. The Retrogression and Re-Ageing (RRA) is a multi-stage heat treatment that reduces the tradeoff between T6 strength and T73 corrosion resistance. In the present study, the influence of RRA on the properties and microstructure of high strength aluminium alloy conforming to AA7049 specification has been studied. This is compared with T6 and T73 temper designation. The phase transformations associated with the different steps of RRA treatment were studied using differential scanning calorimetry (DSC) and were compared with Mechanical Properties and Electrical Conductivity.

The results of microstructural analysis of the aluminium alloy conforming to AA7049 specification in several tempers are shown to provide a sound basis for the interpretation of various calorimetric studies reported in the open literature. The study indicates that all the prominent features of the DSC curves can be streamlined with the precipitate microstructures produced by the various heat treatments, specifically η′ precipitates in the peak-aged alloys and mixtures of η′ and η precipitates in the slightly overaged and RRA tempers. A DSC thermogram of extruded AA7049 Al-alloy subjected to retrogression treatment at various temperatures for different time durations, followed by re-aging, overlapped with DSC thermogram of extruded AA7049 Al-alloy subjected to T6 and T73 temper heat treatment is presented in the following figure 1.

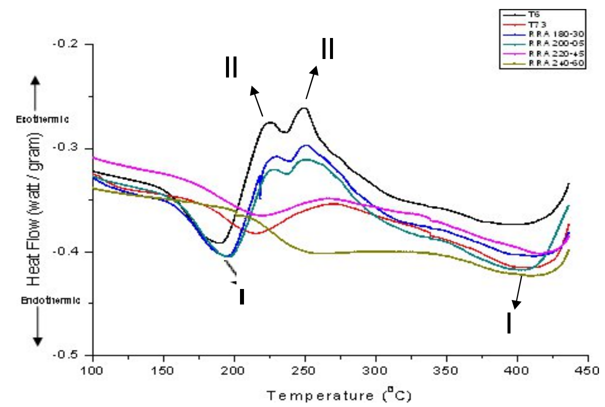


**Fig. 1: DSC thermogram of extruded AA7049 Al-alloy at various Tempers.**

**Keywords**: Aluminum alloy AA7049; Retrogression; Re-aging; Microstructure; Differential Scanning Calorimetry (DSC) and Mechanical properties

# Study of machining-induced surface integrity of silicon steel

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**Abstract**

Silicon steel is emerging as an alternative to ferritic and austenitic steels. This alloy steel has good strength, ductility, and good corrosion resistance. Recent study has shown that silicon addition can also be used to manipulate the phase composition. Low silicon content leads to austenitic microstructure, while high silicon content leads to formation of duplex microstructure. Surface of a component is the interface to its environment and hence several functional properties like wear, corrosion and fatigue characteristics are directly dependent on the surface integrity of the component. Since steel components are primarily manufactured by machining, it is important to understand the effect of machining-induced surface integrity.

In this work, we study the effect of alloy composition and machining parameters on surface integrity parameters like surface roughness, hardness, sub-surface microstructure and residual stress. Surface roughness was assessed through optical profilometry, and microstructural changes in the surface and subsurface regions were examined using SEM and EBSD techniques. The primary causes of microstructural alterations during machining are the generation of heat and the occurrence of significant plastic deformation. Residual stresses which arise due to thermomechanical stresses, were determined using the $\sin^2\psi$ method.

# Influence of cyclic heat treatment on the microstructure, texture evolution and mechanical behaviour of α+β Ti-alloy

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Abstract

The current study investigated to understand an effect of cyclic heat treatment on the microstructure, texture evolution and mechanical behaviour of Ti-6Al-4V alloy. The as-received Ti-6Al-4V alloy subjected to solution treatment at 1000 °C+water quenching. Cyclic heat treatment in the temperature range of 850-950 °C for 2-10 cycles followed by air cooling was carried out for the solution treated Ti-6Al-4V alloy. The as-received and cyclic heat treated alloy is subjected to room tensile tests in the initial strain rate range of $1\times10^{-3}$ to $1\times10^{-1}$ $s^{-1}$. Vickers hardness of the as received and cyclic heat treated Ti-6Al-4V alloy was measured using the load of 500 g for the dwell time 10 sec. Microstructure, texture, phase examination were carried out using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD) and Electron back scattered diffractometer (EBSD) . The as-received Ti-6Al-4V alloy comprised of two phase (α+β) structure with equiaxed α, transformed β microstructure. Stress-strain curves after room temperature tensile tests revealed increased strength and work hardening rate depending on the strain rate, cyclic heat treatment condition. The trend of stress-strain curves could be related to the morphology, grain size, volume fraction of α, β phases and texture evolution at corresponding test conditions.

key words : Ti-6Al-4V alloy, cyclic heat treatment, mechanical behaviour, microstructure, texture

# Determining mechanical properties of materials using microscopy techniques

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## Abstract

The mechanical properties of materials play a critical role in material selection, quality control, and performance prediction. However, accurately measuring these properties at the nanoscale presents a significant challenge. This study addresses the challenge of measuring nanoscale mechanical properties using a combination of Scanning/Transmission Electron Microscopy and Electron-Energy Loss Spectroscopy (EELS). To investigate this correlation, we employed EELS technique to measure the plasmon energy of a selection of materials commonly used in engineering applications: Zinc (Zn), Zirconium (Zr), Titanium (Ti), Niobium (Nb), and Stainless steel (SS 304). The measured plasmon energies exhibit a clear dependence on the material's properties like elastic modulus, hardness, and valence electron density, suggesting a strong correlation between these properties and the electronic structure probed by EELS. This Finding provides a foundation for using microscopy techniques as a potential tool for the characterization of mechanical properties at the nanoscale.

**Key words:** Mechanical Properties, Electron-Energy loss spectroscopy, S/TEM, Valency Electron Density, Elastic Properties

# Effect of Annealing Conditions on B2 Precipitate Formation and Mechanical Properties in Low Al-CoCrFeNi Alloy

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**Abstract**

Equiatomic CoCrFeNi alloy has been one of the most studied high entropy alloy (HEA) systems to which further alloying additions are done to obtain superior combination of properties. Aluminum addition to this CoCrFeNi base alloy has been known to produce an ordered B2 phase in a disordered FCC matrix. The present study reports the extension of two-phase (FCC-B2) coexistence to a low Al content alloy ($Al_{0.2}$CoCrFeNi) through a combination of deformation and annealing treatments. Microstructural stability of the alloy during long term annealing is investigated and mechanical properties as a function of heat treatment temperature and time are reported. The alloy has a single-phase FCC structure after annealing at 900 °C, while B2 precipitates formation in FCC matrix was observed at 700 °C. These precipitates pinned the grain boundaries effectively and resulted in a very stable microstructure with fine grain size (~5 µm) even during longer annealing durations. However, the grain size increased rapidly in the single-phase alloy during annealing at 900°C with a corresponding decrease in hardness as per the Hall-Petch-type correlation. Consequently, the low-temperature annealed material exhibited a significantly higher tensile yield strength without significant sacrifice in ductility**.** Further research into precipitate evolution, size distribution, volume fraction and their influence on various mechanical characteristics could provide valuable insights for advancing the alloy's development for structural applications.

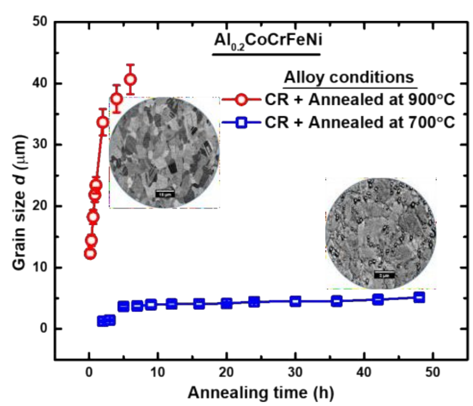


Fig: Evolution of grain size with annealing time in A900 and A700 samples

Keywords: High entropy alloys, Grain boundary strengthening, Precipitation strengthening, Microstructural stability

# Role of molybdenum on high temperature deformation of Fe30Mn5Al1C (0-3) wt. % Mo Light Weight Austenitic Steels: Monotonic Tensile and Creep

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## ABSTRACT

Lightweight austenitic steels based on the Fe-Mn-Al-C system can be candidate materials for high-temperature applications. The reports on understanding the behavior of these classes of alloys at high temperatures are limited. In the present work, four lightweight austenitic steels Fe30Mn5Al1C (0-3) wt % Mo were designed and processed through a vacuum induction melting route followed by hot-deformation and cold-working. The cold-rolled alloys were annealed to common grain size (~ 80 ± 5 µm). Their deformation behavior is studied using uniaxial tensile tests in the temperature range of 300 - 973 K at an initial strain rate of $10^{-3}$ $s^{-1}$ and tensile creep tests at 650°C in the stress range of 100-165 MPa respectively. The microstructural characterization is done at different stages using FESEM-EBSD and TEM. The flow strength of the alloys up to 673 K is dominated by solid solution strengthening by carbon than by molybdenum due to greater dislocation - solute interaction energy. However, beyond 673 K, the strength of the alloys increased with an increase in molybdenum by solid solution strengthening by molybdenum in 0.5 wt. % Mo and additionally by precipitation strengthening by molybdenum enriched carbides in 2 and 3 wt. % Mo alloys. On the other hand, a significant drop in fracture strain with an increase in molybdenum was observed at 973 K, due to transition in fracture mechanism from transgranular ductile to quasi-ductile with intergranular cleavage fracture due to the formation of molybdenum-enriched carbides. Serrated flow observed is attributed to dynamic strain aging (DSA) phenomena occurring due to the interaction of dislocations with carbon at low temperatures and with molybdenum at high temperatures respectively. The creep studies revealed a decrease in steady-state creep rates with an increase in molybdenum at all stresses, with the stress exponents decreasing from 8.6 to 3.5 from 0 to 3 wt. % Mo. The calculated activation energies, the presence of primary creep, and stress exponents suggested that the dislocation-based creep mechanism could be the active creep mechanism among these alloys.

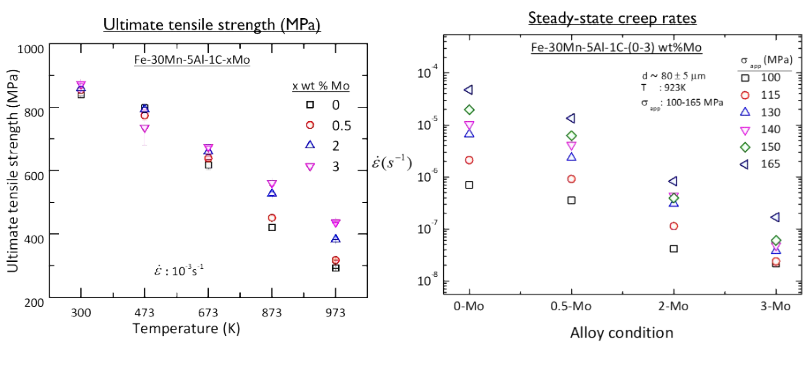


Fig: UTS at different test temperatures and steady state creep rates at 923 K with varying molybdenum content

**Key words:** Fe-Mn-Al-C lightweight austenitic steels, high temperature tensile testing, creep, microstructure.

# Microstructural and Mechanical Properties of 28CrMoNiV4-9 Steel

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## Abstract

The microstructure and mechanical properties of the 28CrMoNiV4-9 steel in hardened-tempered condition are investigated. The chemical composition of the steel is analysed using ICP-MS. The steel is hardened with solutionizing from 950 °C and quenched in water. The hardened steel is then subjected to tempering heat treatment at 640 °C. The microstructural characterization of the 28CrMoNiV4-9 steel in hardened-tempered condition is carried out using optical microscopy and SEM. The microhardness values of the steel are taken using a Vickers hardness tester at a load of 0.5 kg with a dwelling time of 10 s. The steel specimens are subjected to tensile testing according to ASTM E8M standard at a strain rate of $6.66\times10^{-4}$ /s. The chemical composition of the as-received steel confirms the steel is 28CrMoNiV4-9. The microstructure of the 28CrMoNiV4-9 steel in hardened-tempered condition consists of lath-type tempered-martensitic. The values of yield strength, ultimate tensile strength, and fracture stress for the 28CrMoNiV4-9 steel in hardened-tempered conditions are 1098.3±5.3, 1140.2±6.7, and 660.6±3.1 MPa, respectively, with %Elongation 34%. The strain hardening rate of the steel is significant, and the value of the strain hardening exponent (n) is 0.52. The average Vickers microhardness value of the 28CrMoNiV4-9 steel in hardened-tempered condition is 367.2 ± 4.0 VHN. A detailed investigation is in progress.

Keywords: 28CrMoNiV4-9 steel; Hardened-tempered; Microstructure; Hardness; Tensile behaviour

# Microstructure and creep behaviour of SiC nanoparticles reinforced MRI230D alloy

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## Abstract

The microstructure and creep behaviour of the MRI230D alloy reinforced with SiC nanoparticles ($SiC_{np}$) are investigated. The primary Mg (α-Mg), lamellar C36 $(Mg, Al)_2Ca$, and blocky $Al_8Mn_5$ phases are identified in the MRI230D alloy and nanocomposites (NCs). Additionally, the SiC phase is identified in the nanocomposites, as expected. The additions of $SiC_{np}$ result in significant grain refinement and increased volume fraction of the $(Mg, Al)_2Ca$ (C36) phase. The nanocomposites exhibit superior creep resistance compared to the MRI230D alloy under all testing conditions, with NC reinforced with 2.0 wt.% SiC demonstrates the best creep performance. The enhanced creep resistance of the NCs than the MRI230D alloy is attributed to the combined effects of the increased fraction of the C36 phase and Orowan strengthening owing to the dispersion of SiC nanoparticles in the α-Mg matrix. The creep deformation mechanism in the MRI230D alloy and NCs is the dislocation climb with pipe diffusion under the experimental conditions employed.

**Keywords:** MRI230D magnesium alloy; Nanocomposite; Microstructure; Creep

# Influence of microstructure on erosion-corrosion resistance of micro-alloyed steels

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## Abstract

Development of steel compositions with enhanced wear resistance, corrosion resistance, wear-enhanced corrosion resistance, and corrosion-enhanced wear resistance is essential to counteract the damaging effects of erosion-corrosion synergy on the service life of slurry pipelines.

In the present development, an approach to enhance erosion-corrosion resistance of line-pipe steels via microstructure tuning and synergistic micro-alloying was adopted by adding Mo and Ni in base API X70 steel and controlling rolling parameters to obtain favourable microstructure. A plant scale trial followed by detailed testing and characterization enabled us to reveal the influence of microstructural characteristics and micro-alloying on enhanced erosion-corrosion resistance of steels and underlying mechanism behind it. Pure erosion, pure corrosion and erosion-corrosion performance was assessed with help of electrochemical impedance spectroscopy (EIS), linear polarization test and jet-erosion testing. The developed steel with improved composition and tuned microstructure, demonstrated an 85% increase in pure erosion resistance and a 41% enhancement in pure corrosion resistance. Additionally, these improvements in alloying and microstructure led to a 63% boost in erosion-corrosion resistance. Microstructural characterization was performed using SEM, SEM-EBSD, XRD and additional metallographic techniques. Post quantification of phase fraction, grain size, grain orientation and distortion, structure-property correlation was established. Enhancement in erosion-corrosion resistance is attributed due to increased proportion of hard carbides and martensite phases in the microstructure as well as increased resistance to localised corrosion (pitting corrosion) by Mo addition. Furthermore, correlation of mechanical attributes such as DWTT shear area, ductility, hardness, CVN Impact energy with erosion rate, corrosion rate and erosion-corrosion rate was also attempted to enable us and industry for preliminary assessment of these type of steels before going to tedious erosion-corrosion testing at lab scale as well as on-field testing and implementation for such applications.

Key words : Erosion-Corrosion, EIS, Microstructure, line-pipe stee

# Effect of dispersion technique and applied load on the dry sliding wear behavior of combined stir-squeeze-cast AA6061-0.5 wt. % CNT composite against a steel counter body at both room temperature and elevated temperature

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**Abstract**

Wear and friction behavior have been studied for different AA6061-0.5wt.% CNT composite samples fabricated by combined stir-casting and squeeze-casting. Three distinct dispersion methods have been employed to manufacture the composites - direct mixing of CNT (DD), a mixture of Al and CNT pellet drop (PD), and direct mixing of ultrasonicated CNT (USDD). The PD composite shows the lowest coefficient of friction (COF) and specific wear rate (SWR) due to the uniform distribution of CNTs. The wear mechanism of different dispersion techniques has been discussed and compared with AA6061. Furthermore, the effect of load on friction and wear behavior has been tested only for the PD sample. Both COF and SWR increase as the load increases from 5 N to 10 N, but drop as the load increases further to 15 N. Comparison of the SWR for the PD sample at 5 N, 10 N, and 15 N shows that the SWR at 10 N load is marginally lower than 5 N. Even at elevated temperatures (150˚C), the presence of CNTs improved the tribological performance of AA6061. A detailed study of CNT morphologies on the worn surface and Raman spectroscopy indicate their role as a solid lubricant which helps to reduce both COF and material loss during wear.

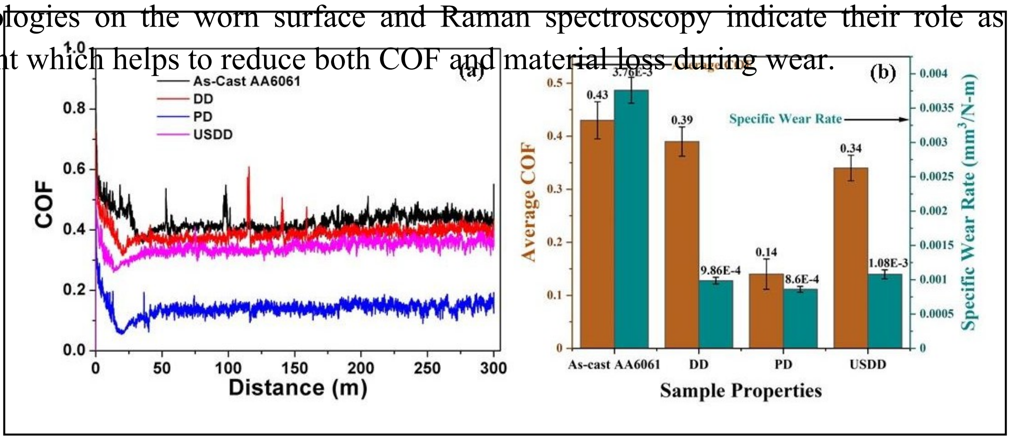


Fig. 1: (a) COF vs distance plot of as-cast AA6061 and composite samples (b) average COF and SWR of as-cast AA6061 and composite samples over the complete wear track length

Keywords: Aluminium- CNT composite, Stir casting, Tribolayer, High-temperature wear, Raman spectroscopy

# Strategy to improve strength-ductility together by TRIP effect in a 2101 lean duplex stainless steel

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**Abstract:**

To understand the microstructure and mechanical properties of a lean Duplex stainless steel (LDSS), four different process routes were applied which is also feasible to produce industrially maintaining the standard phase fraction in the range of 45-55 vol% austenite-ferrite. The microstructural variation was obtained by varying cold reduction in the range of 30-70% and annealing treatments (temperature in the range of 910°C-1140°C). The microstructures of the studied samples were evaluated by using optical microscopy, SEM, and EBSD analysis, and tensile properties were determined at room temperature. It was observed that simultaneous improvement in the strength and ductility at room temperature by applying the 30-50% cold reduction and annealing at 910°C for a short time (10 min). The reason behind the increase in the strength and ductility together was correlated with the evolution of fresh secondary austenite and partially recrystallized austenite-ferrite in the microstructure. The harder partially recrystallized austenite along with only a few fresh austenite promotes instability during tensile deformation and causes TRIP-induced ductility. At the same time, the harder partially recrystallized austenite-ferrite provides better yield strength compared to fully recrystallized microstructure. The strain partitioning and damage evolution was also analysed by characterizing the tensile-tested sample. As the phase fraction is between 45-55% which is following the requirement of ASTM standard, the process can be followed to improve the strength-ductility together which is uncommon for any alloys at room temperature

Keywords: Lean Duplex stainless steel, strength-ductility, TRIP, tensile proper

# Selective composite strengthening of wrought nickel alloy by thermochemically induced Ni3Al (γ′) precipitation

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## Abstract

The wrought nickel alloy is subjected to homogenization treatment followed by modification of surface chemistry by aluminum deposition on the sample surface. The resultant specimen is treated to modify the microstructure at the component surface into Ni3Al (γ′)-precipitation hardened, with the center part of the sample retaining base alloy composition and microstructure.

Initially, the induction of aluminum on the sample surface forms a layer of aluminum- rich phases like NiAl, with a thickness of a few microns, which can offer high hardness to the sample surface yet susceptible to brittle failures. The formation of phases on the aluminum side of nickel-aluminum binary systems like Ni2Al3 and NiAl3 shall further weaken the system. The component post-to modification of surface chemistry is subjected to heat treatment for diffusion-controlled phase transformation leading to the transformation of the NiAl layer into a network of Ni3Al and Ni-gamma (γ) matrix. The resultant sample is a composite system with outer layers composed of γ-γ′ network within a granular structure and the inner part of the sample is a retained wrought system (base metal at initial conditions). The strip of γ-γ′ region near the surface of the sample has a hardness above 350 HV while the inner part of the sample has a hardness of less than 300 HV. The sample has high-performance characteristics in high-temperature applications like steam tubes, boiler applications, etc, where components are subjected to creep and fatigue loads. The precipitate-modified granular microstructure on the outer surface of the components provides better resistance to fatigue failure when compared to samples with mere surface hardening by quenching methods. The quenching methods often involve martensitic transformations which lead to the formation of acicular structures with higher chances of failure initiation under fluctuating loads, compared to γ′ precipitates which have symmetric structures with smooth interfaces (edges). The process discussed in the paper can be used in industrial applications like on-site repair or enhancement of components applications like boiler tubes, heat shields, etc. to improve performance, avoiding the cost of replacement of damaged or aged components.

