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78th Annual Technical Meeting of IIM

International Symposium on Transformational Technologies in Materials & Manufacturing

20-22 November 2024 at GKVK, Bengaluru

BOOK OF ABSTRACTS

ORAL PRESENTATIONS

ARCHAEOMETALLURGY

Oral abstracts

Iron Beams of Konarka Temple: some uniqueness

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Abstract

The magnificent Sun Temple on the Odishan coast, declared a World Heritage Site in 1984 by UNESCO was constructed in the mid-thirteenth century (1250 CE) at Konarka, about 35kms. northeast of Puri. The main temple at Konarka stood around 230 ft. (~ 70 m) in height; its grandeur having been described in an eye-witness account in *Ain-e-Akbari* by Abul Faizl the reputed historian in the court of Akbar. Sadly, the main temple has collapsed sometime in the 17th century.

While clearing the debris from the premises of the temple, massive iron beams were found scattered around, ostensibly used for structural purposes in the main temple that has caved in. The iron beams have been gathered together and placed in one designated area by the ASI.

Some of the iron beams of Konarka (now 32 in number) are massive, around 30 ft. in length and weigh around 8 tons (to provide an idea, the Delhi Iron Pillar has a height of 23 ft. 8 in. & the weighs around 6.0 tons). The broad method of manufacturing the Konarka beams is similar to the process adopted for other heavy iron structures in ancient India; that is, the Bloomery process. Here, a pasty mass comprising liquid slag and reduced solid iron are taken out of the furnace, and are hammered to expel the liquid component (slag) and retain the solid fraction (known as the wrought iron). This is similar to the case of all the four iron pillars of India, i.e. Delhi Iron Pillar (the oldest), Dhar iron pillar (the tallest) and other two, at Mandu and the Kodachadri.

Investigations show that the Konarka beams have several **smaller plates embedded inside**, indicating their **'composite' nature**. Thus, these beams would have provided good resistance to crack propagation when subjected to high stress in service. Using basic and phased array ultrasonic techniques, and electro-chemical behaviour, the presentation would attempt to throw light on the manner of inserting the plates, the soundness of the interface between the plate and the subsequently poured bloom-matrix; composition and microstructural features in critical portions, the local and global electro-chemical characteristics of the iron beams contributing to their corrosion behaviour as evidenced over 800 years of exposure to the saline sea-atmosphere at Konarka and comparison of the same with other bloomery iron structures in India (especially, Delhi Iron Pillar).

MPR_468

Application of Cost-effective 50Hz AC Cold Plasma for Cleaning & Restoration of Metallic Object Surfaces

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Abstract

Cultural heritage objects and artefacts are important records of any civilization. It also showcases historically significant advancements in cultural and social developments, which are valuable in terms of resources and knowledge. Most of these heritage objects are continuously threatened by anthropogenic activities, leading to either surface deterioration or undesirable deposits on the surfaces of objects. Some prime examples are *graffiti vandalism* and chemically deposited contaminants from the air, including "*black crusts*" and "*soot*" deposited on the object's surface. Metal surfaces also face similar surface deterioration over time because of oxidation and reduction reactions upon atmospheric exposure. The current metallic object cleaning techniques employ contact-based chemical, electrochemical and mechanical means of removing undesirable surface deposits. Among many advanced techniques, plasma cleaning can be an ideal non-contact, chemical-free method of removing surface contaminants. The plasma cleaning technique can provide promising results in removing such contaminants from the surfaces of metallic objects without adversely affecting the bulk of the metal. In the work reported here, we have demonstrated the cleaning effectiveness of dielectric barrier discharge (DBD) plasma in cleaning coin surfaces using an inexpensive 50 Hz frequency AC supply with different operating voltages ranging from 5kV to 20kV under vacuum and atmospheric pressure for durations ranging from 15 – 120 minutes. The cleaning effectiveness from the variations in operating parameters has been studied and systematically recorded using Raman spectroscopy, X-ray photoelectron spectroscopy, FE-SEM, EDAX and FTIR.

Keywords: Cultural heritage, Metal surface, DBD Plasma, Cleaning

AME_011

Archaeometallurgy: Analysis of Iron Slag and Tuyere Sample from Timana and Limodara Sites of Gujarat, India

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Abstract

The emergence of iron-making technology in India during the second millennium BCE marked a significant industrial revolution and has captivated various archaeologists. Different centres of iron production could be seen in the Gangetic Plains, Vidarbha and South India, wherein from the mid-second millennium BCE onwards, evidence for iron working is noticed. The evidence from western India, in particular, Gujarat is yet to be explored extensively and requires attention. Thus, the present work intends to make a beginning in this regard to understand the iron-working from Timana, Bhavnagar district and Limodara, Bharuch district of Gujarat, India, both datable to the early medieval times (950-1300 CE). The samples consist of slag materials and one tuyere from Timana village. These samples were subjected to metallurgical analysis to examine the type of iron ore, smelting technique, iron-making procedure, the regional context of iron-working, and the mineralogy of the slag. The several scientific analyses performed included X-ray Fluorescence (XRF) and wet-chemical analysis for the chemical composition, visual examination and stereomicroscopy for the morphology, Scanning Electron Microscopy (SEM) for the detailed microstructure analysis, SEM-Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) for phase analysis and the micro-Vickers hardness test for mechanical analysis. Aspects related to composition and technology could be understood from the analysis. The findings underscore that iron-making technology was extensively practiced and flourished in Gujarat during the medieval period.

Keywords: Iron Slag, Iron-making Technology, Gujarat, SEM-EDS, Archaeometallurgy

AME_012

Microarchitectured and Nanoscale Hierarchical Structures of Carbon in Ancient Archaeological Crucible Slags

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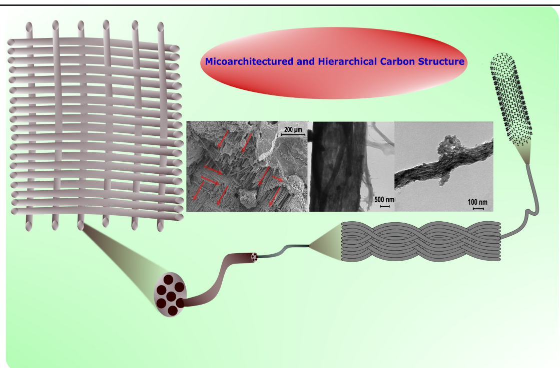
Abstract

The famed Wootz steel, which originated in India involved the development of a crucible process to generate high-carbon steel. Such high carbon steel was feedstock to generate, so-called "Damascus Swords". Numerous investigations have shown the application of non-traditional ores for the generation of bloomery iron which in turn is feedstock for the subsequent crucible process. Additionally, the TEM study has shown the presence of carbon nanotubes in the Damascus sword fragments. Given the above, we will present a detailed metallurgical analysis of the crucible slag as excavated from Hastinapur archaeological site. Detailed microstructural and spectroscopic analysis shows the use of non-traditional iron ore sources and we show the presence of a micro-architectured hierarchical structure of carbon, which provides the primary context of carbon nanotubes in archaeological high-carbon steel.



Keywords: Archaeometallurgy, Wootz Steel, Carbon nanotubes, Hierarchical Carbon

AME_013

Comparative microstructural and elemental analysis of iron artefacts from Kaveri valley archaeological sites

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Abstract

Iron has been one of the most critical technotraditions that had lasting impact on social formation throughout the Iron Age and historical period. Iron was used in warfare and subsistence economy. Our knowledge on ancient iron smelting and working have generally been derived from ethnography and ethnohistory, which is by all means, time, region, and raw material specific. Scientific analyses of ancient iron have contributed in understanding this heritage to a respectable extent, yet a comprehensive knowledge about the evolution of iron making through time and space in India eludes us. In this work, a comparative study of iron artefacts from two Iron Age/Megalithic-Early Historic sites of Tamil Nadu, south India, that is, Mangadu (burial site) and Ambal (habitation-cum-burial site) is carried out to understand the iron thermal-processing capabilities. The retrieved artefacts were examined using X-ray fluorescence (XRF) for elemental composition. The imaging of the artefacts was done using Scanning Electron Microscopy (SEM), Electron Backscatter Diffraction (EBSD), and Optical Microscopy (OM). In addition, phase identification was performed using X-ray diffraction (XRD) and Energy Dispersive X-ray Spectroscopy (EDS). Combination of these analyses illustrates that inhabitants of Mangadu and Ambal were aware of the iron alloy manufacturing/processing techniques such as forging and hammering.

Keywords: Archaeometallurgy, iron megalithic, microhardness, microscopy, Tamil Nadu

AME_017

Archeometallurgical Investigation of Ancient Sword: Microstructure and Manufacturing

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Abstract

The complexity of traditional craftsmanship is well reflected in tools having archeological importance. Ancient swords are few of such tools which are available to us for its mystery to be revealed. By examining the structure and formation of such heritage items can provide us deep insight into the lost ancient technology which could propel innovation in contemporary material science. The production of high-carbon steel, particularly Wootz steel, stands out due to its exceptional properties. Originating in India as early as the fourth century BC, Wootz steel sword was renowned for its strength and sharp cutting edge. This study focuses on compositional and metallographic analysis of an ancient sword preserved within a family for several generation near Vijayawada. The compositional analysis of few parts of the sword reveals it to be made of high C steel which falls in the range of composition identified for Wootz steel. Optical microscopy shows distinct microstructural differences among different parts of the swords, suggesting the use of different processing techniques to achieve appropriate functional properties of those parts. The distribution of slag inclusions varies uniquely in the blade surface and handle of the sword indicating the implementation of different heat treatment processes. These findings offer valuable insights into the sophisticated metallurgical practices of ancient Indian swordsmiths.

Key words*:* Indian sword, Microstructure, Characterization, banded pattern, wootz steel

AME_018

Surface Engineered Multi-layered Corrosion Resistant 2300-year-old Iron-Based Sample

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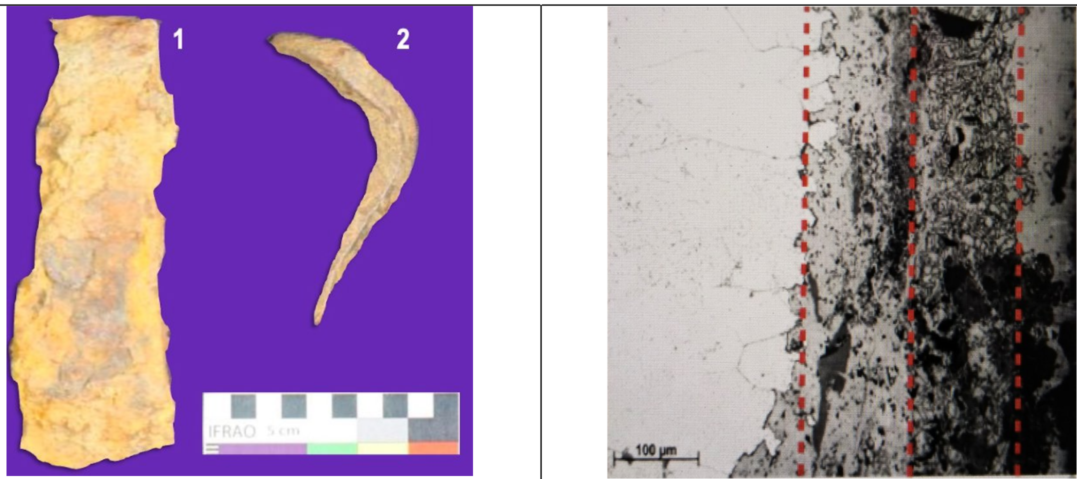
Abstract

The corrosion resistance of man-made iron objects in the archaeological context has been an interesting area of research with a possibility of re-engineering such strategy for the design of corrosion-resistant material for contemporary applications. In the present manuscript, we report a corrosion-resistant iron object obtained from the Asurgarh archaeological site. We compare a rusted iron object obtained from the same archaeological site. With detailed microstructural analysis and potentiodynamic electrochemical analysis, we elucidate the mechanism of high corrosion resistance. We experimentally demonstrate the multi-layered impervious carburised coating as the reason behind high corrosion resistance in the 2300-year-old iron-based sample.



Keywords: Multi-layered Coating, Corrosion Resistance, Archaeometallurgy, Steel.