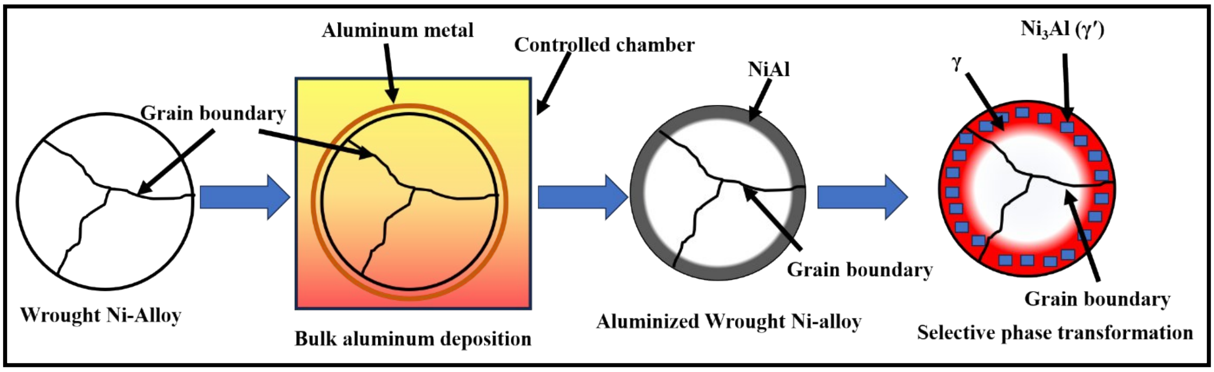


Fig. 1: Selective area phase transformation by composition modification

keywords: Ni3Al (γ′) precipitates, aluminizing, boiler application

# Correlation between Microstructure, Texture, and Mechanical Properties of Pure Mg and its Alloys

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**Abstract**

The present research works describe the correlation between microstructures, textures, and mechanical properties of pure Mg and its alloys. The pre-developed hot-rolled pure Mg and its alloys were annealed at 400 °C for 4 h followed by rolling up to 90 % reduction in thickness at different rolling temperatures. The final rolling temperatures were set at 150 °C, 300 °C, and 350 °C for pure Mg, Mg–Al, and Mg–Al–Ce alloys respectively. Subsequently, isothermal annealing was carried out in a tubular furnace under Ar atmosphere for all rolled samples. The annealing temperatures ranged from 150 to 450 °C for a period of 1 min to 1 day i.e., 1440 min, respectively. For both Mg–Al, and Mg–Al–Ce alloys, annealing at 150 °C was not considered due to the insignificant change in microstructures. However, annealing at 450 °C led to the burning of pure Mg which restricted its annealing temperature up to 400 °C. Present investigation showed that the strength of pure Mg had been influenced by the average grain sizes of the samples, whereas its ductility depends on the decrease in basal texture intensity. However, annealing of pure Mg at 300 °C for 15 min provided the desired combination of strength and ductility. In a similar manner, annealing of Mg–Al alloys for 480 min at 400 °C and Mg–Al–Ce alloys for 10 min at 450 °C led to the similar outcomes. However, annealing at lower temperatures (between 200 and 300 °C), both magnesium alloys failed to exhibit any correlation between their mechanical properties, texture, and grain size. This could be attributed to the presence of precipitates in the alloys. Compared to the annealed pure Mg and Mg-Al alloy, it was found that the Mg–Al–Ce alloy retained the best combination of tensile strength and ductility.

**key words**: Pure Mg, Mg Alloy, Grain Growth, Mechanical Properties, Texture

# Investigation of phase stability in Cantor alloy using amorphous alloy film

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## Abstract

High entropy alloys (HEAs) have emerged as promising materials due to their exceptional mechanical properties and potential applications. The presence of single-phase regions in some of these alloys makes them extremely desirable for certain applications. Cantor alloy is one of the most studied HEAs for which an fcc single-phase stability region has often been reported for near-equiatomic compositions. However, recent studies carried out at elevated temperatures and extended period of time have reported precipitate formation in these alloys. This work investigates the phase stability in Cantor alloy by using free-standing amorphous films of near-equiatomic composition. This approach overcomes some of the inherent limitations associated with the use of crystalline, bulk alloys prepared through liquid metallurgical route to study phase stability in these alloys. In this work, the alloy films of the desired composition were grown on salt crystal at cryogenic temperature to obtain amorphous films. These films were then released from the salt substrate and free-standing films were annealed at various temperatures for different time durations under vacuum. The annealed films were investigated for the phases that formed during crystallization and possible clustering or segregation. There were a few instances of elemental segregation in most of the films studied in this work. On the other hand crystallization of amorphous film repeatedly resulted in the formation of a combination of fcc and bcc phases. These results along with the critical survey of the existing literature will be presented as part of this study.

# Enhancing Shock Resistance of Magnesium and Magnesium-Aluminum Alloys with Cerium Addition

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**Abstract**

This study examines the shock response of forged and annealed commercially pure magnesium (Cp-Mg) and its cerium (Ce)-alloyed versions (Mg-0.5Ce and Mg-3Al-0.5Ce). Shock loading is performed using a conventional shock tube at two pressures along the forging direction (FD). All materials initially exhibit strong basal texture perpendicular to FD, with Cp-Mg showing the highest basal pole intensity. Under low pressure, all materials deform without fracturing, with Cp-Mg showing the highest deflection. However, at higher pressure, Cp-Mg discs fracture, whereas Mg-Ce alloys, with their superior toughness, absorb impact energy without fracturing and display lower deflections. Hardness increases significantly in shock-exposed regions, especially at higher pressures and in Mg-3Al-0.5Ce. Shock loading does not significantly change grain size, but it does lead to a high density of extension twins that complements slip activities in all materials, especially at higher pressures and in Cp-Mg. After shock, Cp-Mg shows the greatest reduction in basal texture intensity, while Mg-Ce alloys experience a moderate decrease. This reduction is due to slip and twinning, with Cp-Mg exhibiting the most twinning. Local misorientation analysis reveals strain localization and stress concentrations at twin-matrix interfaces. Overall, Mg-Ce alloys offer superior shock resistance compared to Cp-Mg.

**Keywords**: Magnesium rare-earth alloys, High strain rate, Conventional shock tube, Texture, Deformation twinning

# Role of nitriding in industrial applications of stainless steel

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**Abstract**

The steel industry is regarded as one of the biggest and most dynamic industries globally. The building and infrastructure sector accounts for the largest share of steel, which was around 52% in 2022. Other industries also include food and kitchenware, automotive, pharmaceutical, and oil and gas industries. The widespread use of steel is attributed to its corrosion resistance property due to the presence of a stable chromium oxide layer formed on the surface.

Steel being a versatile material comes in different types depending upon its composition and utility; the one with most utility is stainless steel which contains essentially 10.5% chromium. Stainless steel has high corrosion-resistant properties, but it lacks wear resistance and surface hardness. To overcome these, surface modification of stainless steels for the purpose of simultaneously achieving improved corrosion resistance and surface mechanical properties is of scientific advancement. Introducing interstitial elements i.e. N & C into steel components via thermo-chemical treatments such as nitriding and carburising led to drastically enhance the properties of steel [1,2].

Now-a-days of nitriding of stainless steels has become common in industry after the invention of the low temperature nitriding treatments which upon optimized application led to the development of nitrided layers with only colossal amounts of N dissolved in austenite matrix. This colossal amount of N dissolved in austenite solid solutions have resulted in increased hardness levels of treated stainless steel surfaces [3].

As industries move towards environmentally friendly alternatives for replacing carbon-based fuels, nitrogen offers an eco-friendly option to enhance the surface properties of stainless steel. Recently, the efforts have been done on reducing the time required to nitride the stainless steel at lower temperatures. Decreasing the duration of the process makes it more energy and time efficient. Shorter period nitriding treatment of stainless steels also prevents the formation of Cr-nitrides in the nitride layer, which negatively impacts the corrosion properties of stainless-steel components due to removal of Cr from the solid solution which is necessary for the corrosion resistance. In this way reducing the treatment time for nitriding also reduce capital costs, positively affecting the industry's economy.

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# Effects of Tantalum & Niobium additions on the microstructure evolution and thermal stability of non equiatomic CoCrNi medium entropy alloys

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**Abstract:** In the field of MEAs, equiatomic CoCrNi is one of the most promising alloys for cryogenic and room temperature applications. However, it doesn't show promising ductility and fracture strength at elevated temperatures which limits this alloy for structural and high temperature applications. To enhance the high-temperature mechanical and functional properties, in such cases, secondary phase former elements could be added intentionally (Ex: Ta, Nb Mo, W, etc.). In this work, the effects of Ta & Nb additions on thermal stability, microstructure evolution and precipitation kinetics of non equiatomic CoCrNi medium entropy alloy are investigated. As a proof of concept, based on the thermodynamic calculations, we developed a non-equiatomic alloy using phase separation to create an alloy matrix with high content ordered nanoprecipitates.

The alloys were prepared by using a vacuum arc melting furnace, repeated melted at least five times, under a Ti-gettered high purity Ar atmosphere. To chemically homogenize the as-cast alloy, the ingots were homogenised at 1200°C for 24 h and followed by water quenching. The homogenised alloys were then aged at 800C, 900C and 1000C for 24 h each and then quenched in water. The alloy achieves a high hardness up to 470 MPa & 400 MPa in Ta & Nb added alloys respectively. The arc melted samples were further characterised by using X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) and Electron backscatter diffraction (EBSD) measurements for identifying the phases, thermal stability & precipitation kinetics. This work provides a strategy for developing ultrahigh-strength alloys.

**Keywords:** Medium entropy alloys; Tantalum and Niobium addition; Thermal stability

# Effect of Sn on Microstructure, Mechanical Properties of AZ91 alloys.

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**Abstract**

The effects of Sn addition (0, 2, 4, and 6 wt%) on the microstructure and mechanical properties of the AZ91 alloy in the as-cast condition were investigated. The experimental results showed that the as-cast AZ91 alloy was composed of two phases: α-Mg and β-$Mg_{17}Al_{12}$. In contrast, the microstructure of Sn-containing AZ91 alloys consisted of three phases: α-Mg, $Mg_{17}Al_{12}$, and $Mg_2Sn$. Microstructural analysis revealed that the refinement of the $Mg_{17}Al_{12}$ phase occurred, and a new $Mg_2Sn$ phase formed as Sn was introduced into the AZ91 alloy. The addition of Sn significantly refined the grains of the as-cast alloys. Furthermore, the addition of Sn to the AZ91 magnesium alloy transformed the lamellar eutectics β-$Mg_{17}Al_{12}$ into fully divorced β-eutectics. In alloys containing 2 wt% Sn, the $Mg_2Sn$ phase appeared as a clustered phase within the fully divorced β-eutectics. Tensile test results indicated that Sn addition improved the tensile strength of the AZ91 alloys, while it adversely affected their ductility. Specifically, with the addition of 2 wt% Sn, the ultimate tensile strength (UTS), yield strength (YS), and elongation (εf) of the alloy were 173 MPa, 129 MPa, and 0.76%, respectively. The microstructures, morphology of fractured tensile surfaces was found to be correlated with mechanical results.

Keywords: Magnesium alloy, Optical, SEM, Tensile, Fracture surface

# Effect of electricity on creep properties of AZ31 alloy: High through-put creep test

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## Abstract

Traditional metal forming requires large forces and substantial tooling, high power, and large amounts of energy. Passing an electric current through the metal during forming has been shown to reduce the deformation energy and increase the materials' formability, leading to the possibility of increased. The current is applied to the sample through copper fixtures, which serve as heat sinks due to their high thermal conductivity, leading to a non-uniform temperature distribution. When current flows, a parabolic temperature gradient is developed, with the peak temperature at the centre of the gauge length and the minimum at the ends. This temperature gradient can be leveraged to extract creep data at multiple temperatures under constant stress using DIC. In AZ31 alloy high current (50A/mm$^2$) is passed and uniaxial tensile creep test is conducted. This creep test is compared with conventional creep test to check the effect of current on material. Stress exponent n and activation energy for creep is obtained by performing test in temperature range of 150°C-200°C. It has been found that the steady state creep rate is similar for both type of test in high stress regime, however, in low stress regime the steady state creep rate is 1.5-2 times faster in case of EAD (Electrically assisted deformation) compared to traditional. Both n and Q also give similar values. As in EAD test we can get creep data from a range of temperature, it has potential to be used as high through-put creep testing method.

Key words: Creep, Electron wind theory, Magnesium alloy, AZ31, High through-put

# Effect of annealing process parameters on microstructure evolution and mechanical properties of IFHS Steel

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## Abstract

In contemporary automobile manufacturing, advanced high-strength steels (AHSS) play a pivotal role in improving both safety and performance. Interstitial Free High-Strength (IFHS) steel is particularly valued for its excellent formability and strength, making it ideal for automotive body panels and components that demand intricate shapes and deep drawing.

This study focused on optimizing continuous annealing process parameters such as heating rate, cooling rate, soaking temperature, slow cooling temperature, and overaging temperature to enhance the mechanical properties and microstructure of IFHS steel. A series of annealing experiments were performed using the Gleeble-3800 physical simulator with varying parameters. Post-simulation, tensile tests were carried out to assess the mechanical properties, while the final microstructure was analysed using optical microscopy, scanning electron microscopy (SEM), and electron backscattered diffraction (EBSD).

The findings indicate that annealing parameters significantly affect both the mechanical properties and microstructure of IFHS steel. Specifically, reducing the soaking temperature improved elongation from 30% to 36% due to more uniform grain growth. Conversely, increasing the soaking temperature enhanced elongation but reduced yield strength and ultimate tensile strength, attributed to larger grain sizes. To optimize ductility, it is recommended that the cooling rate from slow cooling stage (SCS) to rapid cooling stage (RCS) be maintained between 45 to 48°C/s.

**Key words:** Continuous annealing process, IFHS steel, tensile testing, microstructural analysis.

# Eliminating Edge Waviness Issue in High Strength Dual Phase Hot Rolled Grades for Cold Rolling at Hot Strip Mill Kalinganagar

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## Abstract

Newly developed hot rolled Dual Phase (DP) grades for further cold rolling were encountering severe shape issues post hot rolling.

The shape issue was edge waviness on both edges of the hot rolled coil post coiling when they were opened for surface and shape inspection at the Coil Dividing Line. (CDL).

This was resulting in coil parting and led to poor coil weight for further cold rolling applications. (Approximately 30% of the coil length was affected).

A scientific study was done to understand the microstructural changes being encountered by grade during hot rolling along with comprehensive study of the hot mill process parameters.

An innovative yet cost effective approach to encounter this problem was thought of and trialled in various campaigns.

Better than expected results were obtained and this resulted in full coils being dispatched to the end customer (Cold Rolling Mill) without any loss due to parting at HSM.

The paper captures the journey of this team to overcome and eliminate this problem of shape.

**Keywords:**
Hot Rolling Flat; Work Roll; Finishing Mill ; Crown , Dead Flat Rolling Curve

# Continuous Monitoring of Flue Gas in two furnace from single Oxygen Analyzer

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## Abstract

The Hot Strip Mill (HSM) makes hot rolled strips (Coils, Sheets & Plates) from cast slabs. In HSM, the slabs are reheated in oxidizing furnaces atmosphere at a high temperature before hot rolling. HSM TSJ has three furnaces, namely Fce#1, 2 and 3. Fce #1 and #2 are recuperative types and Fce#3 is regenerative type. Manual gas sampling of flue gas to check for oxyzen % took place from the recuperative zones of Fce #1 and #2 which were prone to STF hazards and gas exposure while opening the sampling point. Sampling used to happen thrice a week. Recuperative zones are at remote locations and hard to access and prone to gas exposure and burn which may lead to injury. So, it was decided to install a continuous monitoring of Oxyzen analyzer in the waste gas circuit of reheating furnace. Hazards related to manual sampling of flue gas from the waste gas circuit has been eliminated and lead indicator monitoring helps in reduction of excess air and improvement in yield with reduced scale generation. Also, continuous measuring system reduced the cost incurred in deploying an employee for flue gas sampling and analysis.

Fig. 1: Laser based oxygen analyser

**Key words** : Oxyzen analyzer, flue gas, reheating furnace, Hot Strip Mill, etc.

# Reduction in flying scales during descaling through in house primary descaler hood modification

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## Abstract

When steel is heated in the course of rolling or heat treatment, the reaction of oxygen on the hot metal surface inevitably produces a very hard oxide layer, known as scale. This scale not only affects the appearance but also the quality of the material. For the production of high-quality hot-rolled products, it is therefore essential to remove these impurities from the surface. In hot rolling mills, descaling equipment ensures high surface quality. During descaling, the material surfaces are sprayed with water under high pressure to blast off and completely remove the scale. These scales fly off with great velocity and fall on mill floor and roller motor cables making it susceptible to fire. Modification was done in the primary descaler hood by extending the hood and using removable flappers so that the scales are contained within the hood and doesn't fly off, there by improving safety.

Fig. 1: Primary descaler hood


Fig. 2: Use of removable flapper

key words : Primary, descaler, scales, flapper

# Optimisation of cooling parameter to minimise scale formation during hot rolling of low carbon electrode wire rod

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**Abstract**

Scale formation not only impacts product quality but also significantly affects processing efficiency and downstream operations. This study investigates the influence of cooling rate and process conditions on scale formation and subsequent mechanical descaling efficiency in the production of low carbon electrode wires. Controlled hot rolling experiments were conducted with varied cooling parameters during Stelmor cooling, resulting in the formation of predominantly oxide layer of Wustite (FeO) with less transformed magnetite. In contrast, the conventional method showed the presence of magnetite ($Fe_3O_4$) and haematite ($Fe_2O_3$). Surface characterization using X-Ray Diffraction (XRD) complemented these observations. Mechanical descaling trials were performed to evaluate the effectiveness of scale removal. The study found that modifying the cooling rate during Stelmor cooling led to a significant 30% reduction in scale compared to conventional cooling methods. Furthermore, optimized cooling parameters resulted in a minor increase in tensile strength by 3 MPa. Implementing these optimized cooling parameters offers competitive advantages in low carbon electrode wire rod production, ensuring that the final product meets high standards for quality and performance. These findings underscore the importance of precise cooling control in industrial processes to enhance both operational efficiency and product integrity.

**Key words : Oxide layer, Descaling, Stelmor**

# Characterization and Control of Splash mark on the surface of Hot dip Zn-Mg-Al Coating

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## Abstract

Zn-Mg-Al steel, an alloy coating consisting primarily of zinc, aluminium, and magnesium, represents a significant advancement in corrosion-resistant steel coatings. The inclusion of magnesium enhances the coating's self-healing properties, significantly reducing corrosion rates compared to traditional galvanized steel. Despite its advantages, the implementation of Zn-Mg-Al steel faces significant challenges related to surface defects. One notable surface defect in Zn-Mg-Al steel coatings is splash marks.

Splash marks in Zn-Mg-Al steel coatings are a critical surface defect that can significantly impact the aesthetic and protective properties of the material. These marks, which appear as irregular spots or streaks on the coating surface, result from various issues during the coating process. Understanding the causes, implications, and mitigation strategies for splash marks is essential for improving the reliability and performance of Zn-Mg-Al steel in various applications. In the case of this metallic coating type, Top dross generation at the Zinc pot and snout area are more in comparison with conventional GI and GA which will increase the probability of this defect. EDS and SEM analysis of splash mark defects in Zn-Mg-Al steel coatings are done to examine the surface morphology, elemental composition, and presence of contaminants, this analysis helps to identify the root causes of splash marks and informs the development of targeted strategies to improve coating quality and performance.

Addressing the issue of splash marks in Zn-Mg-Al steel coatings requires a comprehensive approach, including optimizing Wiping Medium, Pressure, distance, height and angle. Also keeping the snout and pot area clean is essential. Pot level maintenance influences the consistency of the coating application, and improper levels can contribute to defects such as splash marks. By focusing on these areas, the quality and performance of Zn-Mg-Al steel coatings can be significantly improved, ensuring their effectiveness in various demanding applications.

**Key words : Zn-Mg-Al coating; Splash marks; Coating defect; Surface Quality**

# Reduction of Yield Strength variability in 420LA Steel: Design & Process Optimization

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## Abstract

Variability in the mechanical properties especially Yield Strength (YS) of steel strips significantly affects the structural performance of manufactured components. This study focuses on finding root cause of YS deviation issues in Cold Rolled steel 420LA, a High-Strength Low-Alloy (HSLA) grade widely used in the automotive sector for chassis reinforcement.

A comprehensive statistical approach complemented by machine learning model on the Mass Production Data (MPD) was employed to analyse the effect of design (chemistry) and process parameters at hot strip mill and continuous annealing line. Pearson correlation coefficients and variance analyses were utilized to identify critical parameters that significantly impact yield strength. Based on the analysis, variation in Nitrogen exhibited correlation with YS. In addition to chemistry, parameters such as RMX (Roughing Mill) Temperature at HSM, cooling rate & soaking temperature at CAL (Continuous Annealing Line) show significant relation with yield strength. Microstructural analysis further validates the influence of these process parameters. It was observed that batch exhibiting pearlite banded structures in the rolling direction show variable yield strength along the length of the coil compared to the batch with more homogeneous microstructures.

To reduce variability in YS, Ti/N cycles were employed during CAL process. Further optimization and fine tuning of parameters to maintain the cooling rate brought down the YS variation from 70-90 MPa to 20-30 MPa .

**Key words : HSLA, YS, CAL, HSM, Ti/N**

# Improvement of Gauge Variation in DP980 Steel Grade

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**Abstract**

In the manufacturing process of Dual Phase 980 grade steel, a critical issue of gauge variation affecting approximately 200 meters of inner diameter of the cold rolled coil was identified, leading to significant material yield loss, surface imperfections, and equipment damage. Microstructural analysis of samples from regions exhibiting high and low gauge variations revealed distinct differences in phase fractions. The results indicated an abundance of ferrite or upper bainite in regions with thinner gauges indicating a very low cooling rate. These phases, characterized by lower hardness compared to lower bainite, tempered martensite, and fresh martensite, are more susceptible to deformation under identical rolling forces in Cold Rolling. Analysis of the gauge graphs unveiled a recurring pitch matching the outer diameter of the Hot Rolled coil. Further evaluation focused on identifying sources of external heating.

Through systematic trials and detailed analysis, it was discerned that the gauge variation originated from the saddle heating due to thermal transfer from the hot coil. To validate this finding, coils were tested by directly lifting them post-coiling (from down coiler) using a crane, bypassing the saddle transfer of coils to storage area of hot rolled coils. Remarkably, no gauge variation was observed in coils lifted by crane, affirming the role of saddle heating in generating gauge irregularities. Given the practical challenges of lifting all coils via crane, we intend to implement specialized cooling techniques to maintain the saddle temperature within optimal limits post-coiling. In conclusion, this study highlights the critical impact of post-coiling thermal management on gauge variation in DP 980 grade steel. By identifying and addressing the root cause of saddle heating, significant improvements in product quality and material yield were achieved. This research underscores the importance of meticulous process control and thermal management strategies in enhancing manufacturing outcomes in advanced steel grades.

**Key words** : **Hot Rolling, Cold Rolling, Ferrite, Bainite, Heating Rate**

# Reduction of flange cracking during forming operation in Cold Rolled 590R grade

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## Abstract

Cold rolled steel sheets are significantly used in Automobile industries are known for its part criticality. Different grades of steels are utilised in different parts application and in that Re-phosphorized steel which is used for Reinforcement parking brake application requires intricate formability. So, with addition of phosphorus the material exhibits very good elongation and high R-value in high strength grades (i.e. 590 MPa grade) compared to mild steel grades. But still stretch flange cracking is a concern during forming stage of part production. In this paper steps involved in the reduction of stretch flange cracking are discussed. Cold rolled steel having minimum Tensile Strength 590 MPa with yield strength minimum 390 MPa steel and Elongation minimum 18% has a phase structure of Ferrite + Pearlite + Precipitates where annealing is carried out above Ac1. While forming, this grade material tends to form cracking near flange regions. To resolve the issue, various analysis has been carried out and observed that multiple reasons were leading to stretch flange cracking in this material. In one of the case, it was observed that hole expansion ratio of the not good parts was lower & leading to cracking near hole regions, based on MPD data & detailed analysis, one of the element %S reduced. Further conclusion drawn by studying MPD & comparing with good & not good batches, coils with higher yield strength were more susceptible towards cracking. During data analysis, it was found that process parameter i.e. SS temperature & Ti content to be most effective in controlling YS. SS temperature was increased to control YS below 530 MPA & Ti range restricted to 0.0080 max. With this changes, the performance of the grade was significantly improved & the issues were resolved.

**Key words : Cracking, stretch flange, HER, YS**

# Surface Defect: Pinpoint Uncoated Pock Marks on Pre-Painted Galvalume Surface

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**Abstract**

Pre-painted galvalume (PPGL) is a versatile material that fulfils almost all external requirements for roofing and siding, with variety of aesthetic features, various colors, shades, and profiles. A common issue in production of PPGL is often observed as pinpoint uncoated surface due to the defect in the base Galvalume (GL) surface. This paper studies the significance of pinpoint uncoated pock marks and the causes of their occurrence.

Pock mark can be described as small concave deformity formed during the cooling of GL sheet when a GL bubble burst and leads to formation of a fissure. The density of this defect depends on various production parameters mention in this paper. Scanning Electron Microscopy (SEM) Micrograph images show no paint application and loss of GL coating thickness in the region of the pock marks, which is expected to further reduce Salt Spray Test (SST) life leading to red rust at an early phase of service life. Repainting possibilities and height of fissure have also been observed by SEM at lab scale as well as mass production level. Coated pock marks have also been analysed for further understanding of the coating systems and the effect of their generation during processing of PPGL product.

The extent of pock mark can lead to variety of issues post production. Mitigation of this defect shall help in improvement of the product quality, leading to spotless PPGL surfaces with improved SST and service life.

**Key words : Galvalume; Pock mark; Pre-painted; Pinpoint uncoated**

# Development of Prepainted ZM steel for High Corrosion Resistance Industrial Roofing

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**Abstract**

A vital part of any industrial building is the roofing which contributes to the efficiency and safety of the operations while shielding from the weather. It acts as the first line of protection against weather-wind, sun, rain, and snow. A well-built roof can resist wind uplift, offer thermal insulation, and stop water leaks while making the building more fire resistance and serve as a platform for a variety of electrical and mechanical devices. Metal roofs can be installed quickly and are strong enough to withstand harsh weather conditions and fires.

Conventionally galvanized (GI) and Galvalume (GL) coated steel is used as a substrate for material used for roofing applications. The major challenges with this material is the corrosion life of the product. In highly corrosive environment such industries with corrosive particle emissions, or in coastal areas with high levels of moisture and salt, chemically aggressive processes or materials inside the building, or when there are corrosive external environments, the material has to be replaced within 3 to 4 years. Enhancing corrosion resistance can save energy, lower consumption, and safeguard the environment in addition to extending the service life and lowering the total cost of ownership of roofing materials. The development of Prepainted Zn-Mg (PPZM) steel takes advantage of the superior protection provided by Zn-Mg (ZM) coated product and further improves its by providing additional barrier coating in the form of paint. PPZM material even after 6000 hours of extensive SST testing does not show any red rust, thus allowing better service life and reduced cost of replacement and reinstallation. This allows the product to sustain much harsher environment at a much lower coating weight and enhanced aesthetics with reduced cost and frequency of maintenance, repair and replacement. The material shows superior scratch resistance due to improved hardness of substrate and is formable to the required shape with good bending radius.

This paper seeks to discuss development of PPZM for cost sustainable, and better corrosion properties for industrial roofing application.

Key words : Prepainted; Zn-Mg coating; corrosion resistance; galvalume

# Minimizing the Cracking defect in Automotive body panel made from CRCA-IF Grade

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**Abstract**

Components in Automotive Car body applications will have high and critical draw requirements. Especially exposed panels will have stringent requirement of surface and shape along with good formability.

While forming the component sporadic cracking and shape deviations observed in CRCA – IF Grade supplies in thinner Gauge (0.60 mm thickness) at one of the automotive customer. As the defect could observe while final forming stage of component making Customer was facing production losses, monetary losses and delivery issues.

In response to customer feedback, a detailed data analysis has been carried out for 200 data points using statistical tools and microstructural analysis done using SEM. The SEM analysis does not reveal any inclusions or microstructure issues. Product parameters include Mechanical properties (YS, UTS, %EL, r-bar), Process parameters considered from Steel making (Mould level fluctuations, Scarfing), Hot Rolling process (FT, CT), Cold Rolling (Reduction %), Annealing Temperatures, annealing speed, Skin pass (%Elongation) and customer die parameters considered for data analysis to find out the root cause. Out of the data analysis, cracked components data analysis observed with high amount of free carbon in comparison with good components indicate that %Ti is not sufficient to fix the carbon.

Hence the chemistry is revised with increasing the % Ti to fix the Carbon. The material with the new design was not observed with free carbon and the incidences are reduced drastically near to zero.

Key words : Cracking, free Carbon, %Ti, Automotive BIW, Scarfing, Annealing

# REDUCTION IN PRESS DENTS IN COLD ROLLED IF STEEL SHEETS FOR AUTOMOBILE INDUSTRY

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**Abstract**

Press dents, a common defect encountered in the production of cold rolled Interstitial Free (IF) steels, present a significant challenge due to their small size (approximately 5 μ) and the difficulty in detecting them through conventional online inspection methods. These defects typically manifest post-forming, leading to potential quality issues and needs to enhance product reliability and customer satisfaction. Current manufacturing practices rely heavily on online inspection systems to detect surface defects; however, press dents often evade detection due to their minute dimensions and the limitations of existing inspection technologies.

The dent portion has been analyzed using SEM, EDS (Energy dispersive spectroscopy), WDS (Wavelength dispersive spectroscopy) for the presence of any foreign substance and layer by layer analysis also carried out using the GDOS (Glow discharge optical spectroscopy) study. There were no entrapments and internal source of defect, only the soft surface of strip is found to be more prone for dent. To address this issue, this study investigates modifications in the Continuous Annealing Line (CAL) process parameters specifically to enhance surface hardness and visibility of press dents after stoning. By increasing the Skin pass mill (SPM) elongation and reducing the annealing temperature, the aim was to optimize material properties and to reduce the defect. The increase of SPM elongation by 1% makes the surface harder for forming operation. Furthermore, reducing the annealing temperature contributes to increase in yield strength of the material which enhances the property. The effectiveness of the study is validated by press simulating the blank sample and verifying the presence of defects, without compromising on the formability requirement of material.

In conclusion, the investigation into reducing press dents in cold rolled IF steels through CAL process parameter modifications underscores the transformative potential of applied research in addressing critical manufacturing challenges. By bridging the gap between theory and practical application, this study contributes to advancing quality assurance protocols and setting benchmarks for excellence in steel manufacturing.

Key words : Press dents, IF steel, Surface resistance, Spectroscopy, SPM

# Reduction of Stretcher Strain in Low Carbon Steel

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**Abstract**

Stretcher strains, also known as Luders bands, are a significant challenge in the production of low carbon steel, particularly for materials with a thickness of less than 0.7 mm. These localized deformations arise due to insufficient cold deformation, specifically when the required elongation during the Skin Pass Mill (SPM) process is not attained. The primary cause identified is the use of high diameter SPM rolls, which fail to achieve the necessary elongation for thin materials, even when subjected to high roll forces of up to 600 to 700 tons.

To address this issue, an optimization approach was implemented by replacing the high diameter SPM rolls with low diameter rolls. Remarkably, this adjustment allowed for the required SPM elongation to be achieved with significantly lower roll forces of 300 to 350 tons. This change effectively reduced the incidence of stretcher strains in the thin low carbon steel sheets. The optimization led to the elimination of Luders bands, thereby improving the surface quality and mechanical properties of the final product. This study highlights the importance of roll diameter in the SPM process and demonstrates a practical solution to enhance the performance of low carbon steel in thin gauge applications.

Key words : Stretcher strains, Skin Pass Mill, Elongation

# Analysis of Fe-Zn phase morphology on powdering and flaking in galvannealed automotive steel

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## Abstract

Here in this paper we have investigated the powdering and flaking defect generated in galvannealed steel by analysing the coating cross section and surface morphology. We have characterized the cross section morphology of zinc coating on the interstitial free drawing grade steel by Optical and SEM microscopy. The relationship between the coating morphology and the defect are established. The galvanizing and annealing process parameter are optimized to achieve desired coating morphology suitable of low powering and less flaking.

In the characterization different phases in Zinc coating viz. zeta, delta and gamma layers are analysed. The thickness and composition of the phases are determined by the SEM and EDX analysis. The correlation between the coating layer composition and thickness with the galvanizing and annealing parameter are done at different levels of DOE. The coating morphology hence achieved at different DOE levels are correlated to the level of powdering and flaking.

Powdering particle formation by intracoating failure to produce particles and accumulating in the bead areas during press forming, while this problem was investigated by scan electron microscope and x-ray diffraction methods; it was revealed higher the gamma phase. This was controlled by controlling diffusion of %Fe into intermetallic layer. Whereas, flaking formation of at particles by decohesion of the coating substrate interface to produce particles, this problem is due to excessive zeta phase on the surface which offered higher co-efficient of friction and resulted in the decohesion of the layer. This was controlled by the good control of glavannealing and after pot holding conditions at Continuous Glavannealing Line.

Key words : Powdering, Flaking, Phases

# Impact of cold treatment on the Bake Hardening Index of Bake Hardenable Flat galvanized steel

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**Abstract**

In this paper we have studied the impact of cold treatment parameters of galvanized flat steel by Skin Pass Rolling on the Bake hardening index of Interstitial Free High strength steel. Bake-Hardenable are generally low-carbon steels engineered to achieve increased strength through a post-forming heat treatment process known as baking. The Bake Hardening Index (BHI) quantifies the increase in yield strength that occurs in BH steels after the baking treatment. The baking process here considered is heating the tensile sample at temperatures ranging from 170°C to 220°C for approximately 20 to 30 minutes. This treatment induces additional hardening through the precipitation of carbon atoms and pinning of C atoms at the dislocation sites.

Skin pass elongation plays a significant role in influencing the Bake Hardening Index of BH grades of steel. By skin pass elongation dislocation density is increased which enhances the bake hardening response, leading to higher BHI values. This effect is critical for achieving the desired strength improvements in BH steels used for various automotive and structural applications. In the experimental trial the BHI values are studied by varying the SPM roll force and the SPM Strip tension. Based on the result the SPM roll force and strip tension are optimized to achieve desired BHI as per application requirement.

Key words : Bake Hardening Index, Interstitial Free High strength

# Impact of Chloride Content on Loose-Scale Formation in Hot Rolled Coils

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## Abstract

The presence of loose scale on hot rolled coils (HRC) poses significant challenges in steel manufacturing processes. During the hot rolling of steel, oxide scale forms due to high temperatures and exposure to air. This scale enhances corrosion resistance by protecting the steel from moisture and oxygen. However, elevated chloride levels in the ROT (Runout table) water can penetrate this protective barrier, leading to the formation of corrosive iron chloride compounds. These compounds initiate pitting corrosion, which compromises the integrity of the steel.

Top of Form

Bottom of Form

This experimental study investigates the influence of ROT water chloride content on loose-scale formation on the HRC surface. Controlled experiments were conducted and chloride levels were varied to assess their impact on scale adherence and appearance. Additionally, the research examines the surface morphology of samples exposed to varying chloride concentrations to evaluate material integrity in corrosive environments. The effectiveness of inhibitors, including the Nalco corrosion inhibitor, is evaluated in mitigating surface defects and improving the surface quality of the HRC products. Comparative analysis of samples immersed in chloride water with and without the inhibitor provides insights into how these additives affect surface characteristics under corrosive conditions. Key findings from the results show that elevated chloride levels have a pronounced effect, especially in higher thicknesses. The analysis provides valuable insights into the effect of inhibitors on the composition of scale, thereby influencing product quality. This underscores the importance of ROT water quality for maintaining product surface integrity.

Top of Form

Bottom of Form

**Key words** : Loose scale, Nalco corrosion inhibitor, Hot rolled coils, Corrosion resistance

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# Reduction of waviness defect in Hot Rolled Flat Steel Product

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**Abstract**

Flatness issues such as waviness in hot rolled products can be attributed to a various factor in the hot strip mill (HSM). Uneven stresses throughout the strip are one of the main causes, as they can cause the strip fibre to elongate differently and consequently result in flatness issues. Excessive rolling speed can exacerbate this problem by causing the strip to flutter and become wavy. Waviness can also result from an unequal thermal gradient across the strip during the cooling process. A hot-rolled sheet coil often reveals symptoms of poor flatness, such as wavy edges. Therefore, understanding and addressing these issues is crucial in the production of hot-rolled products.

Majority of flatness defects result from mill setting deviations or from shifting thermal conditions during the ensuing cooling processes. Hot-rolled strip flatness can be measured using IMS graphs located after final strand finishing strand no.7. However, the flatness graphs provided by IMS® technology is not always accurate as the shape of the strip may deteriorate once the strip is cooled after Runout table (ROT). Hence it is pertinent in HSM to correlate the factors which influence the shape of the strip and take counter measures accordingly.

In the Present study various parameters viz. backup rolls life, work roll profile, SDT (Slab dropout temperature), Pair-cross angle, cooling pattern in ROT were studied especially in thickness greater than 4 mm and width greater than 1500 mm in the strength ranging from 250 Mpa to 350 Mpa yield strength. It was found that higher Backup roll tonnage, pair cross angle in conjunction with work roll profile have major effect on the waviness. After results validation and revising the rolling protocol for the grade width and thickness (GWT) considered in the present study, defect percentage reduced from 7% to 1.9%.

**Key words : Hot Rolled Coil, Waviness, Thermal Gradient, Work & Backup Roll**

# Mitigation Strategies for Tertiary Scale Formation in Hot Rolled Steel Production

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**Abstract**

The surface quality requirements for automotive steel grades are becoming increasingly stringent, placing significant pressure on Hot Strip Mills to closely control relevant process parameters. Formation of Tertiary scale on steel surfaces during hot rolling has a direct impact on the surface quality of the final flat steel products used in critical automotive applications. This scale often creates whitish or blackish Pitting after Pickling, leading to downgrading of the material. However, achieving the optimal Finish Rolling Temperature (FRT) to balance roll ability and surface finish while controlling tertiary scale is particularly challenging part. This issue is especially prevalent when rolling thinner sections (t < 2.2 mm). Therefore, controlling this scale at the hot strip mill stage is crucial to prevent significant losses in downstream processes.

This research focuses on identifying and controlling hot strip mill process parameters to prevent tertiary scale formation in low-carbon steel during hot rolling. Scale growth depends on instantaneous surface temperature, exposure time, and, to some extent, the steel grade's chemistry. Tertiary scale formed before finish rolling results in rolled-in scale (RIS) after pickling. Optimizing Finishing Mill Entry Temperature (FMET), the descaling efficiency of the Finishing Scale Breaker (FSB), the distance between the FSB and the finishing mill entry, and Inter-Stand Cooling (ISC) based on the rolling section has significantly reduced rejection rates. Sustaining these procedures ensures consistent product quality and enhances customer satisfaction

**Key words** : Tertiary scale, Hot rolling process, Descaling, Pitting, Pickling

# Study of the mechanical property variations in Ti-Nb HSLA Steel grades

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**Abstract**

HSLA Steels gained their importance especially in the last three decades due to their ability to retain Toughness while improving the strength (both YS & UTS) significantly with even small addition of alloying elements such as Nb, V & Ti, which are identified as micro-alloying elements. These characteristics widely utilized in critical components in automobile, defence sectors, Where consistency in mechanical properties are prime requirement, But ensuring consistent mechanical properties in mass production remains challenging due to temperature sensitive interaction of alloying elements, formation of precipitates such as TiN, TiC and NbC The size, distribution, orientation, nature of precipitation of these precipitates are governing factors for mechanical properties.

This abstract proposes solutions through a multifaceted approach. Firstly, it stresses optimizing and calibrating equipment and automation models at the level 1 & 2 to ensure precise measurements, addressing limitations in handling surge and jerk readings in key parameters, RMX*, FET*, FT*, CT*, Run Speed, Thread Speed and Thickness. Secondly, strategic sampling from transformation stages. Alongside length, width, and thickness-wise coil samples. This is followed by detailed characterization of precipitate characteristics and microstructure analysis, pivotal for developing comprehensive learning models elucidating relationships between precipitate behavior and mechanical properties. Lastly, it explores error propagation methodologies, emphasizing the need to understand nature and propagation of errors and mitigate error impacts across production stages. All these efforts contributes to development of detailed SOP for process control.

Key words : RMX – Roughing mill exit temperature, FET : Finishing mill entry Temperature, FT-Finishing mill exit temperature, CT : Coiling Temperature.

# Reduction of Ovality in as-hot rolled coils of 22MnB5 Steel Grade

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**Abstract**

22MnB5 steel grade is used to manufacture side impact beams for Passenger Vehicles, which demands high strength (~1400 MPa) to provide better crashworthiness, coupled with minimum elongation requirement of 10% to absorb kinetic energy during side collision. Tempered martensitic structure is the ideal microstructural for ensuring these properties. 22MnB5 steel grade is designed to have relatively low strength (~550 MPa) in as-hot rolled condition to facilitate smooth execution of slitting, forming and subsequent Electric Resistance Welding. Subsequently, these are subjected to induction hardening process followed by quenching and tempering to get homogenous martensitic microstructure.

Typically, these steels contain alloying elements which increases hardenability, primarily C 0.13- 0.22 %, Mn 1.0 -1.6 % along with minor addition of boron. The enhanced hardenability is evidenced by the rightward shift in the Continuous Cooling Transformation curve. This rightward shift causes delay in the start of austenite transformation that gets extended till the coiling operation in Hot Strip Mill (HSM) thus leading to Ovality issue (difference between major & minor axes >15 mm) **[Fig.1]**. Hence, the main objective of this study is to eliminate Ovality/ Coil Collapse in as-hot rolled condition by ensuring the completion of austenitic phase transformation to atleast 80% at Run-Out Table of HSM itself.

The HSM process parameters that facilitate an early start of the transformation were identified primarily Finishing Delivery Temperature, Coiling Temperature and Cooling cycle. Finishing temperature was aimed much closer to $Ar_3$ temperature to facilitate early ferrite nucleation at same cooling rate. The coiling temperature was also reduced aiming increase in the ferrite phase fraction. Trials were conducted with revised process parameters, which resulted in an improved coil shape with ovality less than 10 mm. The percentage of transformed austenite, calculated using JMatPro software, was found to be in the range of 80-82% post process design adjustments.

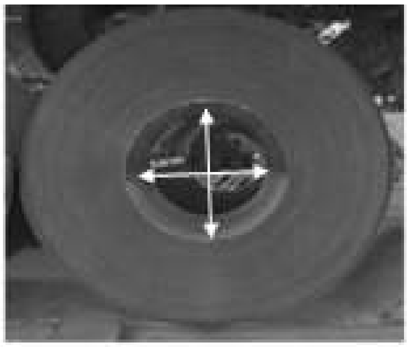

**Fig. 1. Figure showing collapsed coil in as-hot rolled condition**

**Key words** : Martensite, Ovality, Hot rolling, Phase transformation

# Optimizing hot rolling parameters to achieve high strength in Vanadium-based grades by using Taguchi method

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## Abstract

Vanadium-based High-Strength Low-Alloy (HSLA) steels are extensively utilized in various applications because of their exceptional strength, toughness, Weldability, and ability to retain strength after normalizing treatment. In the automotive industry, axle coverings are made using vanadium-based HSLA grades to retain their strength after hot forming. The steel grade is mainly strengthen by precipitation of micro-alloy elements and supported by grain refinement. It's critical to optimize the processing conditions in order to obtain better strength and minimize cost.

This paper investigates the influence of key hot rolling process parameters on yield strength and grain size for vanadium-based microalloyed steel, which is critical for automotive axle cover applications, and determines the optimal parameter levels using the Taguchi method. For this purpose, the parameters such as Slab dropout temperature (SDT), Finishing Temperature (FT), and Coiling temperature (CT) were chosen, with three levels considered for each temperature. Total nine experiments were conducted using an orthogonal array based on the Taguchi method. Analysis of variance, signal-to-noise ratios, and grey relational grade were calculated to optimize yield strength and grain size for vanadium-based microalloyed steel. It was observed that the SDT of 1170°C; FT of 880°C; and CT of 610°C are the optimum parameter values producing better strength and grain size.

**Key words** : Hot Rolling, V-HSLA steel, Taguchi method, ANOVA

# Optimization of Edger roll usage to reduce the edge seam defect in ULC steels

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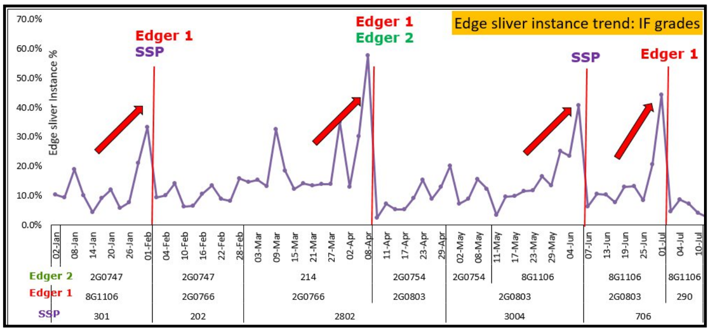
## Abstract

Edge seam defects are predominantly observed in titanium-stabilized ultra-low carbon (ULC) steels. These defects arise when slab corners cool much faster than the center, causing the corners to enter the ferrite zone while the center remains soft. This differential cooling leads to uneven deformation and overwrapping at the boundary, resulting in edge seams. Vertical edger rolls, inclined from top to bottom, push these defects toward the center of the top surface. Although edges are typically trimmed up to 15 mm to remove these defects, our plant has experienced a sudden increase in edge seam defects even after trimming, particularly before edger roll changes. This increase correlates directly with higher edger roll tonnages, where roll wear increases the edger angle from 3° to 3.48°. Based on defect analysis, the working tonnage of the edger roll was reduced from 10 Lac tons to 5 Lac tons. This study explores the relationship between edger roll wear and edge seam defect incidence, proposing adjustments to edger roll maintenance and operation to mitigate these defects and enhance product quality.



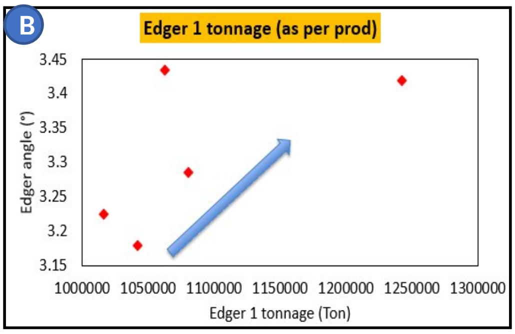




Fig. 1A: Edge sliver instance, 1B: Edger roll angle after usage

**Key words** : Edge seam, Edger roll, Slab corner

**Presenting Author** : Srimon Narayanasamy P

# Production of High Strength Hot Rolled Coils for Automobile & EME segment.

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## Abstract

High strength low alloy steels are used commercially with increased strength, toughness, formability and weldability for a variety of critical applications, such as long and cross members of auto chassis, pre-engineered building (PEB) structures, high mast lighting poles, wind poles, welded pipes etc. To meet these requirements, special quality hot rolled formable grades such as HSFQ (High Strength Formable Quality) 450/550 & IS 5986 Fe 540R have been developed at Rourkela Steel Plant (RSP).Combination of micro-alloying and mastery of processing parameters on final properties ensuresniche customer's requirement.