AME_014

Ancient Iron Technology in Medieval Kerala: Archaeometallurgical Studies on Iron Artefacts from Triprangode

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Abstract

Iron was primarily used for weaponry during the 2nd and 1st millennium BCE. In the later ages, iron artefacts were probably used for religious practices or kept hidden for emergencies, thus making it obvious that iron was utilized for generations. Due to iron's repeated melting, reshaping, and reuse, it becomes challenging to distinguish between ancient and modern iron. Therefore, accurate dating of artifacts is essential, as the characterization of chemical objects is context specific. In the present study, three iron artifacts were recovered from a cave near Triprangode, Kerala, and were analysed using various chemical and microstructural techniques to identify the origin of these artefacts and associated iron-making technology. These artifacts, believed to belong to the 1st millennium BCE based on associated pottery finds and typological comparisons, were dated using Accelerator Mass Spectrometry (AMS). X-ray Fluorescence (XRF) spectroscopy was conducted to obtain the elemental information of the recovered iron objects. Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) were performed to analyse the microstructure. Further, Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) analysis were employed to determine the phases present in the samples. The results of these techniques provided valuable insights regarding the iron-making practices performed during this period in Kerela.

Key words: Archaeometallurgy, Iron Artefacts, AMS Radiocarbon Dating, Microstructure, SEM-EDS, XRD

AME_016

BIO,SMART,& FUNCTIONAL MATERIALS

Oral Abstracts

Deposition characteristics of Zr-Ti-V based Non-Evaporable Getter for Ultra-high vacuum applications: Composition, structure and activation temperature of sputter coated thin film

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Abstract

Non-evaporable getters (NEG) are functional thin films facilitating achievement of ultra-high vacuum based on the sorption pumping principle. The effectiveness of the adsorption mechanism is highly dependent on factors such as compositional uniformity, surface roughness, thickness, porosity and availability of active surface of the getter film. In the present study the deposition characteristics using magnetic sputtering of Zr-Ti-V thin film is reported. Apart from film thickness, surface roughness and composition, the reduction behavior of ZrO_2 over the Zr-Ti-V ternary film surface is characterized using in-situ heating XPS experiments up to 200ºC for developing low temperature activation NEG thin films.

DC Magnetron sputter system is a well-established technique for thin film deposition. In the present application, the thin film coating is required on the inner surface of cylindrical tube for vacuum pumping application. Traditional DC magnetron sputtering system is modified with twisted wire electrode and cylindrical deposition substrate for effective inner wall deposition of thin film. Twisted wire of Zr, Ti, V getter materials in ratio (2:1:1) as electrode and Stainless-Steel sheet cylindrical deposition substrate for effective inner wall deposition of thin film were used. Deposition for the ternary alloy was done in presence of 500 V electric field, 150 G magnetic field and Argon gas (Fig. 1).

The surface roughness of the NEG film was determined using AFM to be ~50 nm (RMS) from 3D micrograph (Fig.2), having sharp spike morphology, that is expected to increase the sticking probability of the coating during adsorption. Surface morphology of the sputter deposited film observed in SEM consisted of compact rounded ball like porous clusters of sizes less than 2µm (Fig. 3) The elemental composition of Zr-Ti-V in a local area was determined to be enriched up to ~ 8:1:1 ratio by EDS measurements, indicating an in-homogenous deposition of the elements during sputtering. (Fig.5). The activation of Zr-Ti-V NEG film at 150-200˚C were analyzed using in-situ XPS measurement. The presence of dual peaks (Fig. 4) suggests the presence of spin – orbital coupling showing prominent spin – orbital doublet Zr $3d_{5/2}$ - $3d_{3/2}$ with a splitting of 2.3 eV. The shift of the XPS peak after in-situ heating of the NEG samples suggested that the peak corresponding to ZrO_2 in the Zr-Ti-V NEG film changes to metallic Zr even though the spatial composition is not uniform. This reduction of metal-oxide to metallic state leads to the formation of active surface helping in adsorption of residual gas molecules to achieve extreme high vacuum. The development will be useful in many vacuum applications which is free from any magnetic

BSF_074

field requirement, using NEG coated films, activated at moderate lower temperatures and in less time

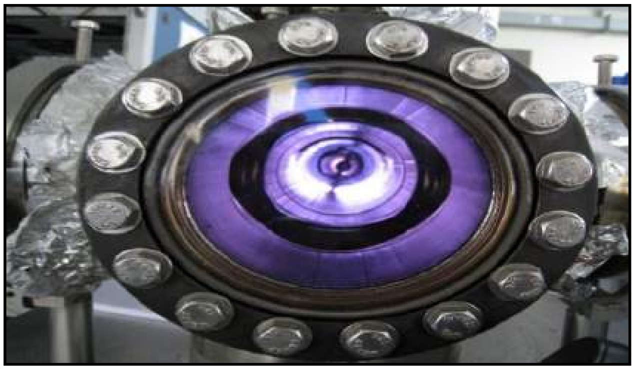

Fig-1 :Argon ion plasma generated during sputtering

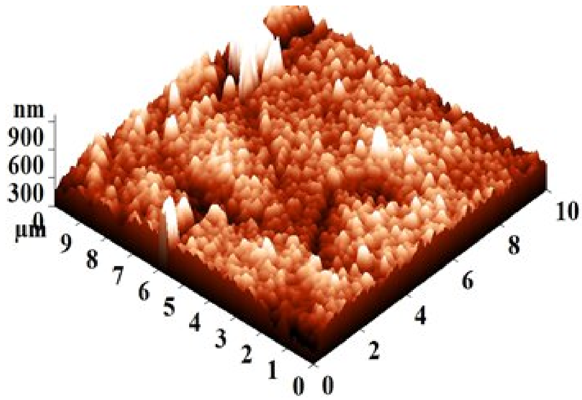

Fig 2: 3-D AFM micrograp

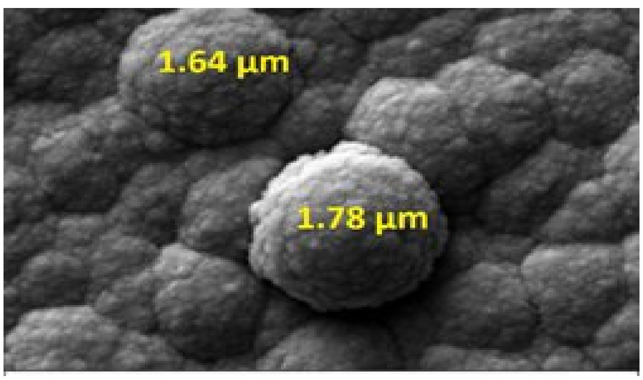

Fig 3: SEM image of NEG thin film sample

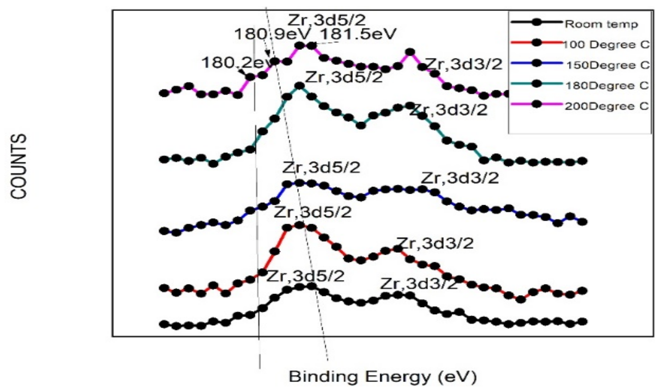

Fig 4: XPS data of Zr peak at different temperature

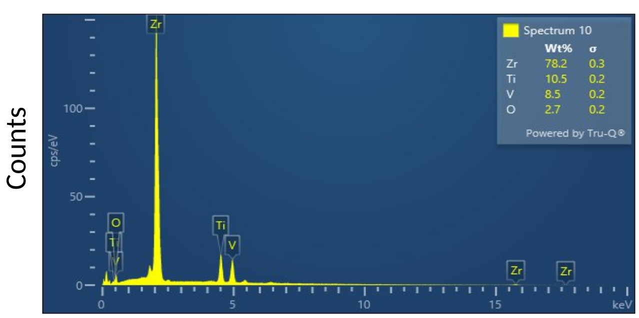

Fig 5: EDS data plo

KeyWords: NEG Nonevaporable getter; XPS X-Ray Photoelectron spectroscopy; EDS Energy-dispersive X-ray spectroscopy; SEM Scanning Electron Microscope

Two-dimensional Cobalt Telluride: An Effective Platform of Sub-picomolar level Dopamine Sensing

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Abstract

Dopamine is an essential neurotransmitter that plays a key function in various physiological processes of the brain like neural signalling, vasodilation beyond the cerebral realm, and reward mechanisms within the brain. Deviant levels of dopamine can serve as an indication of various neurological disorders such as Parkinson's disease, Alzheimer's disease, schizophrenia, or pheochromocytoma. It can also be immensely useful for the detection of drug and alcohol addiction among the masses. To address the challenges associated with ultrasensitive dopamine sensing for regular health monitoring, we have developed a flexible sensor using two-dimensional Cobalt Telluride (2D-$CoTe_2$). 2D-$CoTe_2$ is a potential candidate for electrochemical sensing due to its exceptional semi-metallic behaviour, abundant active sites with surface telluride ions, and excellent electrical conductivity. The 2D-$CoTe_2$ coated glassy carbon electrode sensor shows a limit of detection (LoD) of 0.21 pM measured by Differential Pulse Voltammetry (DPV) in 0.1 M phosphate buffer solution (PBS). The assessment of selectivity, repeatability, and reproducibility has been conducted, to enquire about the efficiency of the sensor. The durability of the sensor has been verified for a duration of one month, demonstrating a minimal loss of 16 % after a period of one month. The interaction of the 2D-$CoTe_2$ and dopamine has been investigated thoroughly by chemical fingerprints using Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy and Raman imaging. Additionally, a flexible paper-based sensor using 2D-$CoTe_2$ has been successfully fabricated and employed for real-time dopamine detection from artificial sweat, which has achieved a LoD of 0.22 pM.

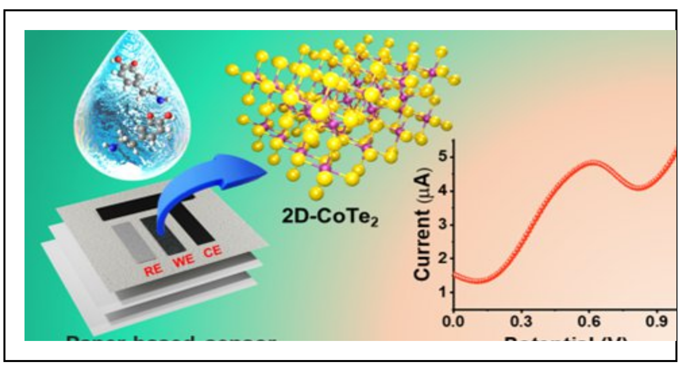

Fig. 1: Electrochemical sensing of dopamine from artificial sweat using paper-based sensor fabricated by 2D-$CoTe_2$

Keywords: Two-dimensional materials, 2D-Tellurides, Dopamine, Electrochemical sensing, Paper-based Sensor

BSF_009

Equiatomic NiTi deposition on structural steel to induce surface smart property

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Abstract

Atmospheric Plasma Spraying (APS) comes under the thermal spraying technique that has wide range of applications due to its versatility on surface modifications. Equiatomic NiTi smart alloy became more focus of interest for researcher and industrialist due to their two extraordinary properties such as, shape memory effect (SME), superelasticity (SE) behaviour. This alloy also gives good wear resistance, corrosion resistance, damping behaviour, and high load bearing capacity. In terms of mechanical property, it has high strength and hardness at high temperature. Due to above properties, NiTi alloy can be used to protect structural materials such as mild steel from catastrophic failure. In this presentation, mild steel, stainless steel and Domex 700 steel have been coated at different substrate preheating temperature by APS techniques using equiatomic NiTi alloy. Surface and interface analysis has been done using optical microscope, SEM, XRD, Hardness test and 3D optical profilometer. The surface morphology of the coatings confirmed the number of unmelted particles decreases gradually with increases in substrate temperature. Interface morphology indicates the gradual decrease in percentage of pore with an increase in substrate temperature. Phase analysis shows the presence of required phases NiTi alongwith some intermetallics and oxide phases on the sprayed surface. The recovery percentage is increasing with the increase in the denseness and oxide/intermetalic free surface. Various intermetallics and dense morphology contributes higher hardness of the coating interface that increases with an increase in substrate temperature. Compressive residual stress was calculated at the coating surface, due to successive development of splat layers on the substrate and analyse the effect on mechanical properties of the sample. The NiTi APS coated mild steel substrate shows better features as compare to stainless steel substrate in terms of adhesion strength, deposition efficiency, and interface property.

Keywords: NiTi, Atmospheric Plasma Spraying, Shape Memory Effect, Superelasticity, Mild Steel, Stainless Steel and Domex 700 Steel

BSF_014

Pectin functionalized silver nanoparticles for the detection of heavy metal ions via surface-enhanced Raman spectroscopy

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Abstract

Contamination of the environment by metal ions such as mercury, chromium, selenium, cadmium, lead, etc has emerged as a serious environmental concern. Recently Raman scattering has emerged as a sensitive and powerful technique for detecting metals using the nanoparticles' localized surface Plasmon resonance (LSPR) property. Surface-enhanced Raman scattering (SERS) created by Nobel metal nanoparticles of favourable size can enhance the optical signal of the analytes by many folds of magnitude. For this, metallic nanoparticles (Au and Ag) have been developed as efficient surface-enhanced Raman scattering agents which can be developed as efficient and specific sensors by tailoring and decorating their surface with such molecules that can add new functionality in them. In the present study, silver nanoparticles functionalized with pectin (P-AgNPs) have been synthesized by microwave-assisted method for the detection of metal ions (Cr^{3+}, Cr^{6+}, Se^{5+}, Mn^{2+}, As^{6+}, and Hg^{+}) in aqueous solution using SERS technique. The Raman measurements of different concentrations of Cr^{3+}, Cr^{6+}, Se^{5+}, Mn^{2+}, As^{6+}, and Hg^{+} ions mixed with synthesized colloidal pectin functionalized silver solution. The scrutiny of the Raman spectra depicts that P-AgNPs show peaks at 257, 586 and 777 cm^{-1}. The addition of metal ions to the P-AgNPs solution induces alteration in the spectral features of the peaks of P-AgNPs. In addition, they also lead to the formation of new characteristic bands. Significant enhancement in the intensity has been observed for these bands in the form of SERS signals. These peculiar characteristic developed peaks can be used for the detection of the metal ions in an aqueous solution. The results demonstrate the applicability of SERS as a potential, simple, prompt, easily accessible and portable tool for the detection of metal ions pollution.

BSF_034

Design of Ni-Ti-Hf based Shape Memory Alloy by Machine Learning

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Abstract

Shape memory alloys (SMA) are a class of smart materials that can regain a given shape under controlled stimuli such as temperature and stress through a reversible Austenite to Martensite phase transformation. The performance of the SMAs in any application is highly influenced by the Transformation temperature and the associated Thermal Hysteresis. Though commercially available NiTi SMAs are potential candidate materials for actuators, relatively lower transformation temperatures (TT) limit their use in high temperature applications such as actuators for automotive and aerospace sectors. Hence there is a growing need to design high temperature SMA by ternary/ quaternary alloying additions to NiTi. For example, replacing some of the Ti with Hf is known to increase the TT. Such replacement is also known to give a higher work output while having moderate ductility in the temperature range of 100-300°C. However, using traditional experimental methods to identify the alloy with specific properties is time-consuming and expensive.

The introduction of machine learning (ML) techniques has significantly sped up the materials development, reducing the number of experimental trials needed. ML also uncovers complex relationships within material systems and offers predictive advantages over conventional constitutive modelling by utilizing surrogate models. This allows researchers to connect the processing, structure, and properties of existing material systems and to design new materials with specific characteristics. In this work, a Ni-Ti-Hf shape memory alloy with an Austenite finish temperature (A_f) ~250°C and a very low thermal hysteresis has been designed using an in-house built software tool (AMDAD) that can perform all the required ML operations in a single platform.
Data for the modelling process, including compositions, atomistic features, and processing parameters, were gathered from the literature. The impact of processing parameters on the desired properties was analysed, and Linear, Polynomial, Support Vector Regression (with three different kernels), and Neural Network models were trained on this data and models were validated with known alloy data. Optimization algorithms were then used to identify few Ni-Ti-Hf compositions with the desired properties and these were experimentally validated. The predicted properties for these compositions were found to align with the experimental results, demonstrating that machine learning-based modelling can significantly accelerate the material design process. Further these alloys will be tested for their performance in actuator applications.
Keywords: Shape memory alloys, machine learning, hysteresis, NiTiHf alloys
BSF_036

Strategically developed strong red-emitting oxyfluoride nanophosphors for next-generation lighting applications

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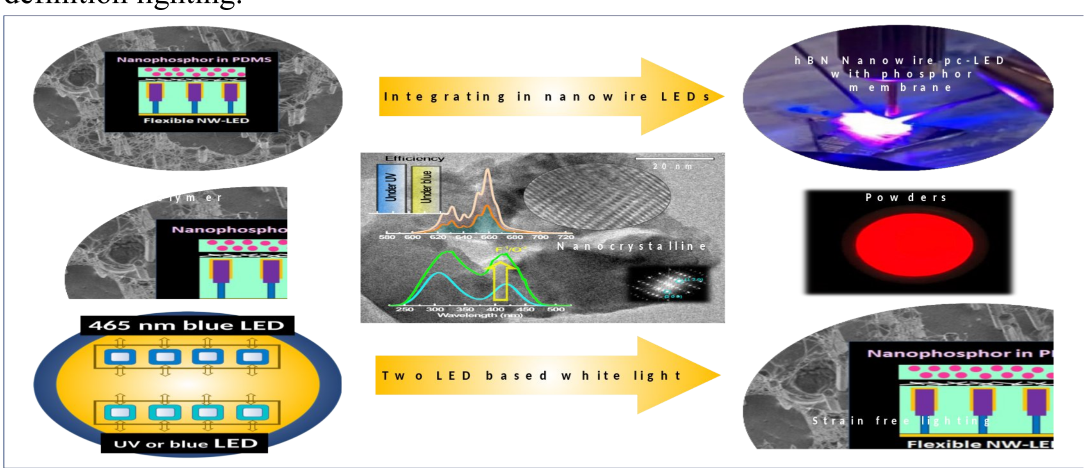
Abstract

Red emitting nanophosphors have a multirole in improvising the next generation bulk/micro/nano-level lighting devices in improving white light quality and device performances. Nonetheless, it is difficult to synthesize nanosized phosphors with good yield and paralleled high absorption efficiency both in the UV and blue regions, which is critical for modern lighting. Herein, new $Mg_{14}Ge_5O_{24-x}F_x$: Mn^{4+} red nanoparticles with sizes below 100 nm are designed to improve not only the luminescence but also the blue light absorption. This approach has validated the applicability of red-emitting nanophosphors into flexible UV and blue nitride nanowire light-emitting-diodes (LEDs), and commercial bulk LEDs, for the first time, with boosted intensity and color superiority for a variety of lighting utilizations. For these pc-LEDs, we used optimized red nanophosphor with a quantum efficiency of 70.39%, color purity ~100%, and photoluminescence stability ~72% at 150°C. This nanophosphor is integrated with a flexible UV-AlGaN/GaN nanowire LED and a blue-InGaN/GaN-LED. The resultant devices show promising red electroluminescence without any degradation at elevated currents. Finally, several unfamiliar LED packaging are designed with a mixture of yellow and red phosphors implemented on two sets of double LED units to reach CRI > 85. Our re-premeditated LED packages are useful for high-definition lighting.



BSF_062

Caption: A new red-emitting nanophosphor with exclusive nanosized morphology, 100% color purity, equally applicable for UV and blue LEDs, and high luminescence (QE > 70%) shows a multirole in either improvising the specially designed next-generation nanolevel lighting devices or in tuning the white light in commercially available pc-LEDs.

Keywords: Red nanophosphors, high blue light absorption, flexible nanowires; light emitting diodes, modern lighting

SMAART MATERIALS-shape memory alloy

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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. -

MSD_029

Lanthanum Phosphate Coated AZ31 Mg Alloy For Anticorrosion and Biomaterial Application

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Abstract

Magnesium (Mg) alloys are light, structural and functional engineering materials with a high strength to weight ratio which are increasingly being used in the automotive, aerospace and biomedical fields. However, the high degradation rates of these alloys in chloride environments hinder their applications. Coatings are an effective way to tackle corrosion on magnesium alloys. Phosphate coatings on magnesium alloys based on zinc, calcium, manganese, barium, strontium, etc. have been developed over the years to provide effective corrosion protection for various engineering and biomaterial applications. In the present study, an attempt was made to develop lanthanum phosphate coating ($LaPO_4$) on AZ31 magnesium alloy through sol-gel route and chemical conversion route. The chemical compositions and structures were characterized using scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS). The corrosion behavior of both the coatings was carried out in 1 wt.% NaCl. Results from the potentiodynamic polarization test and immersion test were used to analyse the corrosion behavior of the coatings. Keeping in mind, the biocompatibility possessed by magnesium alloys, in vitro studies such as degradation tests, cell viability, DAPI analysis were also conducted in physiological conditions. The results were promising and the degradation rate of sol-gel coated substrates (0.09 mm/y) was less than 0.5 mm/y (benchmark) indicating that $LaPO_4$ coated AZ31 alloys have the potential to be used as biodegradable implants.

RCC_034

Effects of Calcium and Zinc on Bio-functionalized 3D Ti Cancellous Bone Scaffold with Enhanced Osseointegration Capacity in Rabbit Model

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Abstract

The objective of this study is to develop a biomimetic bone scaffold with 3D-printed titanium (Ti) incorporated with calcium and zinc (Ca & Zn) to study its osseointegration properties. The scaffold is designed to mimic the natural extracellular matrix (ECM) of bone tissue through surface modification and heat treatment techniques by creating a nanoporous surfaced scaffold decorated with calcium and zinc to achieve enhanced biological response and bone integration. It is learned that the exitance of incorporated Zn as ZnO over the scaffold has antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. The cellular response of MG-63 to the biomimetic scaffold was evaluated through *in vitro* studies with a focus on properties such as cell adhesion, proliferation, mitochondrial membrane potential, and extracellular matrix mineralization. The biocompatibility and osseointegration potential of the scaffold were assessed based on the *in vivo* experiments employing animal models. To study the implant integration as well as bone formation at the tissue-implant interface, micro-CT imaging, and histological analysis were utilized. The results of the above-mentioned studies are suggestive of the superior osseointegration properties of surface-functionalized Ti bone scaffold incorporated with Ca-Zn in comparison with the unmodified 3D-Ti implant. In addition to this, the remarkable upregulation of genes such as OSX, RUNX2, OPN, and OCN in the 3rd, 6th, and 12th weeks of post-implantation further demonstrates the positive impact of the implant. This along with the enhanced biocompatibility and osseointegration properties, can potentially lead to improved clinical outcomes in orthopaedic surgeries

Keywords: Bone-Scaffold, Alkali treatment, Calcium-Zinc, Antibacterial study, Biocompatibility, osteointegration.

BSF_060

Effect of microstructure and texture evolution on bio-corrosion properties and its implication on *in vitro -in vivo* cytocompatibility, and antibacterial properties of Mg-Zr-Sr-Ce alloy

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Abstract

Magnesium based alloys have gained significant attention as temporary fracture fixation devices because of its favourable cytocompatibility and mechanical properties to natural bone as well as it eliminates the requirement of second surgery. However, high degradation properties and brittle nature limits its use in clinical application. Additionally, bacterial infection at the primary stage of implantation is another concern. This presentation will focus on improvement of corrosion and mechanical properties of Mg based alloys by modifying microstructure and texture properties of as cast Mg alloy through solution treatment followed by hot deformation as well as the effect of process parameters of hot deformation in modifying the above mentioned properties. The effect of corrosion properties on cytocompatibility, antibacterial efficacy and in vivo biocompatibility will be discussed.