New grades of hot rolled steelswas developed and optimized utilizing an effective combination of solid solution and precipitation strengthening,resulting in a good ferrite grain refinement. This had an attractive combination of strength and formability which is typically quantified as high elongation (25 % min) coupled with lower YS/UTS ratio (0.80-0.85). Controlled thermomechanical processing has an added advantage of achieving the desired mechanical properties with a lean alloy design. in HR coils. But, the effective application of these steel demands good internal soundness and cleanliness to arrest the cracking susceptibility of the finished products during successive forming / welding operations.

HSFQ-550/450 & IS 5986 ISH-540R grades, has a unique combination of very high strength (UTS: 500-600 MPa and YS: 310-400 MPa) along with reasonable % EL (20-30) for its forming properties. Micro-alloying with Nb,V and Ti helps to achieve the desired properties by obtaining the required microstructures in the hot rolled coils.

This paper exemplifies the innovative alloy design and synergistic effect of Nb, V & Ti during controlled processing exploited to alleviate these problems at RSP. In-house trials had led to process optimization which led to a low-cost solution for current demand in higher strength to weight ratio in Automobile and EME sector.

**Keywords** HSFQ, IS 5986, Hot Rolling, Fine Grains, Strength and Ductility.

# Improvement in productivity of high carbon wire rods at WRM

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## Abstract

A modern wire rod mill has maximum rolling speed of 115m/s. This mill demonstrates versatile capabilities, like rolling a spectrum of special quality plain steel wire rods, including low carbon, high carbon, and alloy-grade steel, diameters ranging from 5.5mm to 22mm, additionally it produces TMT. However, challenges arose during the production of high carbon wire rods, particularly with regards to ensuring consistent mechanical properties at the front and tail ends. This resulted in the discard of 60 rings from each end that is total 120 rings per coil. The issue was more pronounced during the rolling of PC 115 grade, causing significant yield loss.

To overcome this issue a series of measures were taken. Initially, efforts were made to optimize the material temperature during the rolling process. Additionally, dummy rollers were removed from the cooling conveyor table to facilitate better airflow. Tail end losses were addressed by changing the PLC logic of metal tracking. For front end losses, sluggish valves in water boxes were identified as the main reason and suitable ON/OFF valves for water boxes were procured (fig1). Optimization of PLC logic was carried out by trials to reduce front and tail end loses to 30 rings each during normal production. These interventions resulted in a 50% reduction in end losses, significantly enhancing productivity of this mill

**Fig. 1: Fast response valve at water box**

Keywords: high carbon, wire rod, end losses, PLC, fast response valve

# REDUCTION OF ROLL WEAR SCALE ON HOT ROLLED COILS

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## Abstract

The Roll Wear Scale (RWS) represents the major surface defect found in hot-rolled coils. This scale is primarily attributed to several factors. These include the formation of an oxide layer on the slab, thermal fatigue, mechanical stress and fatigue, and abrasion. To minimize the roll wear scale, we conducted an analysis of the data and identified several steps to implement during production. It was determined that roll gap lubrication (RGL) should be applied from the initial slab of the campaign, and anti-peeling measures are consistently in place. The slab's temperature is kept within the range of 900–950 °C at the mill's entrance (F1 stand). For production, rolls are utilized in a combination of Hi-Cr and HSS for thinner gauges, and for slabs with greater thickness (above 2 mm), HSS steel rolls are used. The descaler pressure is maintained at 230 bars upon entry and 330 bars upon exit. An additional descaler with a pressure of 40 bar is also installed at the F2 and F3 stands. By adhering to these measures, we were able to reduce the percentage of roll wear. In the initial trial, we observed a roll wear scale of 7% on the hot-rolled coils. After implementing the measures outlined above, we observed a roll wear scale reduction from 1% to 0% in the subsequent trials.

**Key words:** RGL-roll lubrication gap, anti-peeling, HSS-high speed steel, hi-cr- high chrome roll, rws- roll wear scale

# Enhancing Efficiency in Galvalume Production: Optimal Stirrer System for Dross Reduction

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## Abstract

This study investigates the implementation of SS316L stirrer system aimed at reducing dross formation in Galvalume production by addressing temperature deviations, controlling viscosity in the molten Al-Zn bath, and mitigating oxidation effects. Dross, a persistent challenge in galvanization, compromises bath efficiency and product quality due to uneven temperature distribution, inadequate alloy mixing, and oxidation of the molten metal.

Fluctuations in temperature significantly influence the viscosity of the molten metal and the kinetics of reactions, directly impacting dross formation rates. Higher temperatures can accelerate reactions leading to dross formation, while lower temperatures may slow them down. The SS316L stirrer system plays a crucial role in maintaining uniform heat distribution across the Galvalume bath, effectively minimizing these temperature variations. By preventing localized hot spots and ensuring consistent thermal conditions, the system mitigates conditions conducive to rapid dross formation.

Additionally, high temperatures and exposure to air cause oxidation of the molten metal, resulting in the formation of oxides such as zinc oxide and alumina. These oxides contribute to dross formation by accumulating on the surface. The optimized stirrer system helps mitigate oxidation effects by promoting thorough mixing of the bath, reducing the exposure of molten metal to air, and thereby minimizing oxide formation and subsequent dross accumulation.

Practical benefits of implementing the optimized stirrer system include substantial reductions in dross generation, leading to decreased material wastage and improved operational efficiency. By enhancing process stability and product consistency, these advancements support cost-effective manufacturing.

In conclusion, the SS316L stirrer system, coupled with effective process optimization, represents a significant technological advancement in Galvalume production. By addressing key factors influencing dross formation and oxidation, this integrated approach enhances product quality, reduces environmental impact, and strengthens market competitiveness in the global manufacturing landscape.

Key words: Dross reduction, Stirrer system, Temperature control, Viscosity management

# STUDIES OF INCLUSION AREA FRACTION OF BAR AT WRM

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**Abstract**

In the present paper, studies on the inclusion area fraction of bar (16/20MnCr5, & 20MnCr5 & HC82A) at different locations after rolling in wire rod mill. Controlling inclusions in steel bar is vital to ensuring excellent performance. Accurate identification of inclusion groups is crucial for assessing component quality and using statistical methods for comparison and discrimination. In this study, we analyzed and examined the inclusion size distributions in bar samples from the head, tail, and center of eight heats. The measurements followed the ASTM E2283 standard metallographic procedures. The bar samples were analyzed using a scanning electron microscope (Hitachi S-3400N) and the EDS technique to determine the types of inclusions present. EDS analysis of the bar sample reveals that the inclusion area consists primarily of Ca and Al oxides, Fe and Ca sulfides, and traces of Si, S, and other elements. According to the test results, the inclusion size distributions indicated that no new inclusions were generated during the liquid steel treatment process.

Based on the study and findings, corrective measures were taken to get new tundish furniture designs implemented. The inclusion area fraction was reduced by 26% of the bar without affecting the internal structure of the billet. It is recommended to use the new design of tundish for better continuous cleanliness.

Keywords: inclusion, area fraction, bar, EDS, tundish

# IMPACT OF TEMPERATURE ON HIGH CARBON STEEL ON STELMOR CONVEYOR TO PREDICT THE GRAIN BOUNDARY CEMENTITE

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## Abstract

A novel approach is using a portable thermovision camera to capture the surface temperature profile of wire rods at different points during the moving-stelmor air-cooling process. The cooling of wire rods is determined by the stelmor operation conditions. A series of temperature profiles were recorded at various locations to study the link between the temperature of the wire rod ring (edge and center) and the conveyor zone. Based on the temperature profile of wire rod, finding the temperature difference between edge to center is approximately 80°C. High-carbon grades need powerful blowers for efficient cooling, which refines the pearlite microstructure and imparts more strength. The stelmore conveyor laying head temperature and cooling pattern on stelmore conveyor at wire rod mill were also optimized to reduce the severity of grain boundary cementite (GBC) network in wire rods. To avoid GBC formation, the wire ring passes through the region between Acm and A1 as fast as possible. Based on the detailed results, corrective action was taken to fix the extra additional fan used for cooling in zone 1 to prevent cementite accumulation on the stelmore conveyor.

Keywords: Wire Rods, stelmor conveyor, thermovision camera, temperature, Grain-boundary cementite.

# A METHOD TO RESLOVES WEAK WELD DEFECT IN ERW TUBE MANUFACTURING PROCESS

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## Abstract

JSWBPSL contributes 74,000 MT of precision tubes to automobile manufacturers each year. The steps of a manufacturing process are as follows: forming, welding, sizing, and section shaping. These semi-finished hot-rolled sheets were produced using the compact strip production (CSP) and cold rolling mill (CRM) which produce steel sheets of various grades based on market demand, one of which is the new grade SPFH 590. Quality was commissioned due to its superior mechanical characteristics and contemporary market demands. However, the SPFH 590 grade did not pass either the weak weld or the drift expansion tests. In order to resolve the failures, various brainstorming strategies and approaches were used in an exhaustive analysis. Through proper investigation, a solution came out that greatly improved the efficiency and performance of the SPFH 590 grade with respect to the weak weld and drift expansion tests, thus meeting market standards. The underlying cause of these was the gap between the work coil and the electrical resistance welding (ERW) equipment. The work coil is a critical component that mechanically guides the tubes in the proper alignment for welding. This spacing was initially set to a predetermined measurement. It was found that spreading these components further apart successfully mitigated the issues associated with SPFH 590.
Optimizing this distance and other parameters between the work coil and the ERW considerably improved the SPFH 590 manufacturing process. This meets the market's stringent demands while avoiding prior failures. The change emphasizes the significance of process parameter adjustment in order to achieve desired material properties or product performance goals.

Keywords: CSP, CRM, ERW, SPFH 590 grade, forming, welding, work coil.

# Impact of tensile sample dimension and tensile testing parameter on the mechanical property of IF and IFHS galvanized steel

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## Abstract

Here in this paper we have experimented on the mechanical property of interstitial free and interstitial free high strength grade flat steel samples by varying the tensile sample dimension and the tensile test parameters. The size of tensile sample considered are the gauge length gauge width and gauge thickness. The tensile samples are prepared both in parallel and perpendicular to the rolling direction for the same location sample. The coating weight are stripped off before tensile test. The tensile test is conducted at different strain rates mentioned in ISO 6892-1:2016. A regression analysis is conducted to find the correlation in various strain rates and gauge dimension on the mechanical property. The fracture analysis is done on the broken samples to observe the impact of strain rate and gauge width on the fracture mechanism. It is observed that the tensile sample and the testing parameters impact certain mechanical property more as compared to others. The impact of tensile sample dimension is more significant on the total elongation while the strain rates are more sensitive for YS value. The study gives the understanding of the material behaviour at different loading conditions. The study helps in identifying the feasibility of the property requirement by the customers in different testing methodologies and tensile sample gauge dimension.

**Key words : Tensile Test, Testing Direction, Gauge length, IF Steel, IFHS Steel**

# Processing of Advanced High Strength Steels at Commercial Scale

MBN Raju, Dr.Appa Rao, Rahul Verma, Praveen Thampi, Manas Banerjee

## Abstract

The development of advanced high-strength steels (AHSS), such as cold-rolled dual-phase steel, at a commercial scale, requires precise control over various process parameters. From the initial casting to the coil cooling in the hot-rolled condition, followed by cold rolling and continuous annealing, each stage significantly influences the final mechanical properties of the steel. Subsequent low-temperature annealing is also crucial for optimizing these properties.

Achieving the necessary formability and flange-ability, in addition to the desired tensile strength and phase composition, is essential for the practical application of AHSS. This work focuses on understanding the effect of hot rolling parameters on the subsequent cold rolling process of advanced high-strength steels. By examining these parameters, we aim to enhance the overall quality and performance of AHSS in commercial applications.

# Integrated Approach to Roll Force Optimization for Improved Steel Rolling Efficiency

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## Abstract

This research investigates the optimization of roll force in the production process of Thinner gauge (≤2 mm thickness) hot-rolled steel coils with an emphasis on achieving desired mechanical properties through Optimization of chemistry, slab length and thickness of slab before finish rolling. The aim was to optimize the roll force for energy efficiency, cobble, improve surface quality of hot rolled coils, achieve consistent mechanical properties and improve process stability.

Initially, the focus was on optimizing the chemical composition. To preserve mechanical properties while reducing roll force, niobium (Nb) was removed and manganese (Mn) content increased. Simultaneously, a specific range of slab length was identified to minimize variations in temperature across the length slab that could affect the rolling force distribution. Furthermore, the optimization of transfer bar thickness played a critical role in the rolling process. The initial trials with a higher transfer bar thickness were found to be suboptimal for producing coils in the desired thickness range. Reduction in transfer bar thickness led to a significant reduction in roll force across the stands. This adjustment not only facilitated smoother rolling operations but also contributed to achieving the desired thickness in the final product. The conducted trials provided comparative data on roll force across different stands. Trial with optimized chemistry and adjusted slab length and transfer bar thickness, showed lower roll force compared to the initial trial. This reduction in roll force was consistent indicating the effectiveness of the implemented optimizations.

Overall, the optimization in chemistry, slab length, and transfer bar thickness collectively contributed to a more stable rolling process. The mechanical properties of the rolled coils were within acceptable limits, and the overall coil shape was satisfactory. These findings highlight the importance of a holistic approach to process optimization in the steel rolling industry, ensuring both quality and efficiency.

Keywords: Steel, Hot rolling, Roll force optimization, Mechanical properties

# Development of SPFC590 HSLA grade through CSP & BAF route for CRCA tube product used in Automotive Segment

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## Abstract

Over the past few decades, there has been a significant focus on enhancing the structural characteristics of motor vehicles. As a result, various types of high strength steels have replaced many components due to their superior strength, fatigue, formability, ductility. Reducing fuel consumption, improving passenger safety, vehicle performance and carbon emissions are the topmost goals in current government plans across worldwide. One of the significant steps in the quest has led to the invention of the EV's. India being the largest two-wheeler market in the world, has seen substantial growth in the volume and sales of the two-wheeler EV over the past few years. The Manufacturing of these fuel-efficient EV's requires material with stiffness, strength, fatigue, formability and light weight. This has led to the rising demand of HSS steel (SPFC590 grade) requirement in tubular components such as Handel Bar, cross tubes and side tubes which will provide high yield strength for cold forming application with a good strength to weight ratio. These components are manufactured by subjecting the straight tubes to the processes such as bending, notching and drifting.

In this project, the focus area is to develop high strength (HSLA) CRCA tube product for automotive applications especially for 2-3wheeler EV vehicles.

The objective of this project is to develop JIS G3135 SPFC590 grade in CRCA for automotive tube applications through EAF-LRF-TSC-CSP-BAF route.

Trial taken to develop SPFC590 grade in CRCA tube by maintaining CTQ parameters of SMS and CSP to produce clean steel. Alloy design done considering CSP constraints by adding micro alloy (V, Nb, Ti), manganese, silicon, aluminum in low carbon steel to achieve desired mechanical properties. Mechanical properties achieved by fine ferrite grain size, precipitation (carbide, nitride), substitutional & interstitial strengthening and accelerated cooling during hot rolling. Annealing cycle of BAF process set to achieve desired mechanical properties in CRCA tube.

Mechanical Properties of trial achieved as per requirement in CRCA tube, and the tube successfully processed for automotive application. The CTQ parameters of SMS, hot rolling and cold rolling, annealing cycle and alloy design freeze for future supply.

Key words: High Strength Low Alloy, Electric Arc Furnace, Ladle Refining Furnace, Thin Slab Caster, CSP, BAF

# Serrated Edges in Full Hard Cold Rolled Sheet of Ultra-low Carbon Ti Interstitial-free (IF) Steel

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**Abstract**

Full Hard Cold Rolled (FHCR) sheets of interstitial-free (IF) steel exhibited zig-zag type edge cracks that were not detectable during the hot rolling stage but became visible during cold rolling. Presence of these defects, if left untrimmed, led to significant rejection of steels. To investigate the origin of these defects, whether from casting, hot rolling, or cold rolling, various experiments were carried out, including chemical analysis, stereo microscopy, optical and scanning electron microscopy, EDS analysis and mechanical tests like hardness and tensile tests. Microstructural examination of FHCR sheet revealed projected edges with tiny cracks associated with scale. Severely elongated and deformed ferritic grains at the edges were also observed. The presence of scale at the cracks confirmed that the defect originated during the hot rolling stage. Further examination of multiple samples of this steel from hot rolling stage (HR) showed elongated deformed grains with tiny cracks at the edges, while recrystallized and equiaxed grains were observed 30 to 40 mm away from the edge. The edge hardness (130 Hv) was found higher compared to areas away (94 Hv) from the edge. At low finished rolling temperatures (<850° C) at the edges, the steel cannot undergo dynamic recrystallization which prevents formation new strain free grains, and consequently results deformed elongated ferritic grains with higher hardness and low ductility. These tiny cracks and severe elongated grains with high hardness at edges in hot rolling stage resulted in serrated edges during cold rolling. To minimize this problem two measures were recommended. First, incoming slab temperature was increased 30° C, i.e from 1200° C to 1230° C. Second, the cooling of the hot rolled (HR) strip after finishing rolling was controlled by reducing the water flow in the initial headers of the laminar cooling system, allowing sufficient time for the grains at the edges to recrystallize.

**Key Words:** Serrated Edges, Elongated grains, Hardness

# Consistent Supply of Zero Defect Electrode Quality Grades to M/s Lincoln

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**Abstract**

**The existence of the modern world is highly dependent on the electric arc welding which is one of the oldest processes for joining of the metals. Welding process is necessary for various engineering activities and in the production of several manufactured products. It is a fusion process of joining metals and is used in every field all over the world.**
The wire for the coated electrode is normally of low carbon steel which is popularly known as electrode quality (EQ) steel.

The paper discussed the efforts made by the team to produce High Quality Electrode Grades which is supplied to M/s Lincoln at a potential of 600 Mt/Month. Many process improvements were undertaken at manufacturing Units particularly Mills parameters were relooked and standardized. Reheating Furnace Soaking Zone Temperature was maintained between 1130 – 1150 C. Laying Head Temperature was maintained between 820 – 830 C and Uniformity to be maintained in Laying Head pattern to ensure no bunch formation.

This proactive approach has zeroed down Quality Issue in these grades. This is how we supplied Zero Defect Products to Customer. Revision of Standards was done and has been incorporated in SOP and Work Instructions.

key words: Cold Headed Quality, Upset Test, Zero Rating

# Reduction of Inline Scratch Rejection in Garret Rolling at WRM of TSG

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## Abstract

Wire Rods are of different sizes which is obtained by Block Route(5.5 mm to 18.5 mm) and Garret Route(20 mm to 25.4 mm). Scratch line defects in steel can impact various components depending on the application and the severity of the scratches. Scratch was generated in **Garret Route** of Wire Rod Mill. Precision components like pistons, crankshafts, camshafts, and connecting rods can suffer from scratches, impacting their performance and durability. Many Premium Customers like Omega, Arkkays and Microturners demand Zero Scratch Defect. Scratch Defect can increase Friction, wear, leakage issues and weaken structural integrity by acting as stress concentrators.

First of all, Scratch generating points were mapped and identified. Total of 5 points were identified at different locations. Causes of scratch were analysed. Many preventive and Rectification actions were taken such as Water Box 19 base strengthening and alignment for correcting the misalignment at Water Box Nozzle. Switch Pipe Funnel & Base material was modified to softer grade and Inner Diameter increased from 45 mm to 50 mm. Deviator Box alignment and stopper fixed. Trumpet Guide arrangement was modified. All these modifications were done & implemented.
Plan was implemented in Mid of Mar'24 and after that Scratch issue is almost nil.

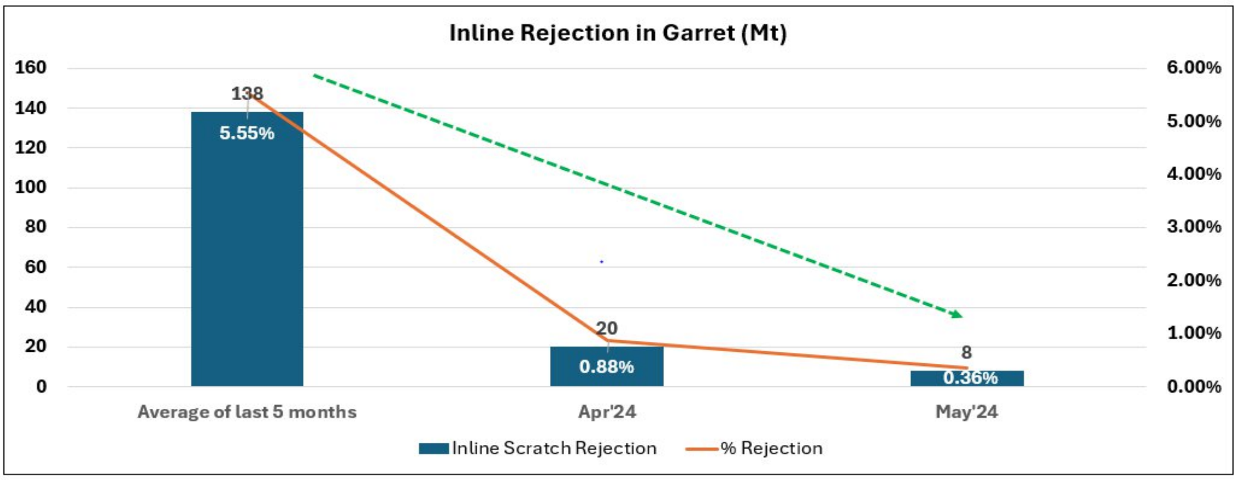


Fig. 2: Results

Key words: Garret Route, Block Route, Scratch

# Surface modification of rolled Steel using Plasma spray of NITINOL

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## Abstract

The surface of hot rolled steel is weaker due to the heat applied, which weakens the metal and prone to surface degradation when it comes for direct application. The surface modification can be done using plasma technology. Plasma spray is one of the thermal spray coating techniques, in which a very high energy source is used to melt the substrate particles and project them onto a finished surface. The molten particles accelerate and on impact with the surface cool down and solidify due to heat transfer between the substrate particles and the surface. Hence by repeated accumulation, they form coatings consisting of a layered structure. Thermal spray of NITINOL (NiTi) on steel enhance the surface properties such as wear resistance, thermal barrier, bio-compatibility. In this work we have thoroughly examined the current techniques to coat NiTi alloy on different metal substrate by plasma spraying. Furthermore, we have also studied the mechanism and process parameters associated with plasma spraying. The various use of plasma spraying in different scenarios has been discussed. It is found that, various properties exhibited by the substrate material due to nitinol coating is feasible for the structural materials commercialization.

**KeyWords:** Steel, Plasma Spraying, NITINOL, Surface Modification

# Improving edge quality of Hot rolled Coils in 11%Cr dual phase Ferritic Stainless Steel (X2CrNi12)

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## Abstract

11%Cr-0.02C is a dual phase grade belonging to ferritic stainless steel group which is widely used in fabrication of railway wagons due to its higher strength to weight ratio and corrosion resistance. It is a sustainable material as after a long service life, there is a very little loss of material due to corrosion. During manufacturing of hot rolled coils from continuous cast slabs, edge cracks were frequently observed thereby leading to unwanted trimming and subsequent yield loss.