Key words : Cerium; Hot deformation; Macro-texture; Antibacterial; *In vivo*

BSF_045

Development of synergistic bioactive hydrogel for wound healing applications

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Abstract

This study aims to develop a novel bioactive hydrogel designed to enhance wound healing through the synergistic combination of modified hyaluronic acid (HA), chitosan, and natural bioactive agents such as curcumin, aloe vera, and green tea extracts. The bioactive hydrogel was synthesized utilizing a combination of hyaluronic acid (HA) and chitosan as the foundational structural components. To enhance the therapeutic potential, natural bioactive agents—curcumin (for anti-inflammatory and antioxidant effects), aloe vera extract (for its soothing and regenerative properties), and green tea extract (for its antimicrobial and antioxidant benefits) were incorporated. Chitosan was dissolved in 1% acetic acid solution to a concentration of 2% w/v under continuous stirring until fully solubilized. The modified hyaluronic acid was prepared in phosphate-buffered saline (PBS) at a concentration of 1% w/v, ensuring complete dissolution. Curcumin, aloe vera, and green tea extracts were introduced into the chitosan solution in their respective optimal concentrations to preserve their bioactivity. This step was conducted under controlled conditions to prevent any degradation of the bioactive agents. The prepared HA-modified solution was mixed with the chitosan-bioactive agent mixture in equal volumes. Crosslinking was initiated by the gradual addition of sodium tripolyphosphate (TPP) as a crosslinker, which was added dropwise while maintaining gentle stirring to achieve uniform gelation. The hydrogel formation occurred over a period of 2-3 hours at room temperature, resulting in a stable, biocompatible, and consistent hydrogel matrix. The in-vitro biocompatibility was tested using standard cytotoxicity assays using L929 fibroblast cells, while biodegradability was assessed over time through weight loss measurements in physiological conditions. The hydrogel showed strong antimicrobial activity, toward *S. aureus* and *E. coli*, as compared to the control. Histological analysis was also conducted in *in-vitro* to assess the wound healing ability using the scratch assay test. Overall, the novel bioactive hydrogel, leveraging the synergistic properties of HA-modified hyaluronic acid, chitosan, and natural bioactive agents, presents a promising multifunctional approach to wound healing. Its capacity to enhance hydration, control infection, and mitigate inflammation positions it as a potential next-generation wound care solution.

Keywords: Chitosan; wound healing; scratch assay; antimicrobial activity; hydrogel

BSF_073

Giant Stark effect assisted Radio frequency energy harvesting using atomically thin earth-abundant iron sulphide (FeS_2)

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Abstract

The advancement of Graphene and other layered vdW materials such as TMDCs have opened new paths of energy harvesting methods such as piezoelectricity, flexoelectricity and triboelectricity and photovoltaics. Considerable research has been well established for the above energy harvesting methods using 2D materials. With rapid rise in wireless technology, Radio frequency (RF) energy harvesting is receiving an increased attention in today's digital era due to its potential to replace or improve the longevity of energy storage devices in low-powered IoT devices, sensors and other electronic devices. RF energy is available in the ambient, but efficient devices are still not commonly known for RF energy harvesting applications. Here, we have focused on developing an RF energy harvesting device using few-layered earth abundant two-dimensional (2D) Pyrite (FeS_2).2D Pyrite was synthesized from its precursor bulk Pyrite a natural abundant ore of Iron through liquid phase exfoliation method. The obtained 2D Pyrite is further characterized to assess the physical and chemical properties. A Schottky diode setup was fabricated by using 2D FeS_2 employing Ti/2DFeS_2/ITO configuration. RF energy harvesting was demonstrated using a handheld radio transceiver with a carrier frequency in FM band (88-110MHz) and VHF band (140-170) MHz.The device extracted RF energy and gave an output DC voltage of a maximum of 3.5V with an efficiency of 30 % which was sufficient to charge a supercapacitor within a range of 100 cm. Density functional theory (DFT) studies were performed revealing the impact of the Giant Stark Effect (GSE) in lowering the bandgap of 2D FeS_2. This insidious phenomenon of GSE in 2D-FeS_2 makes it an ideal material of choice for RF energy harvesting applications.

Key words : Radiofrequency, energy harvesting, 2D materials, Density functional theory
BSF015

Suppressing Intermediate Phases in Wide-Bandgap Perovskite Solar Cells via Additive Engineering Strategies

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Abstract

Wide bandgap (WBG) perovskites (E_g: 1.5-2.3 eV) have been extensively investigated as the photoactive layer in the top cell of tandem photovoltaic devices. These materials are realized by the substitution of bromide (Br) ions in place of iodide (I) ions in the traditional $APbI_3$ perovskites, allowing precise control over the bandgap within the aforementioned range.[1] However, these materials suffer from intrinsic phase instability when a critical Br content (~ 20%) is surpassed.[2] Exceeding a certain I/Br ratio results in a non-uniform crystallization process in the perovskite films due to the lower solubility of Br salts, and gives rise to perovskite films with higher defect density and reduced crystallinity. This study explores the impact of ammonium chloride additive in inhibiting the formation of intermediate phases (2H/4H/6H polytypes) in the 1.73 eV FACsPbIBr perovskite films. In situ photoluminescence measurements conducted during the spin-coating of the perovskite films revealed the initial nucleation stage through Br ions in control films which is subsequently replaced by nucleation through Cl ions, resulting in halide homogenization in the target films. The temperature-dependent XRD measurement also confirms the elimination of the 2H/4H/6H intermediate phases in the target films. This additive engineering strategy improved the photovoltaic performance of the WBG perovskite devices with a PCE enhancement from 15% for control devices to 18% for target devices.

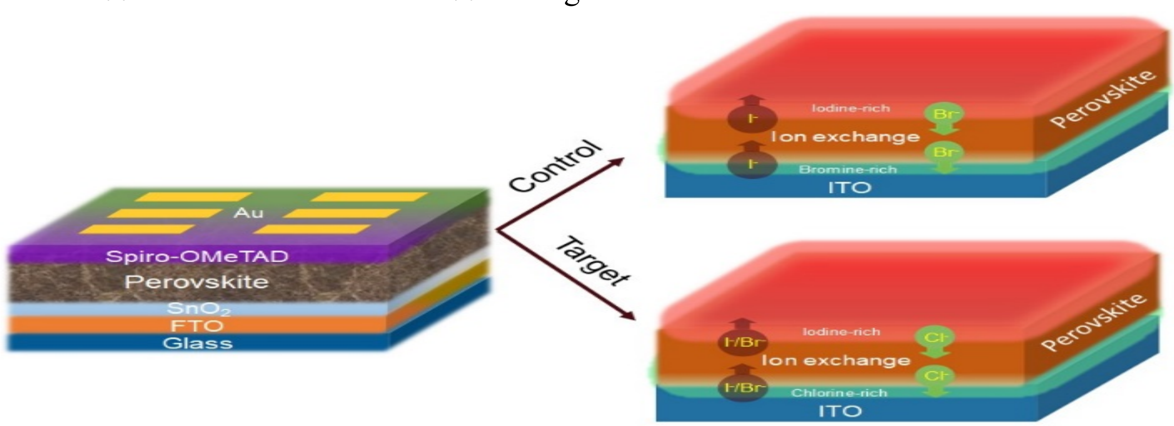

Figure 1: Change in crystallization pathway after chloride ion incorporation in wide-bandgap perovskite solar cells

BSF_016

Keywords: Perovskite solar cells, Crystallization, Additive engineering

References:

1. Oliver, R.D., et al., Understanding and suppressing non-radiative losses in methylammonium-free wide-bandgap perovskite solar cells. Energy & Environmental Science, 2022. **15**(2): p. 714-726.
2. Hoke, E.T., et al., Reversible photo-induced trap formation in mixed-halide hybrid perovskites for photovoltaics. Chemical Science, 2015. **6**(1): p. 613-617.

Structural Properties of Gd_3BWO_9 and Effect of Mo Doping on Structural, Luminescence Properties of $Gd_3BWO_9:Eu^{3+}$

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Abstract

Rare earth borotungstates (Ln_3BWO_9) exhibit interesting polyfunctional optical and magnetic properties like optical nonlinearity, second-harmonic generation large magnetocaloric effect [1,2] at the cryogenic region making them potential alternatives for magnetic refrigeration at ultra-low temperatures and magnetic gas liquefaction. However, detailed structural and optical properties of these compounds are little explored. The hexagonal non-centrosymmetric structure of these compounds with good chemical and temperature stability makes them favourable hosts for luminescent materials. In present study, undoped and Eu doped Gd_3BWO_9 samples were synthesized by high temperature solid state method. Phase identification of samples was carried out using powder XRD. XRD pattern in Fig.1(a) confirms the formation of hexagonal Gd_3BWO_9 phase with P63 space group [3]. Temperature dependent structural evolution from ambient to 973 K was done by in situ high temperature XRD. Raman spectra was recorded by exciting the sample with 540 nm laser. All peaks corresponding to different vibrational modes are assigned and found to be consistent with reference data of Gd_3BWO_9. Photoluminescence spectra of Eu doped Gd_3BWO_9 was recorded and typical excitation and emission spectra is shown in Fig.1(b). In this study effect of Eu concentration, co-doping with Mo on structural and luminescence properties was studied in detail. Co-doping with Mo improves the photoluminescent properties of Gd_3BWO_9.

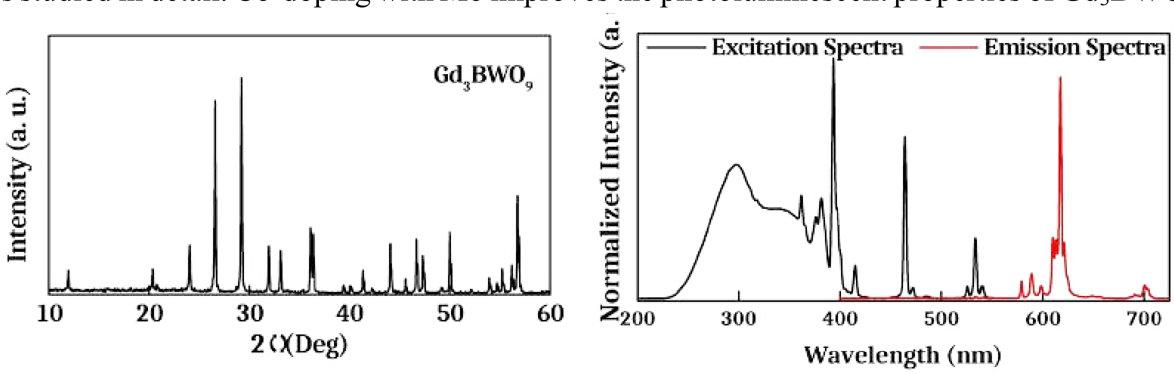

Fig.1 a). XRD pattern, b). photoluminescence spectra of $Eu:Gd_3BWO_9$

References: 1. M. Ashtar, J. Guo, Z. Wan, Y. Wang, G. Gong, Y. Liu, Y. Su and Z. Tian, lnorg. Chem., 2020, 59, 5368–5376.
2. Y. Stefanovich, N. U. Venskovskii, A. V. Mosunov and V. A. Krut'Ko, Russ. J. Inorg. Chem., 2001, 46, 1846.
3. J-Y Liu, .J. Wang, Z-J. Zhang, H-H. Chen, X-X. Yang, R-FuLi, J-T. Zhao, Journal of Luminescence132(2012)2874–2878.
BSF_056

Optical Engineering of Light Absorption in Two-dimensional Halide Perovskites for Photovoltaic Applications

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Abstract

The advent of low-dimensional hybrid organic-inorganic halide perovskite (HOIPs) has attracted immense attention in solar cell technology for myriad reasons including, cost-effectiveness, solution-processability, room-temperature manufacturing, and flexibility in design. Three-dimensional halide perovskites are prone to degradation in ambient atmosphere conditions. A thin layer of two-dimensional (2D) perovskites coated on 3D perovskites has been found to enhance the stability of the 3D perovskites. Further, the grain boundaries in 3D perovskites limit the charge transport compared to 2D perovskites. Despite high stability and long-range charge transport in 2D perovskites, they cannot replace 3D perovskites due to limitations in optical absorption emerging from quantum confinement. 2D perovskite bandgap will be larger than 3D perovskites, that makes them less attractive for solar cells. In this work, we report a strategy for optical engineering the absorption of 2D perovskites, which leads to new light absorption states below the bandgap of the 2D perovskites. In addition, the light absorption reaches near unity (100 %) across the visible-infrared region (400-1000 nm) matching with Si solar cells.

Using an optical engineering strategy, we circumvent the limited absorption in Ruddlesden-Popper phase (RP_x) – a class of 2D HOIP crystals and exceed it beyond 3D counterparts and match it with conventional Silicon cells. 2D RPx perovskites possess strong exciton binding energy at room temperature. Strong light-matter interaction with the perovskites leads to the formation of exciton-polariton (E-P) states. Here we demonstrate that a device consisting of a few alternating layers of graphene and RP_x, each of thickness >10nm coupled with >500 nm thick RP_x crystals on Au substrates capable of supporting multiple orders of self-hybridized E–P modes which can exhibit sub-bandgap absorption in the visible light region and beyond. Further, we show that these alternating layers' of 2D material mimic the quantum potential wells quite similar to distributed Bragg mirrors through electric field simulations. Finally, we also confirm that these alternating layers contribute to efficient photon confinement in the perovskite layer and charge extraction in the graphene layers thereby enabling the 2D HOIPs for light harvesting.

Our results provide new insight into the optical engineering of low dimensional perovskite structure for the formation of E-Ps cavities, sub-bandgap adsorption, and charge extraction, opening new opportunities for their manipulation for polaritonic devices, especially in polariton photovoltaics.

Keywords: Exciton-Polaritons, Ruddlesden-Popper, Bragg Mirror, Photovoltaics
BSF_071

Development of Multifunctional Biomimetic Nickel-Graphene Composite coating by Electrodeposition

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Abstract

Long-time environmental protection of metallic materials is still required in manufacturing and engineering applications. The use of graphene-based composite as anti-corrosion and protective coatings for metallic materials is still a provocative topic worthy of debate [1][2]. Nickel–graphene nanocomposite coatings have been successfully coated over mild steel by electrochemical co-deposition technique. This study explores surface morphology, phase composition, wettability, and corrosion resistance properties of the Ni nanocomposite coatings. The concentration of graphene and deposition parameters like current density, time, and temperature were optimized. The coatings exhibited compact and crack-free morphology which was evident from the SEM images which was in agreement with the XRD results. Wettability studies reveal that the Ni-graphene coating has a water contact angle (CA) of 152º indicating its superhydrophobicity and also possesses self-cleaning properties. Corrosion-resistant properties of the coatings were examined by potentiodynamic polarization studies and electrochemical impedance spectroscopy. Incorporating graphene sheets into a nickel metal matrix leads to enhanced surface roughness, adhesion strength, and corrosion resistance of produced composite coatings. Furthermore, the presence of graphene in composite coating exhibits reduced grain sizes and enhanced erosion–corrosion resistance properties. The simple fabrication method may provide a cost-effective way to prepare mechanically durable, anti-corrosive, self-cleaning, and superhydrophobic coatings on metal substrates.

References

[1] G. Yasin, M. Arif, M. Shakeel, Y. Dun, Y. Zuo, W.Q. Khan, Y. Tang, A. Khan, M. Nadeem, Exploring the Nickel-Graphene Nanocomposite Coatings for Superior Corrosion Resistance: Manipulating the Effect of Deposition Current Density on its Morphology, Mechanical Properties, and Erosion-Corrosion Performance, Adv. Eng. Mater. 20 (2018) 1701166. https://doi.org/10.1002/adem.201701166.

[2] S. Ding, T. Xiang, C. Li, S. Zheng, J. Wang, M. Zhang, C. Dong, W. Chan, Fabrication of self-cleaning super-hydrophobic nickel/graphene hybrid film with improved corrosion resistance on mild steel, Mater. Des. 117 (2017) 280–288. https://doi.org/https://doi.org/10.1016/j.matdes.2016.12.084.

Keywords: Biomimetic, composite coating, multifunctional, electrodeposition

BSF_027

Nano-Metal-Organic Frameworks for Cancer Therapeutics

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Abstract

As per ICMR, in 2022 India reported over 1.4 million cancer cases, with almost 0.9 million fatalities. Currently, the major treatment routes are adjuvant and neoadjuvant chemotherapy, radiation therapy and surgery. However, their effectiveness is often limited as the chemotherapeutic drugs are unable to differentiate between cancerous and healthy cells, thus leading to significant side effects. Further, in the case of stage III and stage IV cancer, there are also chances of treatment incompetence due to metastasis, resistance development, and large gene pool variation making a single treatment strategy ineffective. Some strategies to overcome these issues are increasing the targetability of chemotherapeutic drugs, improving biodistribution to reduce the chances of metastasis, implementing combination therapies to combat resistance development, etc. In this regard, nanomedicines demonstrate the potential to enhance the therapeutic efficacy. One such example is a recently developed type of nanoparticle class, referred to as nano-metal-organic frameworks (nMOFs). These have been proven advantageous by enhancing targetability and allowing combination therapy which reduces the chances of resistance generation, enhanced pharmacokinetics, and potential theranostics.

MIL-100(Fe), a type of MOF, possesses a high surface area-to-volume ratio and high porosity, but its application in the biomedical field is limited due to its irregular shape and size. Thus, we developed a modified one-pot micelle-assisted synthesis method to reduce the size and obtain a spherical morphology. The obtained nanocarriers, Fe-BTC nMOF were crystalline (FCC) and spherical with an average diameter of 120 nm and a narrow size distribution. Further, to test its efficiency as a drug delivery vehicle, a model anti-cancerous drug, Camptothecin (CPT) was used. Fe-BTC nMOF demonstrates high drug loading capacity along with moderate toxicity to cancer cells. Further, due to the presence of iron, its applications as a diagnostic agent are being investigated.

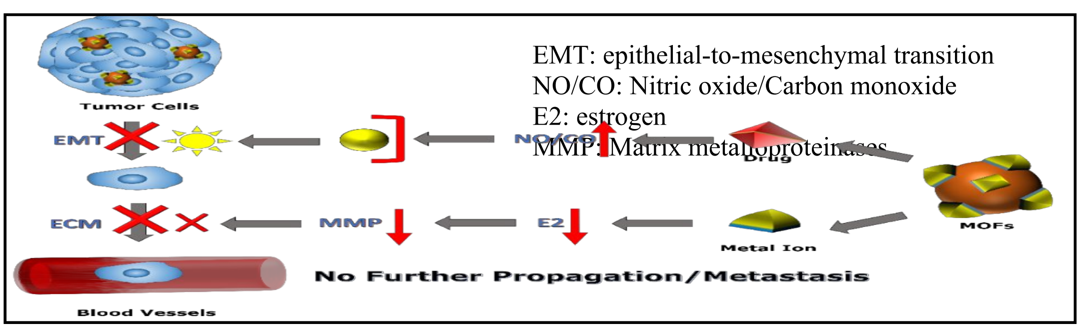

Figure: Illustration of nMOFs as cancer therapeutics

Key Words: MOFs; Cancer Therapy; Drug Deliver

BSF_038

Biodegradable magnesium based alloy for orthopedic applications

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Abstract

Magnesium alloys are known for their natural degradability, good biocompatibility, and favorable mechanical properties, making them suitable for load-bearing implants in the medical industry. They have a Young's modulus (41-45 GPa) similar to that of human bone (10-30 GPa), which helps reduce stress shielding during load transfer at the bone-implant interface. However, their use as biomedical implants are limited due to poor corrosion resistance and resulting mechanical integrity issues. Therefore, improving the corrosion resistance of Mg-based materials is essential for their feasibility in orthopedic implants. Additionally, as-cast alloys exhibit insufficient mechanical properties and corrosion resistance, mainly due to the presence of brittle secondary phases such as Mg2Ca. To address this, optimizing the percentage of alloying elements, particularly intermetallic-forming elements like Ca and Zn, is studied.

In this work Mg-Ca-Zn alloys was fabricated with addition of Ca and Zn by stir casting and bottom pouring in metallic mould. Further effect of Ca and Zn content on mechanical, corrosion and biodegradable properties was studied. The alloy was prepared in a controlled argon atmosphere and cast in a closed, pressurized argon chamber to form ingots. The alloys were extensively characterized for their microstructural and mechanical properties. The results showed that increasing the Ca content decreased grain size (from 60 µm to 8 µm) and improved hardness values (from 30 HV to 68 HV). Additionally, higher Ca content increased the amount of Mg2Ca phase at grain boundaries, resulting in higher corrosion rates. However, the addition of Zn improved the corrosion resistance of the alloy, although it reduced the mechanical properties. The combine effect of the Zn and Ca was also studied and found more suitable for the orthopaedic implant applications. The cast alloy was used to fabricate implants in the form of screws and plates, demonstrating superior surface quality and machinability, which are essential for orthopedic implant applications.

Keywords: Biodegradability, Corrosion, Microstructure, Hardness

BSF_042

Exploring the feasibility of fabricating functionally graded metal-ceramic components by spark plasma sintering for dental implants

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Abstract

Dental implants are considered the best option to replace missing or damaged teeth. Conventional dental implant materials are mostly Ti-alloys and Zirconia due to their good biomechanical properties. These are mostly two-piece or three-piece implants and the main cause of their failure is Osseo-disintegration as the different parts are fixed either mechanically or by dental cement. Moreover, Ti-alloys suffer from galvanic corrosion and gingival recession when contacted with saliva and fluoride and have poor wear and aesthetic appeal. These issues can be avoided by using ceramic implants. But, titanium alloys, with a lower Young's modulus, provide better load transfer to the surrounding bone promoting its remodeling and minimizing stress shielding. Both titanium alloys and Zirconia have advantages and limitations; obtaining their benefits in a single implant is desirable. Combining Ti6Al4V and YSZ in a functionally graded implant is ideal for extending its lifespan, offering a synergistic approach to leverage the strengths of both materials while minimizing their limitations.

The current work demonstrates the feasibility of fabricating functionally graded single-piece Ti6Al4V- Yttria stabilized zirconia (YSZ) components in a single step using spark plasma sintering. Three and Five-layered metal-ceramic samples are fabricated at a low processing temperature of 1100°C. Tailoring the powder mixing and sintering conditions led to crack-free samples. The fabricated FGMs are dense (>99%) with no interface defects and have stable Ti6Al4V and YSZ phases, are hard, and have good biological, wear & mechanical properties.

The functionality varies at the implant's respective locations due to the composition's gradation. Accordingly, the FGM design places the Ti6Al4V-rich section in the jawbone to enhance osseointegration and reduce stress shielding while the YSZ-rich section forms the crown, providing superior wear resistance and chemical stability, and effectively addresses the shortcomings of traditional two-piece and three-piece dental implants.

Keywords: Biomaterials, Dental Implants, Functionally Graded Materials, Spark Plasma Sintering, Biomechanical properties

BSF_053

Biocompatibility investigation on Zr based metallic glass

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Abstract

Zr based metallic glasses (MGs) are potential material for making surgical equipments. Proper alloy design using suitable addition of elements play an important role in improving the glass forming ability (GFA) with minimal biotoxicity. Present study is undertaken to design metallic glass forming composition with good GFA in Zr-Co-Ti, Zr-Cu-Ti-Al and Zr-Co-Cu-Ti systems. Alloy design strategy is based on thermodynamic modelling by rationalizing the effect of chemical enthalpy and atomic mismatch entropy along with statistically controlled atomic arrangement through configurational entropy. Rapid solidification technique was used to synthesize MG in melt spun ribbon form. Structural nature and glass stability of the ribbon are confirmed by X-Ray diffraction and differential scanning calorimeter, respectively. Biocorrosion studies on MG is investigated using potentiodynamic polarization and electrochemical impedance spectroscopy in simulated body fluid (SBF) environment. Improvement in corrosion resistance is observed in all the SBF solutions along with in vitro biocompatibility study using MG-63 cell viability experiment.

Keywords: Thermodynamic modelling, Zr-based metallic glass, Biocorrosion, Biocompatibility

BSF_063

Applications of Pulsed and CW Lasers Micro-to-Nanoscale Inorganic-Organic Materials Coatings s for Medical Device Engineering

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Abstract

In this presentation, we demonstrate the application of nano and femto-second pulsed and continuous wave laser based processing of novel glass, ceramic, and glass-polymer thin films, deposited on glass and Ti-metal substrates.

In the first example, we demonstrate the application of rare-earth ion $(Er,Yb)^{3+}$ doped silicate and phosphate glasses on silica substrates for engineering photonic device waveguides for photonic applications; e.g. sensing, optical imaging for compact medical photonic device engineering.

The second example focusses on fs-pulsed-laser engineering demonstrates the restoration of acid-eroded lesions on tooth surface using hydroxyapatite coating on human enamels for preventing the onset of hypersensitivity and progression of tooth wear. The discovery of this methodology has led to the applications of restoring extracted human tooth samples by demonstrating in vitro pulsed laser-based restoration of 20 acid-induced enamel lesions, followed using the in situ mouth appliances for oral challenge test of restored enamels in 20 different selected healthy volunteers. The preliminary results of in situ appliance tests in volunteers' mouth were compared with the control untreated enamels using brushing trials. The results demonstrate a pathway for laser-based surgical restoration of acid-damaged and worn teeth for personalized treatment in which the sensing and imaging technologies may play important roles.