In order to minimize this defect, effect of different rolling parameters, like re-heating furnace discharge temperature, mill roll force & strain rate on edge crack was analysed. It was observed that higher roll force and higher draft in each pass was leading to higher strain rate on the material.

To reduce the strain on material, it was decided to modify the pass schedule at roughing mill. After rolling the material with the suggested changes, edge crack occurrence was minimized in hot rolled coils. It was also observed that the average roll force and draft in each pass of rolling also decreased which resulted in lower strain rate in material. This resulted in reducing wastage of material due to trimming losses thereby improving the yield of the final product.

**Keywords:** Ferritic Stainless Steel, Edge Crack, Roll Force, Strain Rate.

# Influences of Heat Treatment on the Quality of Heavy Plates

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## Abstract

The requirements of heavy plates in terms of enhanced strength and wear resistance have greatly increased in recent years. Driven by this demand for extra high strength steel plates required for specific application by the downstream industries, heavy plate manufacturing have undergone an evolution from a mass-produced commodity to a specialty product. Depending on the application and the sheet metal geometry, the heat treatment carried out need to be individually adapted. The cooling (quench) speed as well as the use of special alloy trace elements has an influence on the quality of heat-treated plates.

Years back the term “heavy Plate” used to cover a thickness range of 6 mm to 150 mm. With the advent of newer technological usage, the range have widened in both direction. In today’s world the thickness range , in general, is considered as  2 mm to 250 mm.

In order to keep up with the stringent quality requirement of final properties, it is no longer sufficient keep the main alloying component in a narrow tolerance range. In addition, the determination of cooling rate during solidification from the liquid phase as well as the introduction of trace elements for metallurgical properties play an important role.

# Processing Strategies to Develop Third Generation AHSS for Automotive Applications

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## Abstract

The first generation advanced high strength steels (AHSS) such as dual phase, martensitic and a part of complex phase and TRIP steels are extensively used in the automotive industry for the weight reduction. The difficulty arise with the first generation AHSS is their reduction in ductility with increase in strength. Although second generation AHSS such as austenitic stainless steel, twin induced plasticity (TWIP) steel and low density induced plasticity (L-IP) steels give superior strength and ductility, they hardly get place in the automotive industry due to high alloying content, weldability issue with dissimilar metal joining and cost of production. Hence, third generation AHSS are gaining attention to the automobile manufactures. Third generation AHSS are characterized by their ultra high strength and superior ductility to get the product of ultimate tensile strength and total elongation greater than 30 GPa. %. The attractive properties of such steels helps in manufacturing automotive components of thinner sections to reduce the overall weight of the automobiles resulting improvement of fuel efficiency, reduce $CO_2$ emission and gives greater safety.

In the present study various processing routes such as single and two stage quench and partitioning (Q&P), quench and tempering (Q&T), austenite reverted transformation (ART) were employed to a commercially available TRIP assisted steel to achieve third generation AHSS properties. The microstructure of the steel was correlated with the mechanical properties. To further enhance the mechanical properties, a newly developed lean medium manganese steel was subjected to ART treatment providing attractive mechanical properties suitable for automotive industry. The steels superior properties are due to the presence of retained austenite produced by the unique processing routes which aided the strength and ductility by TRIP effect while deformation in addition to the ferrite, bainite and martensite as the other phases present in the steels with various proportions. The benefits and limitations of each processing route is discussed for the development of the third generation AHSS.

**Key words:** Third generation AHSS, Unique processing routes, Microstructure, Mechanical Properties, TRIP effect

# Optimizing Hot Billet Charging in Bar Rolling Mills to Reduce Gas Consumption

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## Abstract

The BRM-2 reheating furnace (RHF) at JSW Steel is designed with a capacity of 220 tons per hour (TPH) and utilizes mixed gas as fuel. The gaseous heat rate, defined as the "Mixed gas consumption (in Gcal) per ton of billet discharged," is a critical metric for operational efficiency. To achieve an average billet exit temperature of 1000°C, the furnace consumes an average fuel rate of 0.235 Gcal per ton of billet processed. A plant-level energy study identified several factors affecting the gaseous heat rate, including billet charging temperature (hot charging percentage), furnace utilization (enhancing heating capacity), and combustion efficiency (proper air-to-fuel ratio). Notably, for every 10°C change in the inlet billet temperature, there is an impact of 0.003 Gcal/T on fuel consumption. It is well established in the literature that increasing the hot charging percentage significantly reduces gas consumption. To achieve this, a time study was conducted to monitor the temperature of billets from the SMS3 caster to the BRM2 furnace charging door. The study revealed that billet temperature dropped below 350°C within 5 hours and 30 minutes. To mitigate this heat loss during transit, a series of insulated hoods were installed over the 6-billet roller table, extending the temperature sustainability to 6 hours and 15 minutes.

Additional measures to reduce furnace gas consumption include the development of a Standard Operating Procedure (SOP) encompassing a heat casting plan, maximized utilization of Caster-1 in SMS-3, and streamlined casting sequencing in SMS-3 with rolling grades in BRM-2. These actions have been systematically implemented to enhance the efficiency of the reheating furnace. The optimized hot billet charging process has led to a significant reduction in gas consumption, contributing to overall energy efficiency and cost savings.

| KPIs | UoM | FY22 | Dec'22 | Jan'23 | Feb'23 |
|---|---|---|---|---|---|
| Production | t | 7,52,724 | 1,15,547 | 1,10,343 | 97,446 |
| Hot charging % | % | 40% | 42% | 48% | 52% |
| Slope | GJ/t per 100% | 0.39 | 0.39 | 0.39 | 0.39 |
| Fuel cost | INR/Gcal | 2,538 | 2,538 | 2,538 | 2,538 |
| Cost savings due to fuel saving due to hot-charging impact | **INR Cr** | | **0.05** | **0.21** | **0.28** |

**Key words** : bar mill, hot slab charging, energy efficiency, cost optimization.

# Increase of Finishing Stand Pass Life by Using Composite Rolls

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## Abstract

JSW Steel Vijayanagar works operates a Bar Rod Mill (BRM) with a capacity of 1.2 MTPA, producing TMT bars for various applications. The quality of TMT rebars is significantly influenced by the performance of rolling rolls in the TMT bar mill, particularly in the finishing stands where projected ribs and identification marks like the manufacturer's logo, grade, and section are introduced. Traditionally, Spheroidal Graphite (SG) Iron rolls are used in the finishing stands for 25mm and 32mm bars, featuring an acicular structure and a hardness of 67-73 Shore C. However, excessive wear in the finishing pass necessitates frequent replacements, with the average pass life being 500-600MT for 25mm and 700-800MT for 32mm bars.

To address the issue of low pass life, composite rolls have been introduced in the finishing stands. These composite rolls (Fig 1) consist of Tungsten Carbide (WC) rings with binders such as cobalt, nickel, and chromium, comprising 30% of the material. Tungsten carbide is renowned for its exceptional wear resistance, which has resulted in a tenfold increase in pass life compared to SG iron rolls. The implementation of these composite rolls in the finishing stands has significantly extended pass life and reduced mill downtime, thereby enhancing overall productivity and efficiency.

This transition to composite rolls demonstrates a strategic improvement in roll performance, contributing to higher quality TMT bar production and operational cost savings. The increased durability of tungsten carbide rings ensures longer intervals between roll changes, minimizing disruptions and maintenance requirements. This advancement underscores the critical role of material selection in optimizing rolling mill operations and achieving superior product quality in the steel industry, also increase in roller pass life by 10 times with good surface finish.

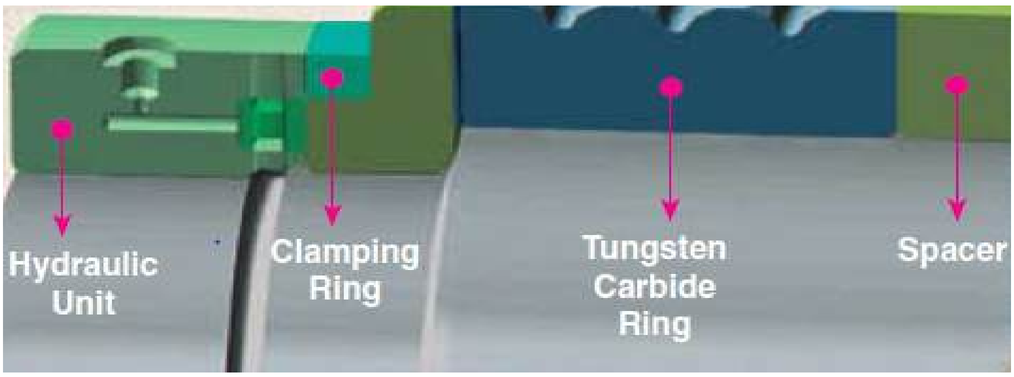


Fig. 1: Composite Roll arrangement

**Key words:** TMT bar Mill, Rolling, Roll, Composite Roll, Pass life

# Alloy Design and Processing of High Strength Hot Rolled Steel Coils for Automotive Structural Components

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## Abstract

The automotive industry from all over the world has been constantly pursuing development of new design and materials for achieving reduced weight and improved crash performance of vehicle. High strength steels owing to their higher strength with moderate forming capacity favour application of thinner gauge sheets, reducing overall weight of car and saving in fuel consumption. Besides high strength, these steels also require superior formability and flangeability characteristics, high elongation, low YS / UTS ratio for applications in automotive segments.

The objective of the present work was to design and develop high-strength hot-rolled coils with an optimal alloy composition and process design using Thermo Mechanical Controlled Processing (TMCP). This approach aimed to achieve an attractive combination of strength and formability characteristics suitable for automotive structural components.

Steel heats were produced and cast into slabs measuring 220mm x 1510mm. The alloy composition was based on the principles of high-strength low-alloy steel, featuring a carbon content of less than 0.15 wt.%, manganese in the range of 1.2-1.3 wt.%, and micro-alloying additions (Nb+V+Ti) less than 0.08 wt.%. These slabs were hot rolled to thicknesses of 12.8 and 13.5 mm, and widths of 1725 mm and 1970 mm, respectively, in a Hot Strip Mill (HSM). The finish rolling temperature was maintained around 820-830°C, and the coiling temperature was approximately 580°C.Microstructural characterization revealed a fine ferrite and pearlite structure in the steel. The mechanical properties included a Yield Strength (YS) range of 500-545 MPa, Ultimate Tensile Strength (UTS) range of 580-675 MPa, and elongation percentages between 22-29%. This grade of steel is well suited for automotive structural components, particularly in load-bearing applications.

Keywords: Automotive Steel, Micro Alloyed, TMCP

# Optimization of Heat Treatment Cycle to Prevent Quench Cracks in 5150 Grade Rolled Steel Shafts

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## Abstract

Quench cracking in 5150 grade rolled steel shafts is a significant issue affecting the structural integrity of these components. This study investigates the root causes of quench cracks and proposes an optimized heat treatment cycle to eliminate these defects. Metallurgical analysis of cracked samples revealed a grid-like pattern in the microstructure, linked to issues during the quenching process.

Induction heating, widely used in the surface hardening of 5150 grade steel, introduces complex local thermal cycles that lead to rapid heating and cooling, resulting in significant metallurgical changes. Our study identifies that martensite tempered at 600°C can become overaged, forming coarse carbides along lath boundaries, leading to the grid patterns observed. This is attributed to carbide precipitation rather than chemical inhomogeneity. While tempering aims to form fine carbides within the martensitic matrix, excessive heating beyond the optimal tempering range results in coarse carbide formation within the ferritic matrix, negatively impacting the material's mechanical properties.

An optimized heat treatment cycle, involving hardening at 850°C with a 2-hour soak followed by tempering at 550°C for 4 hours, was developed. This cycle successfully eliminates the undesirable grid patterns and enhances the mechanical properties of the steel shafts. The study details the microstructural analysis methods and experimental trials conducted to reach these conclusions.

The time- and temperature-dependent microstructural developments observed in this study are directly applicable to induction hardening processes, providing a practical solution for improving the quality and durability of 5150 grade steel shafts. These findings offer valuable insights for manufacturers addressing similar quench cracking challenges, ultimately contributing to the production of more reliable components for high-stress applications.

**Key words** : heating rate, induction heat treatment, steel, 5150

# ITS RIM SPRAYING PATTERN AT WHEEL & AXLE PLANT, DSP

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**Abstract**

Durgapur steel plant produces EMU wheel and supplies it to the Indian Railways along with various types of other wheels like Broad Guage (BG) Coach, (Meter Gauge) MG Locomotive, (S Profile) SP Locomotive, WAG-9/WAP-5 etc. The wheels are forged, rolled and heat treated before machining. At this plant more than 7% wheels are rejected on account of hardness variation in EMU Wheels as Indian Railway Specification states that the difference between extreme hardness values within a batch shall not exceed 30 BHN.

At the wheel shop, rim spraying machine consists of one rotating disc and a water spraying hood that has 24 no. spraying nozzles all along its circumference. The hood has a fixed diameter of 1360 mm and is used for all types of wheels with varied diameters.

The locomotive wheels are having diameter of 1120 mm whereas EMU wheels of 982 mm in cold/ black state. The distance from nozzle tip to the tread of locomotive wheels is 120mm (i.e- 1360-1120 = 240/2) and 189 mm ( i.e- 1360-982 = 378/2 ) is for EMU coach wheels . So, in case of EMU wheel, the flat jet of water has to travel 7cm more to reach to the tread in comparison with Loco wheels (Fig 1). The purpose of effective quenching is veering off as the water jet is becoming more wide when it reaches to the EMU wheel tread. The water jet is also striking the hood roof as well as the wheel base after travelling longer distance.

Analysing hardness rejection pattern in different types of wheels, it shows that the locomotive rejections are always less than that of low diameter wheels.

To optimise this factor, in house fabrication was carried out for advancement of nozzles towards 'EMU wheel tread', (Fig 2). This resulted effective hood diameter of 1222 mm so as to have a nozzle to tread distance 120 mm for effective quenching like locomotive wheels.

These modification and optimisation led to hardness rejection from 7% to 5%; resulting improvement in productivity as well as quality.

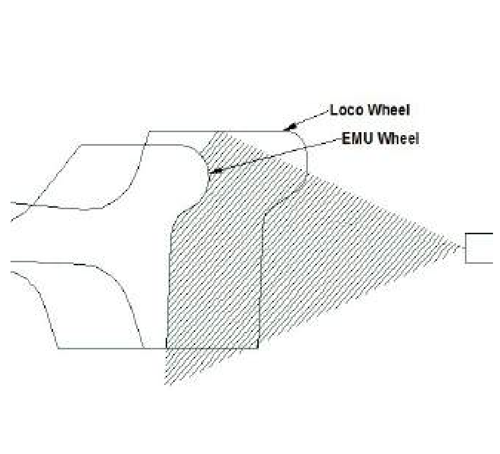


Fig 1: Water jet more wide in EMU wheel

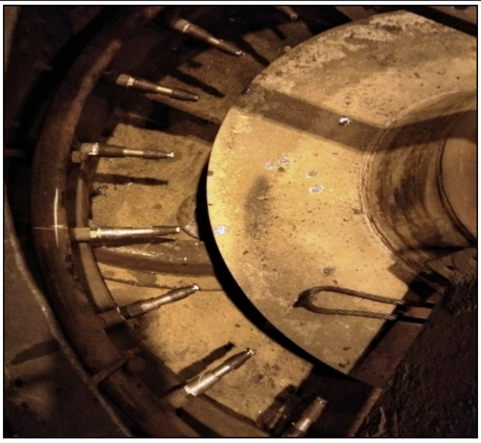

Fig 2: The modified hood with nozzle

# Crystal structure and morphology of carbides development upon heat-treating C alloyed CoCrFeMnNi high entropy alloy

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**Abstract**

This study investigates the precipitation of carbide phases in $CoCrFeMnNiC_x$ (x = 0.9 at. %) high-entropy alloys subjected to heat treatment at various temperatures. Detailed microstructural characterization was performed using optical and scanning electron microscopy, X-ray, and electron backscatter diffraction. Microstructural analysis revealed that at lower temperatures, carbides localize along grain boundaries and within grains, while at higher temperatures, they localize predominantly along grain boundaries, signifying their dissolution in the matrix as temperature rises. Above 1000°C, Cr-rich $M_7C_3$ carbides exhibit specific crystallographic orientation relationships with the FCC matrix: $(112)_{FCC}//(\bar{1}2\bar{1}3)_{M_7C_3}$ and $[\bar{1}10]_{FCC}//[10\bar{1}0]_{M_7C_3}$. Below 1000°C, along with $M_7C_3$ carbides, $M_{23}C_6$ carbides form, demonstrating cube-on-cube orientation relationships with the FCC matrix. Additionally, an increase in both lattice parameters and hardness of the matrix phase with rising temperatures indicates carbon dissolution into the matrix. Thermodynamic calculations further support these observations by demonstrating the decrease in stability of $M_{23}C_6$ and the increase in stability of $M_7C_3$ with rising temperature. It also predicted that the complete dissolution of carbides at specific temperatures, aligning with experimental observations and confirming distinct carbides and limited carbon solubility in the alloy matrix.

keywords: Interstitial high entropy alloys, Carbides, Thermodynamics, Orientation relationship

# Study of machining-induced surface integrity of silicon steel

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**Abstract**

Silicon steel is emerging as an alternative to ferritic and austenitic steels. This alloy steel has good strength, ductility, and good corrosion resistance. Recent study has shown that silicon addition can also be used to manipulate the phase composition. Low silicon content leads to austenitic microstructure, while high silicon content leads to formation of duplex microstructure. Surface of a component is the interface to its environment and hence several functional properties like wear, corrosion and fatigue characteristics are directly dependent on the surface integrity of the component. Since steel components are primarily manufactured by machining, it is important to understand the effect of machining-induced surface integrity.

In this work, we study the effect of alloy composition and machining parameters on surface integrity parameters like surface roughness, hardness, sub-surface microstructure and residual stress. Surface roughness was assessed through optical profilometry, and microstructural changes in the surface and subsurface regions were examined using SEM and EBSD techniques. The primary causes of microstructural alterations during machining are the generation of heat and the occurrence of significant plastic deformation. Residual stresses which arise due to thermomechanical stresses, were determined using the $\sin^2\psi$ method.

**Eliminating Center Looseness issue in Bearing Grade Bars**

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**Abstract**

The Blooming Mill (BLM) at JSW Steel Salem Works specializes in producing bars ranging from 65 mm to 200 mm in diameter and Round Corner Squares (RCS) from 55 mm to 265 mm. A major challenge has been rejections of roller products due to centre looseness in bearing grade materials. In order to improve the internal soundness of the rolled bars critical parameters influencing centre looseness, including furnace dwell time, furnace heating parameters, and rough rolling output size were studied. By employing hypothesis testing, these factors were systematically examined to understand their impact on product quality. Subsequently, a DOE methodology was applied to optimize these parameters, aiming to determine the most effective combination to minimize centre looseness.

For inputs sized at 340 x 400, the optimized process parameters were established as follows: a dwell time of 6 hours, a Pre-Heating Zone (PHZ) temperature of 950°C, a Heating Zone (HZ) temperature of 1180°C, a Soaking Zone (SZ) temperature of 1180°C, and an input size to the Horizontal Vertical (HV) mill of 191 x 191. For inputs sized at 250 x 250, the optimized parameters were determined to be: a dwell time of 4 hours, a PHZ temperature of 850°C, an HZ temperature of 1050°C, an SZ temperature of 1180°C, and an input size to the HV mill of 142 x 152. By extending the furnace dwell time and adjusting the temperatures in the heating zones, the internal integrity of the bars was greatly enhanced, effectively eliminating centre looseness. The effectiveness of these optimized parameters was evaluated using Ultrasonic Testing (UT) to measure internal soundness in the rolled products. UT, a non-destructive testing method, provided precise detection of internal flaws, thereby serving as a reliable measure of the improvements achieved. The results of UT demonstrated elimination of rejections due to centre looseness, reducing from 34% to 0%. The DOE approach was instrumental in identifying the critical factors and their optimal settings, leading to significant improvements in the internal structure of the bars. The comprehensive measures undertaken by modifying the reheating pattern and reduction pass schedules to address the issue of centre looseness in bearing grade materials have proven highly effective.

key words : Centre looseness, bearing grades, Hypothesis testing, DOE, UT.

# Determination of Coefficient of Friction at Higher temperature using Bending Under Tension machine

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## Abstract

Formability under the hot stamping process is significantly influenced by various input process parameters and tribological conditions, with friction being a crucial factor in determining the formability of components at elevated temperatures. Previous studies have shown conflicting results regarding the relationship between temperature and the coefficient of friction: some indicate an increase in friction with rising temperature, while others report a decrease. This study aims to resolve these discrepancies by analyzing the effect of temperature on the coefficient of friction using the Bending Under Tension (BUT) test. An L27 Taguchi array was employed for the experimental design, incorporating input parameters such as temperature, sliding distances, and velocities. This methodical approach allowed for a comprehensive examination of the interactions between these variables and their individual effects on friction. The experiments revealed that an increase in temperature, sliding velocity, and sliding distance generally leads to a higher coefficient of friction.

The Analysis of Variance (ANOVA) method was utilized to determine the statistical significance of the process variables on the friction coefficient measurements and to explore the interactions among these variables. The ANOVA results indicated that temperature significantly impacts the coefficient of friction. The Design of Experiments (DOE) methodology proved to be effective in systematically studying the effects of multiple variables and their interactions. In summary, the study confirmed that temperature is a critical factor affecting the coefficient of friction during the hot stamping process. Higher temperatures, increased sliding velocities, and longer sliding distances all contribute to an elevated friction coefficient. These findings have significant implications for the optimization of hot stamping processes, as controlling friction is essential for enhancing formability and ensuring the quality of stamped components.

key words : Hot Stamping, Friction, Bending Under Tension Test, L27 Taguchi Array, Temperature, Sliding Distance, Sliding Velocity, ANOVA.

# Optimizing Roll Usage in Hot Strip Mills: Repurposing Worn Intermediate Rolls to Reduce Costs and Downtime

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## Abstract

In the integrated steel plant of JSW Steel Limited, the Down coiler Pinch Roll is a critical component in the hot strip mill process, known for its frequent wear and high maintenance costs. Traditionally, these rolls are made either cast materials or cladding material which require regular cladding and replacement, leading to significant operational downtime and increased expenses. This paper presents a novel approach to mitigate these issues by repurposing worn-out intermediate rolls from the PLTCM (Pickling Line Tandem compact Mill) unit as pinch rolls.

The study explores the technical feasibility of adapting used PLTCM rolls—initially designed for intermediate processes—to function effectively as pinch rolls in the hot strip mill. By grinding and modifying these rolls, JSW Steel Limited aims to eliminate the need for frequent cladding, thereby extending roll life and reducing maintenance costs. This approach leverages waste rolls from PLTCM, turning them into valuable assets, which not only cuts material costs but also minimizes production interruptions.

Key benefits include significant cost savings, reduced downtime, and enhanced roll durability. Additionally, this practice supports sustainability by repurposing otherwise discarded materials. The paper provides a detailed analysis of the modification process, the operational impact, and the economic benefits derived from this strategy.

This innovative solution demonstrates a practical application of resource optimization and cost management in steel manufacturing, offering valuable insights for similar industries facing analogous challenges.