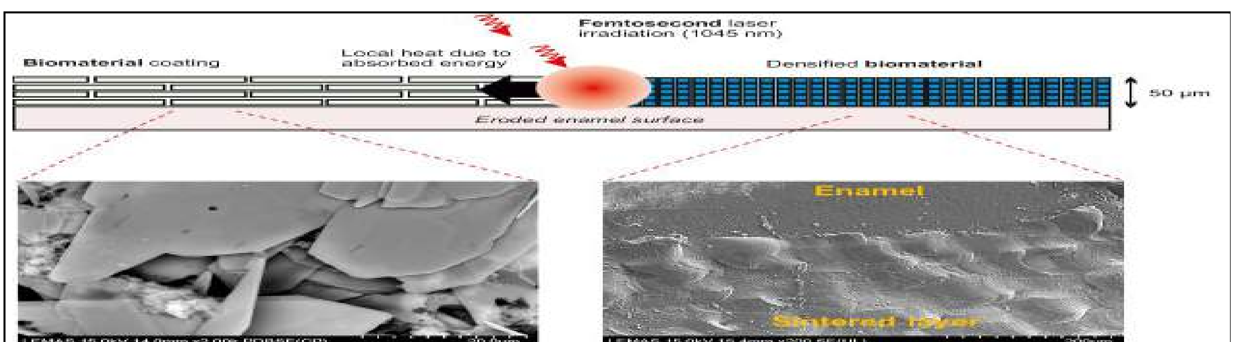

Fig. 1: Demonstrate schematically the steps involved in restoring acid-eroded enamel using photo-active biomineral and 1040nm 130fs pulsed laser

Key words: pulsed and CW lasers, dental enamel, RE-doped minerals, bio minerals, hypersensitivity

BSF_011

Surface Functionalization of Additively Manufactured Titanium Scaffolds with Cerium Ions: Promoting Biocompatibility, and Bone Integration in Rat Models

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Abstract

In this study, additively manufactured (3D) commercially pure Ti scaffolds were subjected to alkali-based surface biofunctionalization followed by cerium incorporation and evaluation of enhanced *in-vitro* and *in-vivo* biological characteristics. Cancellous 3D Ti scaffolds were subjected to NaOH treatment followed by ceric nitrate and heat treatment at 600 °C. Different surface characterization techniques were employed to examine the surface morphology, roughness, hydrophilicity and chemical composition of the functionalized Ti surfaces. Alkali treatment resulted in the formation of nanoporous interconnected titania surface layer over 3D Ti scaffolds and subsequent ceric nitrate treatment incorporated Ce ions into the surface layer which later oxidised and densified by the heat treatment. The functionalized surfaces exhibited improved surface roughness and hydrophilicity compared to bare 3D Ti constructs. XPS analysis confirmed the integration of Ce ions by replacing Na ions in the surface nanoporous titania layer with peaks specifying the existence of Ce as CeO_2 after heat treatment. Evaluation of antibacterial properties of Ce functionalized 3D Ti surfaces against *Escherichia coli* and *Staphylococcus aureus* revealed a significant reduction in the number of bacterial colonies confirming its bactericidal properties. *In-vitro* cytocompatibility assessment towards human osteoblast-like MG-63 cells was conducted to evaluate the cellular response to the Ce-functionalized 3D Ti surfaces. Non-cytotoxicity and enhanced cell proliferation and viability of cells over functionalized surfaces were revealed by the MTT assay and LDH assay. Improved ALP activity displayed the osteogenic potential whereas the ARS assay demonstrated improved extracellular matrix mineralization over functionalized scaffolds. Evaluation of cytoskeletal attachment, mitochondrial membrane potential and nuclear integrity by microscopic imaging showed enhanced cell spreading and adherence suggesting improved cytocompatibility of Ce-functionalized surfaces. *In-vivo* bone implantation study was performed in the Wistar rat (*Rattus norvegicus*) model by the surgical insertion of functionalized 3D Ti scaffolds in the tibial bone. Bone integration and new bone formation at 3 and 6 weeks post-implantation were analysed by histological staining. The results indicated enhanced osseointegration around the functionalized scaffolds compared to the bare 3D Ti scaffolds. Additionally, Micro-computed tomography (μ-CT) analysis demonstrated well-integrated bone tissue with enhanced bone ingrowth, BV/TV (bone volume/total volume), bone mineral density (BMD) and bone mineral content (BMC) specifying the excellent biocompatibility and

BSF_023

osseointegration of Ce-functionalized 3D Ti surfaces. The surface characteristics and *in-vitro* and *in-vivo* biological properties suggest the Ce surface functionalization of 3D Ti surfaces as a promising candidate for orthopedic implant applications.

Keywords: CP-Ti, Alkali treatment, Ce biofunctionalization, Antibacterial activity, *in-vitro* and *in-vivo* compatibility

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.

MSD_071

Exploring Innovative Thermoelectric Materials for Mid-Temperature Waste Heat Recovery

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Abstract

Thermoelectric materials are promising candidates for effectively converting heat into electricity. Their ability for conversion can be evaluated using the Figure of merit (zT), which is given by (S^2 T)/ . The electrical conductivity () and Seebeck coefficient (S) should be high with lower thermal conductivity () to achieve a high figure of merit. As these parameters are interrelated, one has to employ different approaches for decoupling the electrical conductivity, Seebeck coefficient and thermal conductivity. Different approaches like Band structuring, Synergistic band effect, and fostering resonant levels are to be employed for increasing the figure of merit. Different materials like PbTe, GeTe, SnTe, SnSe, Skutterudites, and Half Heuser alloys have been extensively studied for their use as thermoelectric materials. Due to the toxicity and limited availability of high-quality thermoelectric materials, it is unlikely that the development of large-scale thermoelectric generators will be feasible, especially with materials such as PbTe. Hence, there is a great need to work on choosing the right materials that are efficient and not as toxic as lead telluride. MnTe is one such option that has yet to be explored well as a potential alternative to PbTe.

MnTe is an intrinsic p-type semiconductor with an indirect band gap of 0.8 eV. It has a NiAs-type hexagonal crystal structure. Symmetrical crystal structure and low hole concentration have made pristine MnTe exhibit a high Seebeck coefficient (580 mV/K at room temperature). The thermal conductivity of the pristine MnTe is decent (1.4–1.6 W/m/K at 323 K and 0.7–0.8 W/m/K at 873K), making it a straightforward alternative. Although it has a good Seebeck coefficient, its relatively higher thermal and lower electrical conductivity limit the figure of merit. Pristine MnTe exhibits a figure of merit of 0.41 at 773 K, which is far lower than that of conventional TE materials like PbTe[4]. Since the number of charge carriers is less, different aliovalent dopants like (Cu, Li, Na, K, and Ag) have been tried and also resulted in a good figure of merit (zT) close to 1. Here, in our work, the effect of one of the dopants on the transport properties has been studied, which will be presented during the conference.

Keywords: Waste heat recovery, Thermoelectric materials, MnTe, Electrical conductivity, Thermal transport

BSF_017

Coercivity enhancement on Sm-Fe-N using novel low melting Zn based eutectic alloy

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Abstract

$Sm_2Fe_{17}N_x$ is a promising hard magnetic intermetallic compound for high temperature applications in automotive sectors owing to its excellent intrinsic magnetic properties. However, consolidation of these powders into magnet remains as a major challenge through conventional sintering due to the decomposition of $Sm_2Fe_{17}N_x$. The present work reports the coercivity enhancement and the reason thereof achieved in Sm-Fe-N powders by annealing with Zn-Al eutectic powder mixture. Anisotropic $Sm_2Fe_{17}N_x$ powder (Magvalley China, $H_c \approx$ 9koe, particle size = 0.5-3μ) was mixed with Zn-5Al (wt. %) alloy prepared through melt spinning in different proportion (10,20 and 30 wt. %) by ball milling. Optimal annealing of the mixture in a temperature range between 400- 460 °C yielded a coercivity enhancement of 66% compared to original as received powder. Detailed microstructural characterization has been carried out using SEM, TEM and 3D-APT techniques. The observed enhancement in coercivity could be attributed to effective reduction in the free-Fe by the formation of non-magnetic ᴦ-FeZn (Fe_3Zn_7 phase) and the formation of smooth coating of Sm-Fe-Zn-N phase observed from 3D-APT studies.

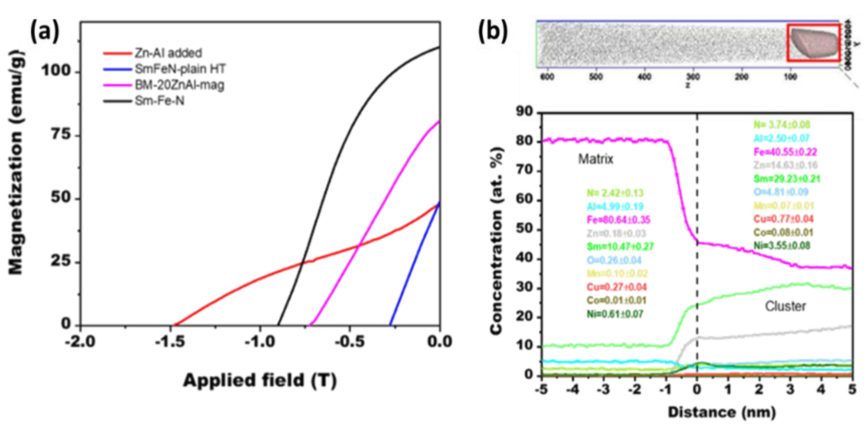

Fig. 1. a) Demagnetization curve of Sm-Fe-N, plain Sm-Fe-N annealed and Zn-Al added sample b) Zinc rich regions in the elemental map (top) delineated with 8 at.% isoconcentration surface and the representative proximity histogram obtained from the rectangular (red color) region with 0.1 nm bin width.

BSF_022

Reference:

1. C. Kuhrt, K. O'Donnell, M. Katter, J. Wecker, K. Schnitzke, L. Schultz, Pressure-assisted zinc bonding of microcrystalline $Sm_2Fe_{17}N_x$ powders, Appl. Phys. Lett. 60 (1992) 3316–3318. https://doi.org/10.1063/1.106678.

Keyword: Sm-Fe-N magnet, Atom probe tomography.

Microstructure and Grain refinement mechanism in Fe-rich FeSiB(P)NbCu Nanocrystalline Soft-magnetic Alloys

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Abstract

The development of next-generation soft-magnets for sub-kHz applications requires a combination of smaller core volume, high switching frequency, low core loss, and a scalable production process. Fe-rich nanocrystalline soft magnetic alloys offers a balance of low core loss (P) and high saturation magnetization (M_s). However, challenges exist in achieving amorphous formation due to limited glass-forming ability, rapid nanocrystal coarsening during annealing, and control of technical magnetic properties. To address these challenges, a systematic study was conducted to design Fe-rich nanocrystalline alloys with a controlled nanocrystallization process. Amorphous precursor alloy ribbons with a nominal composition of $Fe_{83}B_{13-x}P_xSi_2Nb_1Cu_1$ (x = 0, 2, 4, 6, 8 at%) were prepared using the melt-spinning route. An in-house designed IR furnace with a moderate heating rate of 100 K/min was used to achieve a controlled nanocrystallization process, resulting in nanocrystals sized between 10-20 nm. During annealing, the progressive addition of P in FeSiB(P)NbCu nanocrystalline alloy led to grain refinement of a-Fe(Si) nanocrystals, including dense nucleation and inhibition of grain growth. The addition of P from 0 to 8 at% resulted in a consistent reduction of a-Fe(Si) nanocrystallite size (D) and an increase in nucleation density (N_d) from~ 30 nm and 2.5 x 10^{22} (P-free) to ~ 15 nm and 0.9 x 10^{23} (P-rich). The mechanism of P-assisted synergistic grain refinement is explained through crystallization activation energy (E_a), selective solute redistribution, and enhanced stabilization of intergranular amorphous matrix (IGA). In-situ TEM heating experiments were then conducted to understand the nucleation and nano-crystal coalescence process. Overall, the nanocrystalline ribbon annealed at 733 K exhibited optimal properties with coercivity (H_c) <15 A/m, saturation magnetization (B_{800}) ≥1.6 T, and core-loss (P) of 0.34 W/kg under 50 Hz/1.6 T. The microstructure-magnetic relationship of the developed alloys is explained within the framework of the Extended-Random Anisotropy Model (E-RAM).

Keywords: Soft-magnets; Iron amorphous; nanocrystalline; microstructure; core-loss

BSF_030

Synthesis, characterization, and comparative analysis of Monophasic SrFe12O19

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Abstract

Strontium hexaferrite ($SrFe_{12}O_{19}$), a prominent member of the hexagonal ferrite family, is a widely studied magnetic material due to its excellent magnetic properties, thermal stability, corrosion resistance, and cost-effectiveness. This compound, commonly used in permanent magnets, electronic devices, and data storage applications, exhibits high coercivity, high magnetic anisotropy, and significant magnetization. In this experiment, Strontium hexaferrite (SHF) was synthesized using a unique synthesis process i.e microwave-assisted refluxing technique by keeping the Fe3+/Sr2+ ratio at 10 and then conventionally sintered at 900 °C for 2, 4, and 6 h. From the XRD analysis of the samples, it confirmed that the sample sintered for 6 h could result in a single phase. The EDX analysis could show the elemental compositions nearly equal to its formula. This conventionally sintered single-phased strontium hexaferrite displayed the best magnetic properties, i.e., M_S = 50.3 emu/g, M_r = 27.6 emu/g, and H_C = 5.20 kOe. To compare the microwave sintering technique, an as-synthesized sample (Fe^{3+}/Sr^{2+} = 10) obtained from the microwave refluxing method was microwave sintered at 900 °C for varying time periods (i.e., 20 min, 30 min, 60 min, 120 min). Single-phase SHF was advantageously formed after implementing microwave sintering for 30 min. FESEM of this sample shows hexagonal plate-like structures were formed all over the sample.

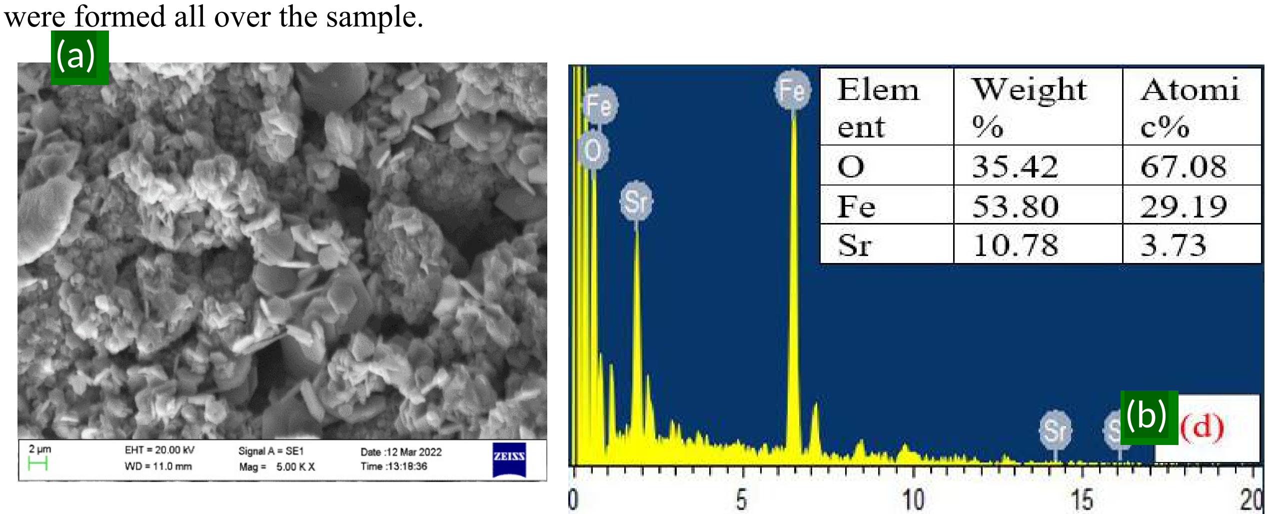

Figure 1. (a) SEM image with (b) spectrums of different elements present in SHF sintered at 900 °C for 6 h.

Keywords: Hard Magnets, Strontium Hexaferrite, Microwave Refluxing, Conventional Sintering, Microwave Sintering

BSF_033

Mn-Ni-Cu based ternary system for Magnetocaloric application using a combination of thermodynamic calculations and experiments

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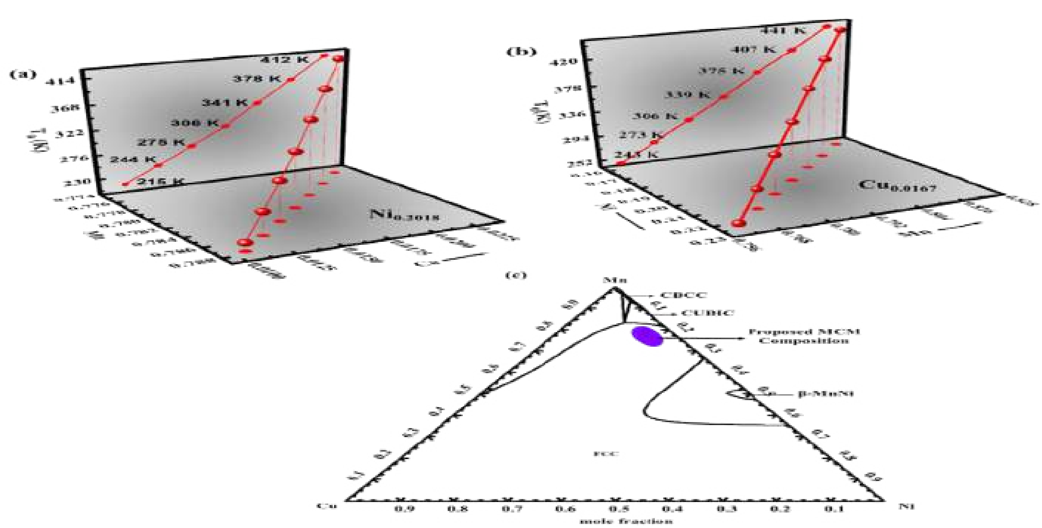
Abstract

Magnetic refrigeration is an active research area considering its potential to replace gas-based refrigeration systems, which are detrimental to the environment owing to Chlorofluorocarbon (CFC) emissions. Heusler alloys such as Ni_2MnGa are known for their magnetocaloric effect, and the addition of elements like Cu has increased the refrigeration capacity of the system. Magnetocaloric properties are a strict function of composition, and few alloy compositions in Mn-Ni-Cu-Ga can exhibit enhanced magnetocaloric properties. Hence, in the present study, the thermodynamic optimization of the Mn-Ni-Cu-based ternary system and its three sub-binaries, Mn-Cu, Mn-Ni, and Ni-Cu, are performed using the CALPHAD approach. However, despite their potential, practical application of Heusler alloys is hindered by the poor mechanical properties of Heusler alloys. In this study, two promising compositions within the Mn-Ni-Cu and Mn-Ni-Ga ternary alloys, selected based on thermodynamic calculations. These alloys exhibited notable magnetocaloric effects near room temperature with minimal temperature and thermal hysteresis. The optimal entropy changes, calculated from isothermal magnetization curves at applied magnetic field of 4 Tesla were found to be 13.86 J kg^{-1} K^{-1}, reported for the first time in the Mn-Ni-Cu ternary alloy. In addition, mechanical behaviour of investigated alloys studied extensively. Our approach aimed to suppress the p-d orbital hybridization, which is associated with poor mechanical properties, by replacing Ga with Cu to achieve relatively weaker hybridization.



BSF_051

Fig. 1: (a) Calculated T_o with varying concentrations of Mn and Cu by keeping Ni constant. (b) Calculated T_o with varying concentrations of Mn and Ni by keeping Cu constant. (c) Calculated isothermal section of Mn-Ni-Cu ternary system along with proposed MCM composition at 873 K.

Key words: Magnetocaloric Materials, Mn-Ni-Cu, Mn-Ni-Ga, CALPHAD

Grain Boundary Engineering and Enhancement in Coercivity in Ce containing Nd-Fe-B magnets using Dy-Cu / Dy-Al-Cu alloys

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Abstract

The grain boundary diffusion process (GBDP) using $Dy_{70}Cu_{30}$and $Dy_{70}Al_{20}Cu_{10}$ was carried out in (Nd-Ce)-Fe-B magnet through the two-step thermal treatment process. The scanning electron microscopy (SEM) back scattered electron (BSE) microstructures at different depth shows better diffusion for $Dy_{70}Cu_{30}$ as compared with $Dy_{70}Al_{20}Cu_{10}$ in the magnet. In addition, the asymmetric faceted shell evolution of (Dy-Nd)-Fe-B phase in the diffused magnet is responsible for the enhancing the anisotropy and magnetic exchange decoupling to achieve the coercivity of 2.1T ($Dy_{70}Cu_{30}$ diffused) and 1.74T ($Dy_{70}Al_{20}Cu_{10}$ diffused) which is 36% and 13% higher than the intrinsic coercivity of 1.54T. At 150°C, the $Dy_{70}Cu_{30}$ diffused magnet exhibits the better coercivity of 0.9T which is 125% better than the pristine magnet with the thermal temperature coefficient of coercivity of -0.476 %/°C. The 3D atom probe tomography (APT) data provides the evidence to Dy enrichment shell and GB region.

Keywords: Nd-Fe-B, Grain boundary diffusion; Permanent magnet; Atom probe tomography.

BSF_052

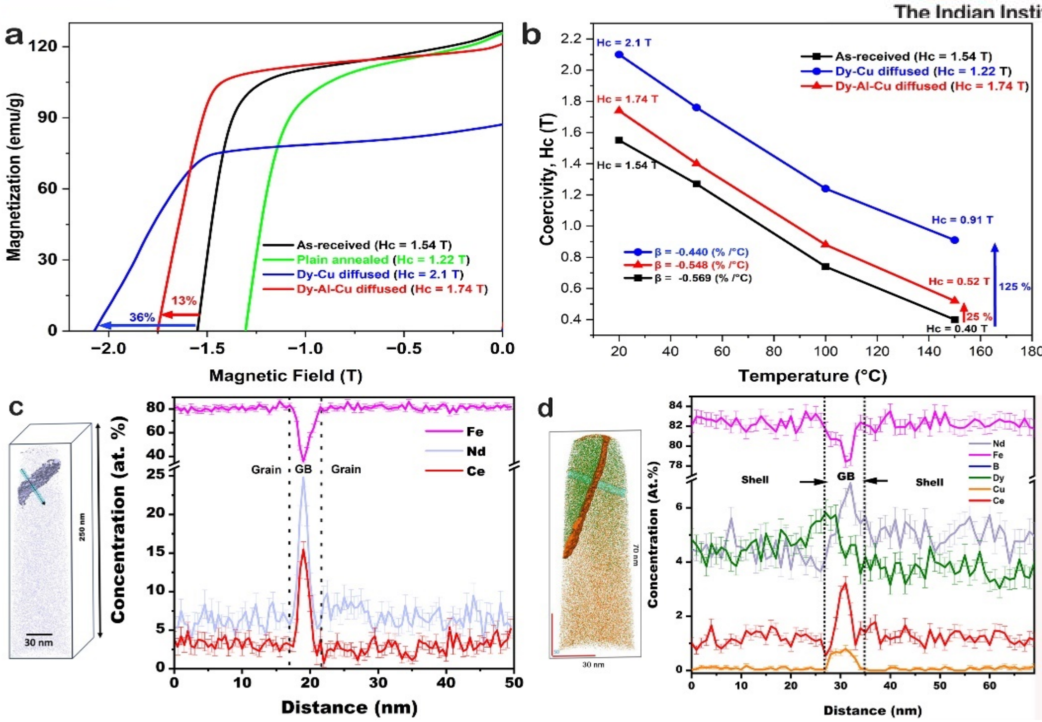

Fig.1. (a) Demagnetization curves showing enhanced coercivity obtained in GBDP and (b) High temperature coercivity measurement showing GBDP sample retaining higher coercivity at elevated temperatures. 3APT data representing elemental analysis of c) As received and d) GBDP with $Dy_{70}Cu_{30}$.