**Keywords:** Roll Optimization, Cost Reduction, Downtime Minimization, Steel Manufacturing, Sustainability, Resource Efficiency

# Elimination of Red scale during hot rolling of a low carbon wire rod grades

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## Abstract

In current work, red powdery scale generated during hot rolling of low carbon wire rod grade is investigated. Extensive plant trials based on Stelmor parameters are conducted to identify the controlling parameter for red scale during hot rolling. Laying head temperature, Conveyor speed and blower combinations are changed during trials and surface severity of red scale is captured. Detailed characterization in terms of scale thickness, scale loss percentage by acid pickling, tensile property and other microstructural aspects are done for each trial category to evaluate the overall impact. Result shows that higher laying head temperature and lower conveyor speed reduces the red scale. Scale thickness and percentage scale loss increases with increase in laying temperature. Blower selection is found as an important parameter in controlling the red scale. Based on trial findings, Stelmor parameters are optimized to achieve hot rolled property without red scale defect.

**Keywords:** Hot Rolling, Red Scale, laying head temperature, conveyor speed, blower selection

# Establishing manufacturing approach for the development of high-performance Al/Mg laminated composite clad sheets

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## Abstract

Magnesium (Mg) is the lightest structural metal available commercially, and it is widely used in the automotive and aviation industries to reduce vehicle weight, thereby enhancing fuel efficiency and lowering emissions. Additionally, Mg possesses excellent damping characteristics, superior fatigue life, good fracture resistance, and a high strength-to-weight ratio. However, Mg often exhibits poor corrosion resistance and inferior ductility/formability. Al has excellent corrosion property, very good formability/ductility and similar strength-to-weight ratio as like Mg alloys. Therefore, there is a promise to combine Al and Mg sheets into the Al/Mg laminated clad sheets (LCS) in order to obtain individual characteristics of Al and Mg in the Al/Mg LCSs with high strength-to-weight ratio and improved corrosion properties. Due to lightweight characteristics, the Al/Mg LCS has wide applications as a structural material in the aerospace and automotive industries. The performance of the Al/Mg clad sheets is mainly governed by the formation of good mechanical and metallurgical bonding at the interfaces. The main challenge for developing clad sheets is to avoid the formation of intermetallic compounds at the interface caused by the interatomic mobility of Al and Mg atoms, which deteriorates the clad sheet's mechanical properties. The present study is focused to establish a manufacturing methodology to develop a high-performance Al/Mg laminated clad sheets (LCS) with strength-ductility-bonding synergy. The manufacturing methodology includes large strain-controlled roll bonding-based thermos-mechanical processing followed by post processing. The developed Al/Mg LCSs showed significantly higher strength-ductility combination than its bare Mg and Al counterparts. The interfacial phases between Al and Mg were examined using XRD, and no intermetallic compounds were detected at the interfaces, confirming the excellent bonding in the Al/Mg LCS. Additionally, tensile and three-point bend and peel tests were performed to assess the mechanical properties and bonding characteristics of the Al/Mg LCS. The detailed planar and cross section microstructural characterizations were carried out using optical, FESEM and EBSD analysis to establish the scientific knowhow for obtaining strength-ductility-bonding synergy.

**Keywords:** Roll Bonding, Thermo-Mechanical Processing, Al-Mg Laminated Clad Sheet, Microstructure, Mechanical Properties

# Hardness prediction for Refractory Complex Concentrated Alloys (RCCAs) using Machine Learning

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## Abstract

There is a new class of materials called High Entropy alloys which have a huge compositional space and hence, hold potential for many undiscovered alloys having attractive properties like strength, ductility, corrosion resistance, high temperature stability etc. which can match the high temperature property requirements of aero based component of various systems.

This study involves multi principle element alloys having almost equiatomic elemental composition along with minor elements in small proportion to form a Complex concentrated alloy (CCA). We are concentrating on Refractory based metals as principle constituent elements. This RCCA (Refractory Complex Concentrated Alloy) is a potential candidate for high temperature application (above 1000°C) with all the constituent elements having high melting point. We are designing a new RCCA with a new combination of major and minor elements (4 major and 4 minor) to obtain desired set of mechanical properties for high temperature applications. Alloy design for such a multi component system using only experimental approach takes enormous amount of time and large number of experiments to come to a conclusion about the targeted properties. In order to accelerate the alloy development process, people are trying the recent concept of Integrated Computational Materials Engineering (ICME) approach in which there are various computational methods like First Principle Calculations, CALPHAD, Machine Learning Algorithm (ML)/ Artificial Intelligence (AI) to arrive at a desired composition and property theoretically in order to guide the experimental approach.

In the present study, we have used ML based linear regression (LR) techniques to establish highly interpretable composition- hardness relation for RCCAs where the hardness values can be predicted for new RCCA. We have implemented various LR models such as Lasso, Ridge and Elasticnet for obtaining relationship between composition and hardness. These models are used for the prediction of hardness of alloys in as cast condition. All the ML based regression steps were carried out using python programming language in which the codes were written, compiled. The composition of the RCCAs are given as X input and experimental hardness as Y input for developing the models. The RCCA compositions are featurized to generate 176 features which are scaled using RobustScaler and subsequent feature selection is carried out using Lasso method and Principle Component Analysis (PCA).

Apart from this ML based approach, we have also carried out experiments and studied the phase formation in prospective RCCAs (AMCCA61, AMCCA62 etc) and the amount of intermetallics and characterized them using XRD, SEM, EDS, EBSD etc. Subsequently,

hardness of the alloys predicted by the computational LR models were compared with the experimental hardness values. The predicted and experimental hardness values lies very close to each other although there is a scope for improvement in R2 value which we will be working on. This ML based approach is going to save time and experimentation cost which will accelerate the new RCCA development programme.

**Keywords**: Complex Concentrated Alloys, Machine learning, Linear regression, Hardness

# Enhancing TPM Activities through Online Portal at Tata Steel Limited

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## Abstract

With the strategic deployment of a SharePoint site, Tata Steel Limited is leading the way in the digital transformation of Total Productive Maintenance (TPM) in the era of Industry 4.0. Our dedication to utilizing cutting-edge technologies to promote operational excellence and efficiency is demonstrated by this effort, which was created by the TQM department itself with no financial outlay.

The site on SharePoint has been carefully designed to tackle the problems that come with using standard TPM methods, like delayed reporting, communication obstacles, and data silos. We have completely changed the way TPM operations are planned and carried out by including this potent digital tool. Enhanced data accessibility, real-time monitoring, and department-to-department communication are important characteristics.

In addition to streamlining procedures, this digital platform promotes proactive maintenance and continual improvement. The portal's home page (Fig. 1) allows users to access all eight TPM pillars by redirecting them to pages and sections specific to each pillar.

With a 73% decrease in breakdowns, a 91% decrease in defects, and a 63% decrease in accidents, our TPM Activity with digital TPM portal has produced noteworthy results. Our qualification for the JIPM TPM Excellence Award's first stage audit was made possible in large part by these improvements, which also demonstrate our commitment to upholding the highest standards of productivity and quality.

Fig. 1: TPM Hub Site

**Key words**: Industry 4.0 digital transformation, Total Productive Maintenance (TPM), real-time monitoring, Accessibility collaboration JIPM TPM Excellence Award

# Enhancing Safety Training through VR Technology at Tata Steel Gamharia

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## Abstract

Under the Education Training Pillar and the Safety, Health, and Environment (SHE) Pillar of our Total Productive Maintenance (TPM) implementation, Tata Steel Limited is leading the way in integrating Industry 4.0 technology to transform safety training.

Our creative use of Virtual Reality (VR) training demonstrates our dedication to utilizing cutting edge digital technologies to improve the safety culture among vendors and staff. By recreating genuine scenarios, the VR training modules provide an immersive and dynamic learning environment that greatly enhances engagement and recall of safety measures.

Participants have been able to encounter and traverse potential hazards in a controlled, virtual environment thanks to this digitization effort, which has improved their readiness and more successfully ingrained important safety practices.

Owing to the training initiatives' significant effects, which have included a notable decrease in workplace accidents, Tata Steel Limited is eligible for the JIPM TPM Excellence Award's first stage audit. Our commitment to enhancing safety culture via digital innovation is demonstrated by this accomplishment.

Key words: Industry 4.0, Virtual Reality (VR), SHE Pillar, safety training, digital solutions, safety culture, JIPM TPM Excellence Award

# Navigating the pitfalls of Digitisation and Industry 4.0: Enhancing process improvement through big data analytics in Indian manufacturing

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## Abstract

Implementation of Industry 4.0 in the Indian manufacturing sector presents substantial opportunities for improving productivity, quality, and global competitiveness. The integration of technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, and data analytics can modernise manufacturing processes. This, in turn, can lead to smarter and efficient production systems, which result in significant cost savings. However, this digital transformation journey is fraught with challenges that can undermine benefits and ROI, if not carefully navigated. This paper identifies and critically analyses the key pitfalls associated with the implementation of new technologies in existing operations. These include areas such as performance metrics, workforce skill gaps, change management, technological readiness, cybersecurity threats, infrastructural inadequacies, and the complexities in incorporating data analytics. Each of these are briefly explained below.

Accurate leading and lagging performance indicators are essential for evaluating the efficacy of operations in delivering value to customers. The challenge is disseminating the right information to the right stakeholders at the right time for making informed decisions.

Workforce skill gaps highlight the need for specialised training and education, as well as managing resistance to change among employees. Technological readiness encompasses the challenges related to the integration of new technologies with existing legacy systems and the high initial investment costs. Cybersecurity threats emphasise the increased vulnerability of interconnected systems to cyber-attacks and the importance of robust security protocols.

Infrastructural inadequacies point to inconsistent power supply, internet bandwidth and connectivity, and the set-up to troubleshoot advanced technologies in remote areas.

As mentioned above, this paper also delves into the role of big data analysis in driving process improvement and the associated hurdles. While data analytics can provide deep insights into decision effectiveness, operational efficiencies, predictive maintenance, and supply chain optimisation, one must also consider the associated challenges such as access to quality data, and the need for analytical tools and expertise to convert, interpret and incorporate the manufacturing variables as barriers. Last but important, we discuss the deficiencies in strategy execution as a major problem leading to time and cost blowouts.

Through a review of current literature, case studies, and expert opinions, this paper comprehensively examines the above issues. The literature review provides an understanding of the current state of digitisation in Indian manufacturing and a comparative analysis with global trends. Case studies of successful and problematic implementations offer practical insights into real-world applications and the lessons learned. Personal experience and expert opinions provide diverse perspectives on key success criteria required for transformation.

In conclusion, this paper provides actionable insights and cost-effective strategies to manage the transition and derive benefits and ROI of a more digital and interconnected manufacturing

environment.

Keywords
Industry 4.0, Digital Transformation, Data Analytics, Automation, Process Improvement

# Positive Attitude of the Management is Vital for Achieving Industry 4.0

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**Abstract**

Iron and Steel Sector today have a challenging task with the stiff marketing environment because customers have abundance of choices in seeking to satisfy their needs and therefore look for excellence in quality with value of money while selecting their suppliers. Therefore, the main challenges for Iron & Steel Industries are to aim at most competitive and superior offers for profitable performance and for attaining excellence in the market. For this, amalgamation of cyber, physical and management systems along with effective employee engagement are necessary. These can be obtained by aiming at one Smart/Digital, 4.0 level of Industries using internet of operational items and services, together with a number of contemporary automations, information, data management, manufacturing technologies and integrated management systems like TQM, 5'S', Kaizen, Lean Engineering, Quality Circles, etc. These can be obtained by a positive attitude of the Management of the company.

A crucial, often overlooked, aspect of successful Industry 4.0 adoption is having the right management attitude. Leadership must be forward-thinking and open to change, recognizing the transformative potential of these technologies. This requires a "Leap of Faith" to cross the chasm and deal with ambiguity. This requires focus and a long-term commitment to investing in necessary infrastructure and training, fostering a culture of innovation, and being prepared to navigate the complexities of digital transformation. This paper will first of all discuss about why Attitude is the main thing in your life by mathematical means. Then it will discuss about why attitude is everything in life by using the example of an iceberg in the sea. There after it discusses about what is meant by positive attitude and the factors affecting the attitude of a person. It discusses about change in Management system to make it more effective and also regarding the adoption of Risk Management System as well as Return on Investment for the inherent risks associated with digital transformation, such as data breaches, system failures, and technology obsolescence which must be proactively managed. At the end it narrates a story as a case study, which says that "There is always a better way".

Keywords:
Industry 4.0, Leadership, Management Attitude, Technology, Risk Management.

# Automatic gate changing enabled by AI and Image Processing to enhance productivity in logistics at Noamundi

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## Abstract

Overland Conveying System (OLCS) is for conveying ore fines & calibrated lump ore produced from a wet processing plant consecutively as per requirements for stacking in a bedding & blending yard. These are then conveyed to blended fines bins, calibrated lump ore bins for subsequent dispatch by railway rakes. As OLCS conveys two types of materials, frequent diverter gate change is required to transfer the materials to wet fines and calibrated lumps circuits, as per requirement. This required an attendant 24x7, 365 days to identify the material from the wet plant and operate the hydraulic gate for diverting to the desired circuit. This system caused non-productive delays and errors in segregation.

This paper presents the details on the implementation of a technique that mitigates this issue and thereby reduces human intervention, making the entire system automated with a 100% accuracy rate. This system, an "AI based automated gate changing system", uses a Faster R-CNN model trained on custom datasets using the TensorFlow framework. The system works in conjugation with microcontrollers to pass on the NO/NC output to the PLC network which controls the gate. The entire process operates in real-time, without the need for any supervisory action.

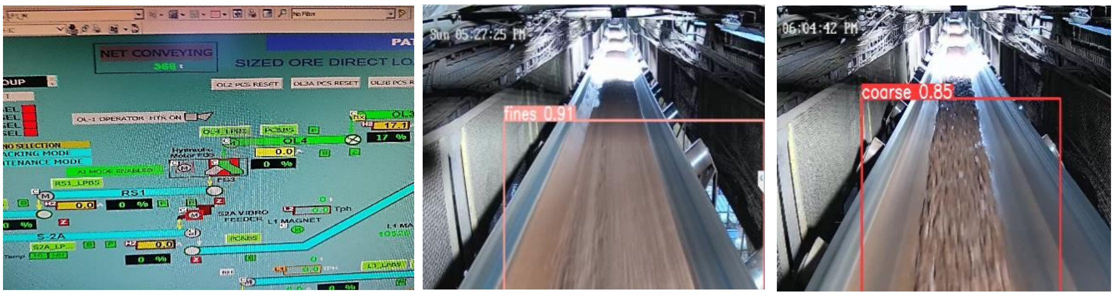


Fig. 1: AI mode button in ABB PLC & camera images of different types of materials Benefits:
System reduced gate changing delays by 30% in OLCS in shifts over FY'23.
Automation eliminates the need for constant human supervision & intervention.

Key words: Automatic gate changing . IP Camera . R-CNN model . TensorFlow framework . Productivity

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# Automation in Wagon Inspection, Number Capturing using AI & ML for improving Productivity and safety in Loading Operations at Rail Logistics in Iron Ore Mines

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## Abstract

Iron ore is transported to various customers from the mines by railway supplied rakes. These are loaded through RLS (Rapid Loading System). A rake consists of 58-59 wagons which are to be inspected for residual/ remaining material and for any damages of inside or outside panels (Refer Figure 1). Since wagon fitting requires direct human interaction, it is associated with several safety hazards. Possibility of free falling of the door due to wagon defects poses hazards with high potential of serious injury. Upon completion of fitting process the rake is back pushed to place at loading point (Rapid loading system). Number painted on each wagon is required to be noted for records. During back pushing of rake the number taking of each wagon is performed for system entry and verification. These activities were being done manually, which is time-consuming with chances of error.

To completely automate this process, we moved ahead with selection and installation of a system with machine vision (MV) system, sensors, and AI-based software. 3 sets of MV cameras were provided for image capturing. Position sensors identifies the rake as it approaches the inspection point. An onsite processor processes the videos and images using a deep learning algorithm. The AI algorithm was built with a convolutional neural network Resent 101, Pytorch framework to enable the creation of very deep neural network. Wi-Fi enabled communication system is provided for seamless data flow integrated with a dashboard provided at the central control rooms for displaying all inspection points and images, highlighting detected defects for user action (Refer Figure 2).

Figure 1: Wagon defects with numbers

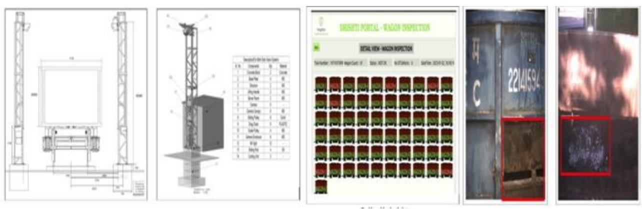

Figure 2: Machine vision system and dashboard

With implementation of this system Pre-loading rake cycle time reduced by 50% and elimination of man-machine interface led to drastic reduction in associated hazards.

key words: Indian Railway, wagon detection, Image processing, Artificial intelligence, Machine Learning

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# A Novel Method to Optimize Coke Consumption in Blast Furnace

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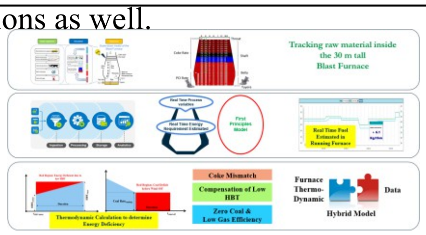
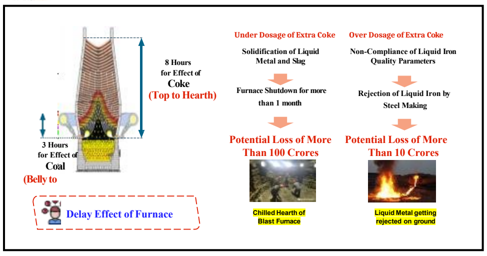
## Abstract

The operational stability of the blast furnace (BF) is highly dependent upon the quality of the raw materials and operating conditions. Several problems arise in BF when raw materials quality is deteriorated leading to the higher fuel consumption and increased hot metal production cost. This in turn disturbs the thermal stability of the BF. The present work is related to a system for optimizing fuel consumption rate in a BF. The present system also optimizes extra coke consumption during normal & abnormal (pre & post shutdown) operation of BF. In normal operation, the system controls variation in HMT, during abnormal operation controls off-chemistry dumping of hot metal torpedoes caused by high Silicon. The hybrid model combines the power of AI to deduce the parameters impacting coke rate and the thermodynamic modelling approach adopted in building it, makes the system practically viable. Starting from digital twin of the BF by tracking the location of each burden batch inside furnace to recommending fuel rate based on target HMT in normal operation, it eliminates over-batching of extra coke particularly during pre and post shutdown, the indigenously nurtured system is a bread and butter of BF operation.

The key challenge faced was to deduce the parameters that directly or indirectly affects the fuel demand of the BF. This was solved by using the AI based approach, using the historical data of BF parameters, and using the metallurgical literature to identify the impacting process variables. Then leveraging the thermodynamic model to deploy the inference from AI engine. Post deployment, due to proactive fuel rate control, benefits were seen in terms of reduction in hot metal rejection which has come down from 1400 tons per shutdown to 200 tons per shutdown. We take 4 shutdowns in a year, the savings from this reduction in hot metal rejection is 2.4 Crs. per annum. This has led to the reduction in the fuel rate by 5 Kg/thm - that has led to benefit of 5.4 Crs. per annum and is equivalent to savings of 4.6 lakhs of trees planting/annum. Not only this the present work has led to the reduction in the hot metal Si from 0.7% to 0.59%, which has improved our customer compliance and a potential savings of 22 crs seen in our customers end. Further, it has brought about cultural changes in the way we used to operate our BFs from the reactive-based approach to the system-based approach. The present system has been horizontally deployed across 3 BFs in Jamshedpur and has potential for deployment across other locations as well.





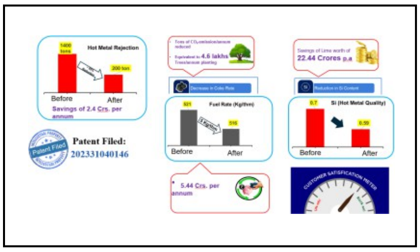




Fig. 1: Problem of coke control Fig. 2: Solution Approach Fig. 3: Benefits of current system

key words : Blast Furnace, Hot Metal Temperature, Coke Rate control, thermodynamic model, shut-down optimization, off-chemistry torpedo dumping.

# Improving plant productivity at Dry Plant Joda involving automation and optimization of input resource.

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## Abstract:

Dry processing plants use a three-stage process of crushing and screening to produce iron ore fines. Run off mine material is first sent to the primary crusher and then conveyed to crushers and screens via conveyors and transfer chutes. When moisture is present in the conveyed ore, it can cause material choking and jamming in transfer chutes as well as clogging of screens. This can lead to interruptions in plant operation, becoming a concern for the flowability of ores in the plant. These issues typically occur when the moisture content in ore is 8% or higher. Additionally, the presence of clay, yellow ochre, and ultra fines can also have an impact on flowability.

To enhance the smoothness of plant operations, SAP (Super Absorbent Polymer) is utilized to absorb moisture in ore and maintain it by swelling. SAP in crystalline form is dispensed into transfer chutes using a dosing machine equipped with a venturi system. Manual dosing of SAP was carried out based on visual observations of flowability. The traditional dosing machines in the existing plant were substituted with intelligent digital dosing machines and were under the control of PLC logic. This logic was created according to the operational parameters of conveyors and screens, which change based on the material's flowability.

The automatic dosing system leads to a decrease of over 50% in SAP consumption, removing the need for manual intervention and enhancing flowability, resulting in increased productivity. Moisture analysers have been placed in important conveyors. The integration with AI and ML algorithms to enhance the optimization of SAP consumption is currently in progress.

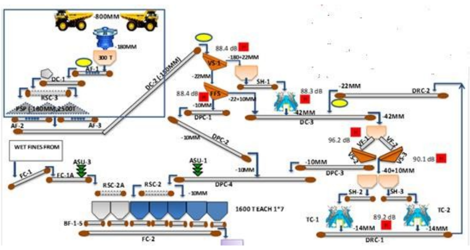

Fig. 1: Flowsheet of Dry Processing Plant

Key words: Super Absorbent Polymer • Automatic Dosing • AI & ML Algorithms References:

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[2] A. Jenike, Storage and Flow of Solids, University of Utah Engineering Experiment Station, Bulletin No. 123, November 1964 [3] www.jenike.com

# Conveyor health monitoring through Computer vision techniques

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## Abstract

Conveyor belts play a crucial role in transporting different raw materials across various industries, with an extensive presence in integrated steel plants which spans various locations, from underground levels to above-ground junction houses. The smooth functioning of conveyor belts is imperative for the efficient operation of a steel plant. However, due to the complex forces they endure, conveyor belts are susceptible to issues like tearing, deviation, and surface damage, which can significantly disrupt production by increasing wear and downtime. Monitoring the health of these conveyor belts is a challenging and labor-intensive task due to their extensive coverage and reach. The paper gives an insight into the work done for the conveyor health monitoring using computer vision technique which is a step towards the predictive maintenance of conveyor belts. The computer vision technique has the potential to bring in the paradigm shift from the visual inspection that relies on human judgment to computer vision which duplicates the effect of human vision by electronically perceiving and understanding an image. The computer vision technology has the characteristics of automation, intelligence and accuracy through deep learning of the system of software through pattern recognition. The approach adopted in this work was (a) Identification of locations for installation of video acquisition system (camera, lens cleaning system etc.) so that the best quality videos during conveyor operation is captured for further processing.(b) Establishing the physical networking system for transfer of acquired video to processing stations.(c) Development of software, its run time testing and execution for detection of desired defined anomalies in conveyor belts in real time. Three different solution modules have been developed as the part of current work to cater different operational requirements such as belt sway detection, foreign material detection and surface defect monitoring modules. This work has demonstrated its effectiveness in detecting belt sway and identified foreign objects transported on conveyor belts under dry conditions, offering satisfactory results during continuous operation. Surface defect monitoring modules has been created to identify various defects on the surface of conveyor belts, both on the loading side (with a frontal view) and the non-loading side (with a slant view) using computer vision. The focus was on detecting surface defects such as wear and tear. In wet conditions, the system is in learning phase for material classification, foreign material detection and wet patch identification on conveyor surface. The system is capable of industry specific customization. The system is being used and holds the potential to evolve into a predictive maintenance system for conveyors using deep learning capabilities. The deep learning capabilities coupled

with ongoing manual data collection are utilized to develop updates for the software module, aligning with user requirements.

Keywords: Conveyor monitoring, Computer Vision, Deep Learning, Predictive Maintenance Asset Monitoring

# Benefits of Technical Delivery Conditions (TDC) creation and integration with Sales Order in SAP

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## Abstract

I am pleased to inform you about a significant enhancement we've recently implemented in our SAP system: the integration of technical delivery conditions (TDC) with sales order processing. This integration brings numerous benefits to our operations and, most importantly, to our valued customers.

Enhanced Accuracy and Consistency: By integrating TDC with Sales Order in SAP, we ensure that all technical specifications and delivery requirements are automatically linked to each sales order. This reduces the risk of manual errors and ensures that all orders are processed consistently according to the predefined technical standards. This precision guarantees that the products delivered meet the exact technical criteria specified by our customers.

Streamlined Processes and Efficiency: The automation of TDC within the sales order process significantly streamlines our workflow. It eliminates the need for repetitive data entry and manual verification of technical details, thereby reducing processing time. This efficiency translates into faster order fulfilment and allows us to respond more quickly to customer needs, enhancing our overall service delivery.

Improved Communication and Collaboration: With TDC integrated into our SAP system, all departments involved in the sales and delivery process have real-time access to the necessary technical information. This transparency fosters better communication and collaboration between sales, production, and logistics teams, ensuring that everyone is aligned and informed. As a result, we can anticipate and address potential issues proactively, ensuring smoother operations.

Better Compliance and Quality Control: Adhering to technical delivery conditions is crucial for maintaining compliance with industry standards and regulatory requirements. The integration with SAP helps us track and document compliance more effectively, providing an audit trail for quality control. This capability ensures that we consistently deliver products of the highest quality and adhere to all relevant regulations.

Enhanced Customer Satisfaction: Finally, the integration of TDC and Sales Order in SAP has been designed to benefit our customers. By improving accuracy, efficiency, and quality control, we can meet or exceed consumer expectations. This creative approach not only confirms our commitment to excellence, but it also enhances our customer connections by providing them with dependable and high-quality services.

Key words: TDC Creation, Integration with Sales order ,SAP

# Enhancing productivity and safety through the automated monitoring and control of dumper stopper height in dump slots at Wet Plant Noamundi

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## Abstract

Iron Ore is transported from the mining faces to the primary Gyratory crusher in processing plants by 100T dump trucks. In the primary crusher, the ore is dumped by the trucks and crushed to the appropriate size for further processing.

Dump trucks are placed in dump slots on either side of the crusher for dumping. There is a stopper on either side made of concrete to stop dump trucks from falling into the crusher. In the process of placement and dumping, some ore spillage occurs on the floor, increasing the floor level. Mud dislodging from the tyres of dumpers also contributes to this. This causes a decrease in effective stopper height. Decrease in effective stopper height may result in running /toppling of the dumper into the crusher.

To avoid this significant risk, the spilled material must be inspected and cleared manually using a mini loader at regular intervals. A system with retro reflective sensors and transmitter/receiver units were positioned on both sides of the dump slot at specific points. If there is spillage on the floor beyond the intended level, the tail end of the dump body blocks the transmitter/ receiver, triggering an alarm at operator SCADA via PLC to cease dumping and intimates to remove the material accumulation. Selecting the right sensor for this application, integrating with the existing control system, and calibrating to our needs has been the main tasks in this project. After installing this system, it continuously monitors the stopper height effectively within safe limits without the need for manual intervention, leading to enhanced productivity and safety.

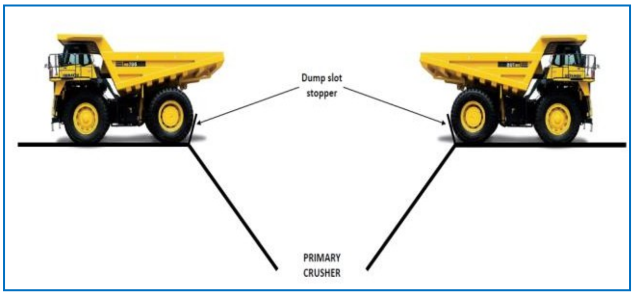


Fig. 1: Positioning of Dumpers at Dump Slots

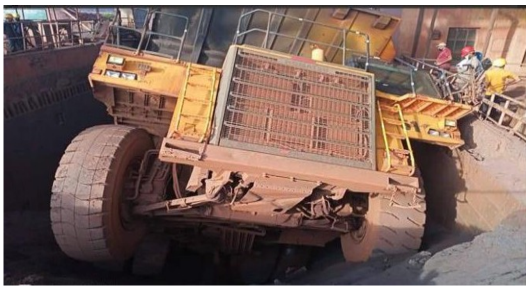

Fig. 2: Possibility of dumper falling.

Key words: Gyratory Crusher• Retro Reflective Sensor • Dumper stopper height 

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# Advanced Machine Learning Algorithm for Efficacy Improvements in Alumina Refinery

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## Abstract

Industry 4.0 enables increased usage of advanced computational techniques for better utilization of resources as well as improved control on process equipment. In alumina refineries, utilization of machine learning (ML) algorithm and its integration with graphical user interface (GUI) is empowering plant operation team in achieving new benchmarks in terms of productivity, efficiency, fuel consumption, safety and environmental norms. In the present study, the application of ensemble ML models at alumina refinery is presented, wherein Bayer process is used for alumina extraction from bauxite ore. Evaporation and calcination are key stages in Bayer process defining the quality and cost of product as well as environmental impact.

To achieve better product quality control, plant operation team needs to take decision of the set point based on the key parameters like Strong Evaporated Liquor (SEL) concentration and Loss on Ignition (LOI) obtained through laboratory analysis. This analysis takes considerable amount of time (8-10 h), and the lagged information is used for decision making by operation team retrospectively. Therefore, extensive work was undertaken to generate real-time predictions of these quality parameters, enabling operation team to make proactive process control decisions and minimizing dependency on lab data. This approach aims to achieve operational excellence and ensure consistent product quality.

In this present work, robust ensemble machine learning techniques such as random forest and extreme gradient boosting (XGB) algorithms were used to predict important parameters for evaporation and calcination circuit. For evaporation circuit Random Forest model is used to develop predictive models based on historian data base for both SEL concentration & steam economy (SE). These models are optimized with hyper parameter tuning to achieve higher accuracy. The model accuracy for the prediction of SEL concentration is obtained in the acceptable deviation of ± 5%. For calcination circuit, XGB model is developed to predict LOI and accuracy was found to be in acceptable range of 80-85% with reference to reported laboratory data. Predictions from models were obtained using real-time DCS plant data on a minute-wise basis. In addition, these models were used to prescribe optimum input parameters based on process variation to maintain better product quality. The predictions along with prescriptions are displayed in web based graphical user interface (GUI) in Hindalco refinery to monitor and to execute corrective actions.

key words: Machine learning, Steam economy, Alumina, Bayer Process, LOI

# Development of Expert System for Operation of Bell Annealing Furnae

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## Abstract

After thickness reduction in Tandem Mill, the grain structure of the steel gets elongated and heavy internal stresses are developed, due to which mechanical properties of the material worsen. To regain the mechanical properties the material is heated up to a temperature of about 680-720 degree C in a Batch process called Annealing. Under annealing process, three or four coils, depending on the width of the strip, are stacked on a base, and in between coils one convector plate is placed. The stack is then covered with an inner cover and a movable furnace having burners around its circular periphery is put over this inner cover by EOT crane. Before lighting the burners, all air inside the inner cover is taken out and protective gas (PG 96%N2 & 4%H2) is substituted. The annealing temperature is raised up to 680- 720 degree C depending upon weight, width and thickness of charge, quality of steel etc and furnace is heated under predefined annealing cycle. The whole charge is then allowed to cool down to a temperature around 100 degree C after which, the coils are transferred to a forced cooling base where it is cooled to room temperature.

The paper gives an insight into the work done in development of an Expert System for operation of the series of Annealing Furnaces. The main functions involved in operation are a) Tracking of Furnace modes (Heating, Cooling, Load, Unload etc) b) Tracking of Coils with identity and specification in each furnace c) Intelligent selection of Annealing Cycle based on Coil Grade, Gauge, Width, weight etc. d) Generation of Set Points and Tracking of Annealing Process e) Production Reports f) Safe storage of annealing data for future reference to address customer complaints. It is obvious that above mentioned operation functions engage a lot of sincere work hours and paper work. Also, the expertise varies from person to person based on intelligence, sincerity and work experience. Therefore, it appeared a fit case for development and implementation of Expert System.

An Expert system was developed and implemented to take care of all the functionalities as mentioned above (under a to f). The platform selected is a Workstation as hardware and Windows 11 as Operating System. The main logic controller for PID loop control for gas control is PLC. To communicate with PLC, a gateway having features of OPC-UA has been installed. OPC-UA (OPC Unified Architecture) is a machine-to-machine communication protocol for industrial automation developed by the OPC Foundation. It has been designed to facilitate the secure and reliable exchange of data between industrial equipment and systems in a way that is both platform-independent and vendor-neutral. The programs has been

developed in C# Forms under Visual Studio 22 ( .Net environment). Microsoft database MsAccess has been used for storage of Annealing Cycle and Coil data, for reports and future reference.

Keywords: Expert System, OPC-UA, Database, Gateway, C#

# Implementation of Slag Suppression Scheme during Slag Slopping of LD Converters of SMS-III of Bhilai Steel Plant through Level-1 Automation

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**Abstract**

LD Converter-1 in SMS-III of Bhilai Steel Plant was commissioned on 31st March 2018. Three Nos. Converters are presently running to achieve the rated capacity of 4.0 Million Tons P.A. SMS-III is the producer of quality steel for Billets, Blooms and Rails by employing state of art technology. The LD Converters must meet the critical performance indices like tap to tap time of 50 mins. A critical process bottleneck in achieving the above parameter was observed to be suppression of foamy slag generated during the blowing process.

After experimentation at site, it was found that by blowing nitrogen with the Lance at a height of 14-15 mtrs. with a flow rate of 400 Nm3 /hr., we were able to suppress the foaming slag. The next challenge was to incorporate the above in the automated blowing process of the LD Converters.

The automated slag suppression was achieved by providing the blower with HMI screens and making necessary programming in the PLC and HMI Softwares. The blower was given the flexibility of making changes in the lance height and also the flow rate of the nitrogen. The new process was integrated with the Level-1 automation system of the LD Converters.

After implementation of the new scheme we were able to save 180 minutes/day of blowing time for the Converter resulting in one extra blow per day. Data from production cell shows a total recurring saving of Rs.7 Crores yearly.

Keywords: Level-1 Automation, Slag Suppression in LD Converters, Tap to tap time, Slag Suppression with Nitrogen blowing

# Auto pilot Casting Technology in Thin Slab Caster

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## Abstract

Casting speed is governed by SOP speed chart, which has been evolved over a period of 7 years. It incorporates all the learning from failures in the speed chart supplied by OEM. Casting process involves multiple/critical variables starting from steel chemistry/cleanliness/temperature/ladle condition/dynamic parameters like heat flux/mould level fluctuations/bps etc. Every operator tries to run the caster according to SOP speed chart taking all the dynamic parameters into account. This calls for understanding of process stability to run caster at maximum speed by different operators. This is also true that higher speed requires most stable casting condition in terms of heat transfer (uniform shell growth), mould level fluctuations & reflection of uniform heat transfer in thermocouple values in BPS. Several machine learning like linear regression, Support Vector regression, random forest and Heuristic model was tested to identify optimum model. Heuristic model gave best result. Multiple Real-time parameters are fed as input and after evaluation, optimized speed is recommended. Many small prescriptive models were designed and collated to one single master model. Based on operator's feedback and abnormality analysis, the model has been fine-developed to run caster at higher speed and reducing breakdown scenarios.

The main objective of Auto pilot casting is to reduce manual errors, conversion of subjective understanding into objective one, making casting operation more safer and more reliable.

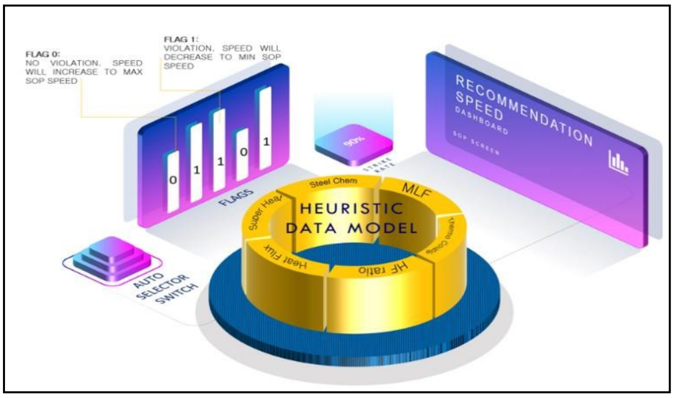


Fig. 1: Heuristic data model in Auto pilot casting

key words : Thin Slab Casting, Auto pilot casting, Heuristic model

# Torpedo Refractory Digital-Twin

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**Abstract**

The blast furnace produces hot metal at a temperature of 1600C.to be converted to Steel at a steelmelting shop. The distance between them could be around 1 Kilometre in Tata Steel, Jamshedpur.There are 6 blast furnaces and 3 steel melting units. Torpedoes carry the hot metal from blast furnace to steel-melting shop. A loss of temperature could hamper the production and productivity downstream to the tune of crores. Hence, torpedoes are lined with refractories to preserve the heat and melt chemistry. The life of a refractory is thus of vital importance . The key to improving refractory life is to improve the campaign life and better refractory maintenance (through optimum usage of gunning material) and also scheduled maintenance.

3 models (Refractory Digital-twin)were developed :
The remainder thickness of the refractory can be predicted leading to estimation of maintenance required and hence improved campaign life.

Accordingly, a predictive model was used to estimate the remainder-thickness of a refractory and wear rate .A random forest model was used for 6 sides of the torpedo each resulting in an overall accuracy of 75% with a tolerance of +/-25 mm of actual thickness.

Optimal amount of gunning material to be used along with the specific location inside torpedo where the gunning is to be done .

The process of gunning is manual leading to overconsumption of gunning material which can be optimised through model prediction . XGBOOST had best performance in terms of training (0.6 ) and test error (0.73 )
The mean absolute error for model was less than 1 ton .This model performance led to better TLC maintenance and reduced gunning consumption by 10% .
Recommending the operator as to when (after how many trips ) the gunning is to be done for a certain torpedo.This leads to improved maintenance and relining of refractories, hence enhancing campaign life. Model developed for prediction of schedule on a trip-wise basis incorporating dynamic market cost of gunning and refractory material for maintenance recommendation. XGBOOST had best performance as mean absolute error for model was 0.75 .Model recommends at least 2 more trips/ day leading to significant cost/trip savings
This lead to a combined savings of 20Cr.

Key words : Digital Twin; Refractory; wear; gunning ;optimization ; model ; prediction; machine learning

# Enhancing Maintenance Efficiency by IoT-Enabled Predictive Maintenance with Smart Sensors for Mining and Steel Industry

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**Abstract: Digital Transformation in maintenance domain within the perspective of Industry**
4.0 with a focus on the capital-intensive manufacturing Industry and digitalization on the maintenance process. Furthermore, the maintenance strategies & techniques evolutions, particularly the transformative potential of predictive and prescriptive maintenance through advance condition monitoring enhancing asset reliability.

This paper portrays the evolution of maintenance strategies from reactive to predictive and prescriptive maintenance, highlighting the paradigm shift in sensorization techniques from conventional to IoT-based technologies. The focus is on the enhancement of MEMS-based 3-axis vibration and temperature sensors precisely designed for application in mining & steel Industry-specific assets and environment. The paper addresses the limitations of general OEM sensors, which often lead to unreliable health predictions and increased maintenance costs and efforts of maintenance team. It also discusses the novel features of the developed sensor, such as autoscaling, auto offset calibration, smart adoptive filter, and intelligent hybrid mode, which make it ideal for mining and steel Industry applications. Furthermore, the intelligent algorithms incorporated in the sensor, enabling early fault detection and the utilization of remaining useful life, eventually contributing to improved asset reliability and reduced maintenance efforts. The journey from conventional sensor technologies to advanced IoT-based hardware has facilitated more accurate and reliable asset health monitoring, thereby enhancing maintenance practices in steel Industry environments.

Key words: Digital Transformation, Industry 4.0, Mining and Steel Industry, MEMS sensor, Predictive Maintenance.

# Prediction of Gas Channeling in Blast Furnace using Machine Learning

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## Abstract

Blast furnace is considered as a heart of integrated steel plant, any deviation in productivity of the blast furnace will affect the overall productivity of the plant, so any deviation from steady state should be quickly detected and corrected. Since internal physical states of the furnace are challenging to measure directly so experienced operators play crucial role. Gas channeling in blast furnace is a complex and critical phenomenon that significantly impact the efficiency and performance of these vital industrial process. Uneven distribution of the reducing gases within the burden layer of the blast furnace can result in irregular or fluctuation which causes the gas channeling. This project combines historical 2018 operational data of BF1 from, JSW Dolvi plant with advance machine learning algorithms to develop predictive models for gas channelling, by analysing various operational parameters. Major indicators of gas channeling events, identified by machine learning models and verified by blast furnace operators, include quadrant-wise heat loss, changes in uptake and periphery temperature, top gas composition, variations in Staves temperature, and bed permeability. These insights empower operators to proactively address gas channeling issues, enhancing furnace performance and efficiency. This study focuses on the utilization of machine learning algorithms to predict gas channelling within blast furnaces by harnessing historical data from various sensors and process parameters. Machine learning models are trained to recognize patterns and severity of gas channelling events. This allows to identify gas channeling up to one hour in advance, providing operators sufficient time to take corrective actions and control the severity of gas channeling and to pinpointing of channeling locations and the assessment of its severity, are critical for optimizing furnace operations and maintaining efficiency. Utilizing 2D contour plots provides a robust analytical tool that offers comprehensive visual insights into these phenomena. These models can be integrated into the plant's control systems to provide real-time insights and facilitate proactive decision-making.

Key words: Gas Channeling, Blast furnace, Contour plots, Proactive

# Web-Based Process Platform for Bar Rolling Mill: Enhancing Productivity through Visual Analytics and Integration

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**Abstract**

In the technologically advancing landscape of metal production, specifically in bar rolling mills, the need for real-time data monitoring, analysis, and process optimization to enhance quality and minimize downtime have become paramount factor. This paper presents in-house implementation of a web-based, visually enriching digital dashboard for a bar rolling mill. The system integrates various critical modules, including a comprehensive tracking module for both re-heating furnace & mills, digital twin, equipment health monitoring, graphical trends, reports, and advanced process models such as combustion control model for re-heating furnace and billet tracking model for both re-heating furnace and mills. Additionally, the dashboard facilitates seamless integration of mills, the reheating furnace, and the billet yard, thereby enhancing operational efficiency and productivity.

The digital dashboard is designed to provide holistic information regarding the production shops with user-friendly tracking interface, equipment condition monitoring representing complex process in visually enriching and easily interpretable format. The Process models implemented use real-time data to adjust process parameters dynamically, ensuring optimal combustion efficiency and proper tracking of product in re-heating furnace and the fast-paced rolling mill. The integration of the billet yard, reheating furnace, and rolling mill into a unified system streamlines operations, reduces downtime, and enhances overall efficiency.
The rolls management system integrated into the dashboard ensures the effective management of rolls used in the rolling process. By tracking roll usage, wear, and maintenance schedules, the system helps in optimizing roll performance and reducing operational costs.

Key Words: Dashboard, Process Models, Bar Mill, Tracking System, SAIL-ISP

# An User Friendly Operator's Tool to Minimize Gas Channeling Events in Blast Furnace

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**Abstract**

Blast Furnace is a counter current chemical reactor in which hot blast air passes through the tuyeres and solid burden include iron bearings and coke charged from the top of the furnace, which produce hot metal and slag. Non-uniform gas distribution through the burden layers results in abnormal situations in the blast furnace, which leads to channelling phenomena. Recently, steel companies have spent money on sensors to measure signals and data storage. These databases are used to improve the efficiency and productivity. To avoid abnormal phenomena like channelling or slippage, it is important to build and implement machine learning models to analyse the process parameters that give the important information to blast furnace operating staff to avoid channelling conditions and provide real-time data monitoring and visualization system. In visualization, a large amount of data on shaft pressure and row wise stave temperatures can be visualized. The prediction and control of channelling ensure the efficient, stable and smooth operation of the blast furnace. Based on data collected from JSW BF1 Dolvi, Machine learning methods were used to build a channeling model. The accuracy of prediction in the Decision tree, Random Forest and Extreme gradient boost reaches to 82%, 88%, and 91% respectively. Variations in shaft pressures at different heights and pressure drop between levels, deviations in uptakes & peripheral temperatures are major indicating parameters for the channelling occurrence. Simultaneously, work is carried by creating visualization system in Blast Furnace-1 from important features identified through machine learning algorithms.

keywords: Channelling, Machine learning, shaft pressure, permeability, visualisation

# Prediction and optimization model for heat flux in blast furnace

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**Abstract**

Over the years, the blast furnace used in the iron and steel industry for hot metal production has undergone numerous technological advancements that have enabled it to remain functional till date. However, the blast furnace BF-BOF route generates huge carbon emissions in comparison to other methods such as DRI-EAF route. To address this and make the process sustainable, extensive research is being carried out to optimize the blast furnace process. Process improvement through modelling has played a significant role in enabling new process improvements to lower the carbon footprint.

This paper attempts to model, optimize, and predict the heat flux and its abnormality, together with the key features affecting it, using machine learning. The prediction and control of the heat flux is the next step in ensuring the high efficiency, stability, optimized fuel consumption, and smooth operation of a blast furnace. Based on the industrial data, different machine learning techniques are used to build a prediction model for the heat flux. In addition, a partial dependence plot (PDP) with Shapley additive explanations are used to visualize and quantitatively analyze the impact of features on the heat flux. The model shows the percentage of pellets in the burden, the mean size of coke, the percentage of centre coke, viscosity of slag, cohesive height, %fines input and the reactivity of coke as a few important features that affect the heat flux.

Key words: Machine learning, blast furnace, heat flux, Explainable AI, carbon footprint, sustainability

# Improving Screening Efficiency with digitally enabled screen clog detection system at H Blast furnace Stock House, Tata Steel Jamshedpur

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**Abstract**:

With the improvement in process technology and automation of processes, the productivity of the blast furnaces has increased considerably. This has resulted in the need for close monitoring of blast furnace process. Screen cleaning is important activity in any of the Blast furnace Stock House to ensure screening efficiency and hence stability of furnace in terms of stable K-Value i.e., permeability resistance inside the furnace.

Screen clog detection system is 1st of its kind initiative for real time monitoring of screening system and proactive action to enhance screening efficiency. Screen mesh condition can be monitored online and extent of clogging to alert operator. This solution is developed which consists of a machine vision industrial camera and lens, LED light and custom image processing algorithms to detect and differentiate between the empty and clogged openings in the screener mesh.

Real time detection and tracking of screen mat size clogging and damage is not possible in any conventional Blast furnace and sudden damage of screen mats lead to not only loss of useable materials but also equipment downtime. Increase in the size of gratings also could not be tracked online and for this physical measurement is being done. To measure screen mat size, the screening system has to be stopped with complete energy source isolation.

Keywords: Blast furnace processes monitoring, K-value, equipment criticality, Screening efficiency

# Development of Expert Optimiser System for improved process control

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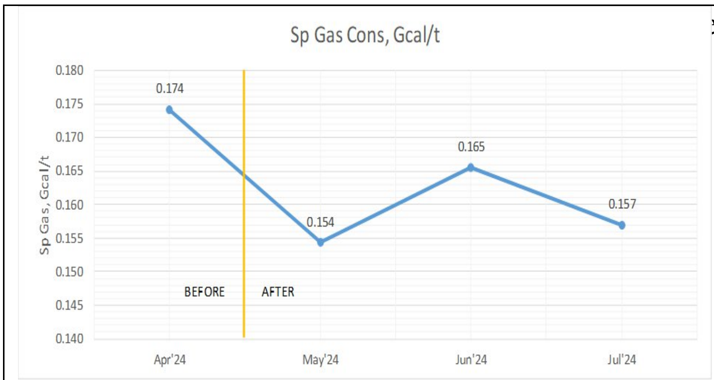
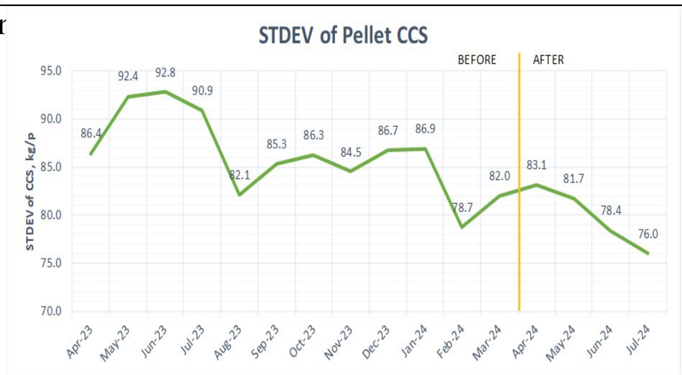
JSW Steel Vijayanagar's Pellet Plant-3, one of Asia's largest with an 8.00 MTPA capacity, processes low-grade iron ore from the Ore Beneficiation Plant (OBP) to produce Blast Furnace (BF) grade pellets. To align with sustainability goals, the plant has implemented advanced digitalization initiatives aimed at reducing the standard deviation of furnace temperature and optimizing green pellet bed levels. These measures have successfully reduced energy consumption and minimized the carbon footprint, contributing to the company's overall sustainability strategy.

The Expert Optimizer System (EOS) deployed at Pellet Plant-3 comprises two independent models designed to enhance operational efficiency and product quality:
Predictive Model for Indurating Furnace Temperature Optimization: This model is crucial for maintaining the desired zone temperature within the indurating furnace. It operates by continuously monitoring the current zone temperature, comparing it with the target values, and making precise adjustments to the fuel control valve. By driving the system towards achieving the set zone temperature, the predictive model ensures consistent thermal conditions, which are essential for producing high-quality pellets.
Fuzzy Logic Model for Green Pellet Bed Height Control: The fuzzy logic model addresses the challenge of maintaining a uniform green pellet bed height in the indurating machine. It normalizes the extent of deviation from the target bed height and processes this information through a fuzzy rule block to determine the necessary corrective actions. The fuzzy rule block value is then scaled to an engineering value, which is used to adjust the bed height. This




Since the implementation of the system, the standard deviation of Pellet Cold Compression

Strength (CCS) has been reduced, reflecting enhanced pellet quality along with a consistent reduction in the specific gas consumption through improved process control.

Key words: Predictive model, furnace temp control, fuzzy logic, bed height control, process improvement.

# Streamlining Job Tracking and Management at Central Repair Shop (CRS)

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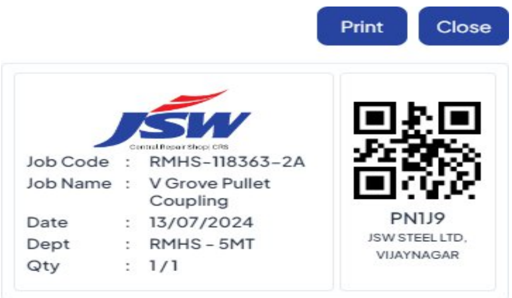
Abstract
The Central Repair Shop (CRS) has implemented a comprehensive system for planning, tracking, and managing repair jobs using a web-based application. Upon receiving a job, CRS logs it into a portal, generates a corresponding QR code, and defines the process sequence. This QR code is then affixed to the raw material or job piece to enable real-time tracking throughout the process. The operation team, equipped with an Android-based system, follows a predefined workflow to manage the job. Quality Assurance (QA) teams monitor the process at each stage, generating Pre-Delivery Inspection (PDI) reports via the Android system. These reports determine whether the job is accepted or rejected, prompting immediate action from the operation team if necessary. Upon completion, the job is identified by its QR code throughout the dispatch process until it reaches the customer. The integration of web and Android applications, QR code identification, and cloud-based storage ensures efficient job tracking and management from start to finish.



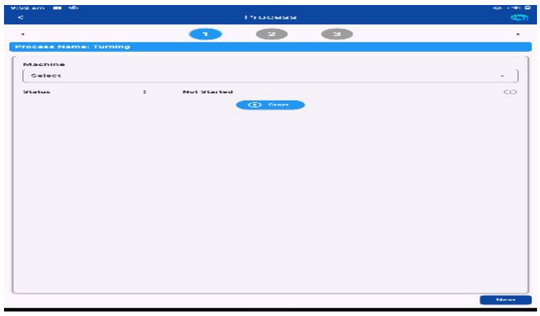



Fig 1: QR code system developed Fig 2: Dash board for data logging

Keywords: Quality Assurance, Quality Assurance, Cloud Based Storage, Pre-Delivery Inspection (PDI)

# Application of artificialintelligence in prediction of properties of stainless steel

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## Abstract

Discovery of materials and Upgradation of Materials has been very time consuming and difficult since beginning. It is very crucial to identify the materials for their application especially Stainless Steel. We Can say stainless steel in nowadays has became a backbone of material industries. And it is very important to know the structure, behaviour and properties of stainless steel in various situations for its applications. But prediction of its properties, behaviour and structure using traditional methods is very difficult, time consuming and even costly as these methods rely on complex physical models. Artificial Intelligence in this case has a crucial role because it not only saves time and energy but also ease the process of prediction. AI uses computing techniques, Algorithms and other data for the prediction of stainless steel. AI not only helps in prediction but is also helpful in analysing the data, real time monitoring, optimizing and many more. This Paper focuses on Application of AI in prediction of the properties of Stainless Steel.

Keywords: Prediction, stainless Steel, Artificial Intelligence (AI), Computing Techniques, Algorithms

# Thermal Vision Cameras and AI in Metallurgical Industries

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**Abstract**

In the metallurgical industry, precise control over high-temperature processes is crucial for ensuring product quality, operational efficiency, and safety. Traditional temperature monitoring methods often fall short of providing the continuous, real-time data necessary for effective process management. This paper explores the application of Thermal Vision Cameras and Artificial Intelligence (AI) in enhancing process control across various metallurgical sectors, including steelmaking, non-ferrous metal processing, and casting operations, highlighting the specific advantages these technologies offer.

Thermal Vision Cameras capture infrared radiation to produce thermal images, providing a non-contact and highly accurate method for monitoring temperature variations and thermal patterns. Unlike traditional thermocouples and pyrometers, which measure temperature at specific points and can be prone to inaccuracies in high-temperature environments, Thermal Vision Cameras offer a comprehensive view of the entire thermal profile of a process. This capability is particularly advantageous in metallurgical settings where temperature gradients and heat distribution are critical.

AI further enhances the value of Thermal Vision Cameras by processing and analyzing thermal data to detect patterns, predict anomalies, and optimize processes. In steelmaking, AI algorithms analyze thermal images to monitor molten steel temperatures, detect hot spots, and ensure even heat distribution. AI can predict refractory wear and optimize furnace operation, addressing issues such as excessive heating or cooling inefficiencies. In non-ferrous metal processing, AI models assist in controlling the heating and cooling rates of metal billets and ingots based on real-time thermal data. In casting operations, AI-driven analysis of thermal images helps monitor mold temperatures, preventing defects, ensuring uniform solidification.

The integration of Thermal Vision Cameras with AI and Automation IoT platforms creates a robust and dynamic monitoring framework. Real-time thermal data is processed using advanced analytics and machine learning algorithms to identify and address anomalies. For instance, AI can reveal overheating areas in the furnace or irregular cooling patterns, allowing for timely adjustments. Predictive analytics leverage both historical and real-time thermal data to forecast potential equipment failures or quality deviations.

Case studies will be presented from metallurgical plants where the combination of Thermal Vision Cameras and AI has been successfully implemented. In a steel mill, this integration has significantly reduced furnace downtime by enhancing the detection of refractory wear and thermal inefficiencies. In aluminum processing, AI-driven thermal imaging has improved extrusion process control, leading to better product consistency, reducing energy consumption.

In conclusion, the combination of Thermal Vision Cameras and AI provides a powerful tool for advancing process control in metallurgical industries. Their ability to deliver accurate, real-time thermal data and leverage AI for predictive analytics sets a new standard for monitoring, maintenance, and process optimization, driving operational excellence and safety in high-

temperature environments.

key words: Thermal Vision Cameras, Artificial Intelligence (AI), Process Control, Steelmaking, Predictive Analytics

# Implementation of Advanced Planning & Scheduling with Centralized Demand and Order management

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## Abstract

JSW is undergoing significant capacity expansion through the establishment of new plants and the enhancement of existing product lines across various regions. This rapid growth introduces challenges related to increased supply chain complexity, order management, and fluctuating market demands. To navigate these challenges, JSW is leveraging digital transformation to integrate its expansions and align supply with demand more effectively.

The initial phase involved a product-agnostic assessment to identify process gaps and standardize practices within the steel vertical, engaging Supply Chain Management (SCM) stakeholders from all locations. This assessment was followed by the adoption of industry best practices, leading to the mapping, analysis, and refinement of processes. This effort resulted in a comprehensive fit-gap analysis and a detailed solution outline.

The implementation of the Advanced Planning and Scheduling (APS) system has delivered several key benefits: optimized planning and scheduling, enhanced resource utilization, and reduced inventory levels. The system has improved on-time delivery, increased agility in responding to market demands, and facilitated data-driven decision-making. Additionally, it has centralized order management, provided better visibility and control, and boosted overall efficiency.

Keywords: Digitalization, APS, BPO, SCM transformation, PSI Metals, Blue Yonder, JDA, FP, I2

# Running two different laboratories through DIGITIZATION from a single location

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## Abstract

SMS 1 department is a very important department of Rourkela Steel Plant, because > 50 % of its production is of special steel variety. For making special steel it is very important that shop has to have a very good laboratory support. With retirement of experienced personnel the support of the laboratory became weak resulting in inability to produce high quality grades of steel consistently. To counter this project was taken in R&C Lab SMS1 area to merge two functioning labs into one single entity leveraging the technology.SMS 1 was served by two labs, one lab was called Express lab and it catered to BOF and secondary steel making's requirement. Another lab called CCM 1 lab, catered to the requirement of LHF and CCM 1's requirements. In view of conserving manpower it was decided that two labs shall be merged into one single entity, but because physical distance between two labs was 500 meters the merging seemed to be an impossible task and all the efforts towards this task failed previously. Main hurdle in this was the fact that sample transfer from one lab to other lab would take minimum of 10 minutes and steel making being very thermally sensitive process it could ill afford this delay in analysis.

To circumvent this problem it was decided to try and operate Express lab OES in remote mode from one single location that is CCM 1 lab. This meant that a man sitting in CCM I lab could now operate both Express lab and CCM 1 Lab from a single location through digitization. Few of the jobs involved in this project were checking the compatibility of the machine and its computer with network, duplicating the hard disk, installing VPN in the computer system and an antivirus protection system in the computer and many more. Few of benefits of this digitalization project are effective cost control due to timely intervention from the process side, time saving of the chemist as he/she need not communicate the analysis reports over phone, availability of the data to all the stake holders across the board right from the top management to the people at the shop floor engaged in day-to-day operations.

Thus, it can be noted that this digital initiative of SMS 1, R & C Lab Collective is a giant step in digital transformation of Rourkela Steel Plant and it will proceed a long way in helping all the user departments to streamline their process and produce good quality products. Here we would like to add that this is a unique initiative in SAIL. We are not aware of any other lab working in a remote mode that is two labs situated in different physical location are operated from a single location. This initiative can be a path breaker for other plants to follow.

Key words: Digitization, antivirus, VPN, network.

# Digital Construction: Parametric Study and Design Optimization of 3D Concrete Printing

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## Abstract

Automation has already been adopted by nearly every significant sector with the exception of construction. Over the last ten years, 3D printing technology has made remarkable development in the construction industry, which has the potential to completely transform the construction sector. It also offers benefits related to sustainability, including higher productivity, better resource efficiency, and the ability to construct complex shaped structures without the need for formworks. This study presents an innovative computational framework designed to simulate the 3D concrete printing (3DCP) process, with a focus on modeling complex structures using predefined toolpath definitions. The study involves a parametric analysis to examine the effects of varying printing speeds on the buildability and vertical deformation of printed objects. The methodology starts with converting toolpath data from GCode into numerical simulations, followed by a detailed analysis of the 3D printing process, focusing on failure patterns and deformation characteristics. Comprehensive parametric studies are conducted to optimize printing parameters, enhancing the structural integrity and performance of 3D printed concrete structures. The findings offer valuable insights for improving the efficiency and reliability of 3DCP in construction.

Keywords: 3D Concrete Printing, G Code, Printing parameters, Toolpath, Structural Integrity

# 5-in-1 remote locomotive operations at Hot Metal Yard

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## Abstract

The 5-in-1 remote control system is designed for comprehensive locomotive operations. The system comprises of five critical functionalities: locomotive operation, drop gate operations, track changeover points, coupling and decoupling, and Advanced Engine Start/Stop (AESS) technology.

The 5-in-1 system allows for seamless remote control of locomotive functions, significantly reducing the need for manual interventions and thereby increasing operational precision and safety. Drop gate operations, crucial for managing rail crossings, are optimized to improve both safety and traffic flow. The ability to control track changeover points ensures smoother and more reliable transitions between tracks, reducing delays and improving scheduling efficiency. Coupling and decoupling operations, traditionally labor-intensive and hazardous, are made safer and more efficient through remote control, minimizing the risk to personnel and enhancing operational speed. The integration of AESS technology within this system further amplifies its benefits by reducing fuel consumption and emissions. AESS automatically shuts down the locomotive's engine during periods of idling, contributing to significant fuel savings and lower environmental impact.

The 5-in-1 system represents a significant step forward in digitalizing locomotive operations, aimed at achieving greater efficiency, safety, and sustainability in the locomotive operations.

Key words : safety, efficiency, remote controlled, locomotive operations

Presenting Author : Vidya Goudar IIM Membership No:

# Realtime Cobble Probability Prediction System


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## Abstract

In a rebar rolling mill, a cobble is when rolled metal becomes tangled or misaligned, leading to sudden stoppages or malfunctions that can damage equipment, waste material, and disrupt production. Manual intervention to prevent any cobble in high-speed rolling mills are impossible. Getting a sense of process stability is very important in such cases where operator can take early decision to intervene and correct any anomaly. New Bar Mill being one of such high-speed mills also suffers from unavoidable cobbles which led to damage and delay both.

This paper introduces an automated real-time cobble probability prediction system for rebar at the New Bar Mill. For the 1st time, we applied real-time time series modeling with statistical thresholding and adaptive data architecture to manage process change and data drift which resulted an anomaly framework that predicts failure probability and identifies critical parameters contributing to potential failures.

As a result, we achieve early failure prediction, predictive maintenance, real-time alerts, and data-driven root cause analysis, leading to a significant 50-60% reduction in cobble events.


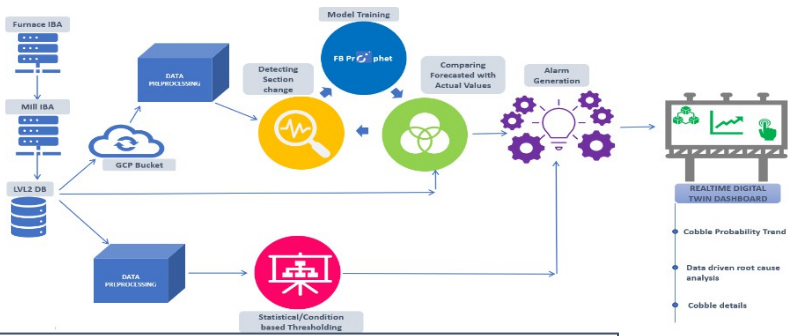


*Figure 1: Solution Architecture*


Key Words: Real-time cobble probability prediction system, Predictive maintenance, Adaptive data architecture, Time series modelling, Root cause analysis

# Automatic Engine Start Stop to Enhance Fuel Efficiency in locomotives

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## Abstract

This paper explores the implementation and benefits of Auotomatic Engine Start/Stop (AESS) systems in locomotives. AESS technology has been implemented to address critical issues in locomotive operations, such as fuel efficiency, emissions reduction, and operational cost savings. The system automatically shuts down the locomotive's engine during extended periods of idling and restarts it when required, thereby minimizing idling time. This study provides a comprehensive analysis of AESS functionality, its integration with locomotive control systems, and its impact on overall locomotive performance. Through empirical data we demonstrate the significant improvements in fuel consumption and emission levels, highlighting the environmental and economic advantages. The paper also discusses the challenges faced during the implementation of AESS and potential solutions to enhance its effectiveness.

Key words : Idling, sustainability, fuel efficiency, emissions reduction

# Real time Quality Prediction System QMS2.0

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## Abstract

Steel industries strive to maintain high-quality standards and require efficient decision support systems for timely decision-making. This paper introduces an automated real-time quality prediction system for rebar at the New Bar Mill, which produces 10/12/16 mm cross-sections. Rebars are tested in a scientific laboratory 1 to 2 hours after sample collection.

Deviations in material properties during this period can lead to high rejection rates and significant operational challenges. This system consists of two aspects: one predicts real-time mechanical properties such as yield strength (YS), ultimate tensile strength (UTS), and the UTS/YS ratio, enabling early material property assessment to minimize rejections and internal diversions of rebars in the production process. Using historical data on chemistry and process parameters, a multi-model adaptive machine learning architecture has been developed to predict mechanical properties during rolling with an average accuracy of 99%. The second aspect is a real-time process prescription system that recommends controllable process parameters based on chemistry data, mill constants, and required quality parameters, significantly reducing rebar rejections during mill start-up. This is the first time a real-time Reinforcement learning based adaptive recommendation system has been developed for a rebar rolling mill, achieving an average accuracy of over 90%. This system provides insights into optimal process regimes and lean chemistry cases, enabling data-driven decision-making and continuous process improvement. It helps NBM reduce rejection and diversion rates by 65%.

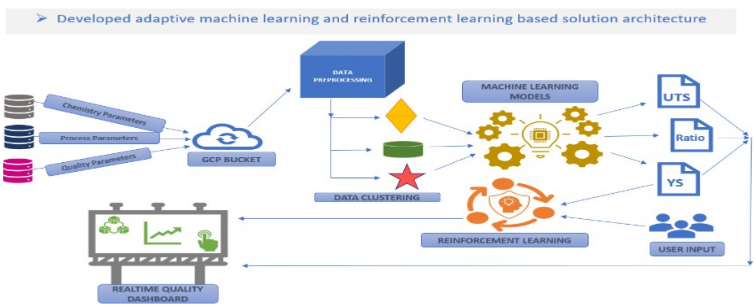


*Figure 1: Solution Architecture*

Key Words: Realtime quality prediction, Multi-model adaptive machine learning architecture, Reinforcement learning, Real-time process prescription system, Decision-making

# Realtime Quality Prediction System QMS 2.0

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## Abstract:

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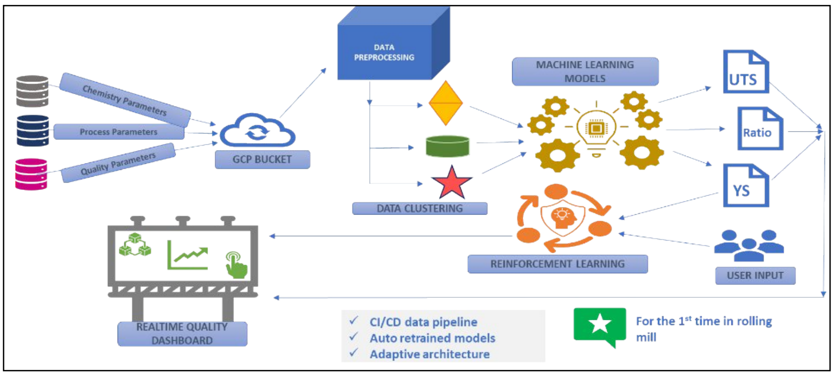


Fig. 1: Quality Prediction Model

Keywords: Realtime quality prediction, Multi-model adaptive machine learning architecture,

Reinforcement learning, Real-time process prescription system, Decision-making.

# Enhancing Locomotive Safety with the Vigilance Control Device (VCD): Implementation, Functionality, and Benefits

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**Abstract**

This paper examines the implementation and benefits of the Vigilance Control Device (VCD), a critical safety feature designed for locomotives. The VCD continuously monitors the driver's interactions with the train, such as using the horn, applying brakes, or adjusting the throttle. If no actions are detected within 30 seconds, the system triggers a 15-second buzzer to alert the driver. Should the driver fail to respond, the VCD automatically applies the brakes, bringing the train to a halt after 45 seconds. The system is designed to reset if any monitored actions are performed within the initial 44 seconds. In the event of a stop or alarm activation, the driver must press the VCD reset button to cancel the alarm, with the brakes remaining partially engaged (at 1.2 kg/cm²) until the throttle is set to zero and the locomotive is moved. This feature ensures continuous driver engagement, enhancing overall safety during train operations.

Key words: Monitors driver interactions, no actions, applies the brakes, VCD reset