Rare-earth doped yttria stabilized zirconia as thermal barrier coating material for improved performance

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Abstract

Thermal barrier coatings (TBCs) are critical for enhancing the performance and lifespan of high-temperature components in gas turbines and jet engines. Yttria-stabilized zirconia (YSZ) has been widely used as a TBC material due to its low thermal conductivity, high thermal expansion coefficient, and excellent phase stability at elevated temperatures. However, as the demand for higher operating temperatures and efficiencies increases, the need for improved TBC materials has become imperative. Rare-earth-doped yttria-stabilized zirconia (RE-YSZ) has emerged as a promising candidate to meet these requirements. The introduction of rare-earth dopants, such as cerium, lanthanum, gadolinium, and ytterbium, into the YSZ matrix enhances its thermal and mechanical properties. These modifications result in improved thermal insulation, increased resistance to sintering, and better phase stability at high temperatures, thereby enhancing the overall performance of the TBC. Coating of Gd_2O_3 (6 to 15 mol %) doped YSZ over CoNiCrAlY bond coated Inconel 718 substrate showed significantly high resistance against sintering at elevated temperature compared to that of pure YSZ. Sinter-resistant top coats aids in retention of porosities, which provides better thermal insulation at higher temperature applications. *In-situ* doped YSZ with Gd during plasma spray coating of premixed powders of YSZ and Gd_2O_3 showed transformation of tetragonal to cubic phase and annihilation of monoclinic phase as characterised by XRD analysis. Modified TBCs resulted in increased hardness and Young's modulus. Isothermal oxidation studies at high temperature (between 900 °C and 1100 °C) showed that modified TBCs have improved oxidation resistance compared to pure YSZ coating. Particle erosion tests revealed that modified TBCs possess better resistant to erosion compared to pure YSZ coating, both at ambient and elevated temperature.

Keywords: Rare earth doping; YSZ; thermal barrier coating (TBC); High-temperature oxidation; Erosion resistance

RCC_047

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 (R_r) and strain fixity rate (R_f) 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

COMPUTATIONAL MODELLING & SIMULATIONS

Oral abstracts

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

CMS_132

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.

Analysis of Coarsening and the Moving Boundary Problem for nucleation and growth

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Abstract

This paper presents a novel exploration of the relationship between coarsening annealing and the moving boundary problem approach, with a particular emphasis on diffusion, Stefan's solution, and non-integer exponents in the power law of interface versus time. The research delves into the complex dynamics of phase transformations, specifically the process of coarsening annealing, and how it can be effectively modeled using the moving boundary problem approach. The role of diffusion in these transformations is explored, elucidating how atomic mobility influences the coarsening process. A significant focus of this study is the investigation of non-integer exponents in the power law of interface versus time. This aspect challenges traditional models and provides a more nuanced understanding of phase transformations. It is demonstrated that non-integer exponents can accurately model the dynamics of the interface over time, offering new insights into the coarsening process. This research has significant applications in materials science and engineering, particularly in the design and manufacture of alloys and composite materials. Furthermore, our findings can inform the development of more efficient manufacturing processes, reducing waste and improving product quality.

In conclusion, this paper contributes to both the theoretical understanding of phase transformations and the practical applications of this knowledge in various industrial contexts. Our findings underscore the potential of integrating the moving boundary problem approach with diffusion, Stefan's solution, and non-integer exponents in the power law of interface versus time in addressing real-world challenges in materials science and industrial manufacturing.

References

1 Alan J. Ardell "Non-integer temporal exponents in trans-interface diffusion-controlled coarsening", https://link.springer.com/article/10.1007/s10853-016-9953-0

2. Basu R Analysis of heterogeneous nucleation for slab and sphere materials
AIP Conf. Proc. 2105, 020002 (2019) https://doi.org/10.1063/1.5100687

CMS_010

Revisiting the statistics of incipient plasticity

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Abstract

Incipient plasticity is frequently associated with thermally stimulated phenomena, such as the nucleation of dislocations in crystalline solids and the activation of shear transition zones in metallic glasses. A common strategy for estimating the activation parameters of these mechanisms is to examine the statistical distribution of critical loads acquired from repeated measurements. However, this approach frequently produces activation volumes on the order of atomic volumes across a wide range of materials and experimental setups. These exceptionally small activation volumes are frequently attributed to intricate nucleation mechanisms.

In this study, we evaluate the statistical method's underlying assumptions and investigate the impact of minor statistical variance in activation parameters. To determine the yield stresses, we run deformation simulations on iron nanopillars under both tensile and compressive loading. While standard statistical analysis shows extremely modest activation volumes, atomistic simulations offer a transition pathway that contradicts the statistical results. Using a simple Monte Carlo technique and altering the statistical model, we show that even modest differences in activation parameters can drastically lower the measured activation volume. This means that the previously reported ultra-small atomic volumes can be explained by ignoring the possible dispersion of activation parameters, rather than requiring unusual methods.

Acknowledgments. We sincerely appreciate the Science and Engineering Research Board, Govt. of India, for supporting this research through the ECRA scheme. We also acknowledge the financial support provided by the Indian Institute of Technology Kharagpur through the ISIRD grant.

CMS_015

Coarsening of Core-Shell Precipitates: Role of Interfacial Energies

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Abstract

Precipitation hardening is a mechanism employed to enhance the strength of several classes of materials, Al-base alloys being the most notable. However, the coarsening of precipitates during alloy manufacturing and high-temperature applications leads to a reduction in strength. Alloys with core-shell precipitates, with a core phase enveloped by a shell of a different phase, exhibit slower coarsening rates, and therefore, have garnered much interest in recent decades. This morphology has been observed in Al-based alloys such as Al-Li-Sc and Al-Sc-Zr, as well as in Cu-alloyed multi-component steels.

Core-shell precipitates exhibit different coarsening behavior compared to single-phase precipitates, which have been extensively studied through experiments and simulations. Since no theoretical model currently exists for the coarsening behaviour of these dual-phase precipitates, we have used phase field simulations to investigate this process.

Our study reveals that both core-shell and shell-matrix interfacial energies have a near-equal influence on the coarsening rate of the core precipitates. This is attributed to the necessity for solute atoms to traverse both interfaces to either reach or depart from the growing or dissolving core. Notably, the impact of shell-matrix interfacial energy is greater (compared to that of the core-shell interfacial energy) on the coarsening rate of composite precipitates.

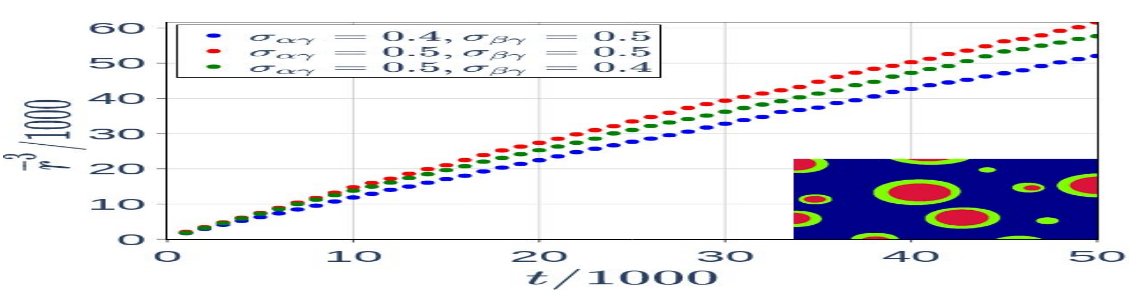

Fig. 1: Effect of core-shell and shell-matrix interfacial energies on the coarsening of composite precipitates. The inset at the bottom-right shows a typical microstructure from the simulations. Note that the shell phase exists as both isolated and composite precipitates.

Keywords: core-shell precipitates, coarsening, phase-field modelling, interfacial energy.
CMS_053

Microstructure and texture-based micromagnetic simulation framework for the design of magnetic materials

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Abstract

The B-H (magnetic hysteresis) curve is a crucial characteristic of magnetic materials, extensively used by OEMs for designing and selecting suitable materials for specific applications. Optimizing the B-H curve requires a comprehensive understanding of processing conditions, microstructure, texture evolution, and their combined impact on magnetic properties. Current micromagnetic simulation frameworks, such as Ubermag integrated with OOMMF or MuMax, are effective in predicting the hysteresis curves of magnetic materials. However, these simulations often overlook the influence of microstructure and texture. To fill this gap, we have developed a micromagnetic framework that incorporates the effects of microstructure and texture on the hysteresis loop of magnetic materials.

Synthetic microstructures were created using python code and texture was incorporated using euler angles assigned to each grain. The saturation magnetization of the grain was varied by as a function of the misorientation of a grain w.r.t its neighbors. Grain boundaries were identified and they were given saturation magnetization values based on the saturation values and misorientation of its adjacent grains. To decrease the effect of the sharp change in the values of the magnetization smoothing function was applied. The microstructure with grain texture was then inputted to open source micromagnetic simulation framework OOMMF, available as a part of the Ubermag package. The OOMMF framework solves the Landau-Lifshitz-Gilbert (LLG) equation numerically and stimulates the hysteresis curve. Different hysteresis curves were observed for electrical steel and permanent magnets, providing clear indications of how texture and microstructure affect properties such as coercivity, hysteresis loss, and maximum energy product.

Key words: Magnetic Materials, Micromagnetic framework, Microstructure, Crystallographic Texture, Hysteresis

CMS_031

Real microstructure based finite element modeling for machining of Aluminium alloy

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Abstract

In this study, we investigate the machining behaviour of a cast aluminium alloy, extensively utilized in automotive, aerospace, and aeronautical applications, where structural components demand high precision. Machining these components with optimal process parameters is crucial to achieve cost efficiency, reduce processing time, and minimize material waste. Given the complexity of predicting machining forces and deformation behaviour, numerical modelling tools like Finite Element Analysis (FEA) have become indispensable. Initially, the aluminium alloy was cast and subjected to a series of characterization techniques, including high-resolution x-ray diffraction (HR-XRD), optical microscopy, and scanning electron microscopy. Mechanical properties were ascertained through tensile tests and micro/nano-indentation methods. The obtained microstructural data were then translated into a representative volume element (RVE) using an image-based, object-oriented finite element tool. Subsequently, a novel physics-based material model was developed, from various quasistatic and dynamic tests of the alloy. This model facilitates the prediction of machining and deformation behaviour under different process parameters, addressing the intricacies of real microstructures, including distinct phases and porosities. The effectiveness of the model was validated by comparing its predictions to experimental results, spanning both macro and micro scales. The comparative studies emphasized the model's accuracy in predicting machining forces across diverse process parameters. These experimental validations confirmed the model's capability to realistically simulate machining processes, thereby providing a robust tool for optimizing machining parameters in practical applications. Our work demonstrates the feasibility of using advanced numerical modelling techniques to enhance the precision and efficiency of machining processes in aluminium alloys, offering significant improvements in both theoretical understanding and practical applications.

CMS_79

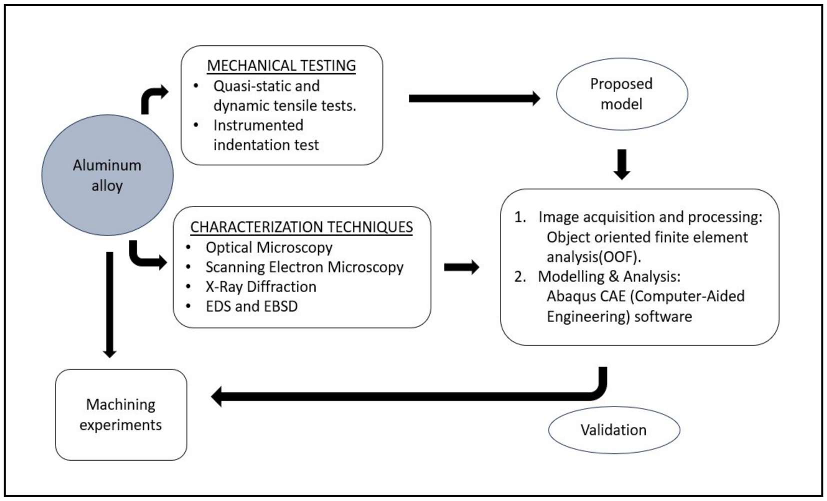

Fig. 1: Graphical representation of the overall work

Key words: Real microstructure based finite element modelling, microstructure-based modeling, aluminum alloy, 3-dimensional material modeling, micromechanical modeling, machining.

Optimal transfer learning strategies for property predictions in materials science

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Abstract

Materials science is a domain characterised by 'small' datasets (i.e., < 10,000 datapoints) of critical properties that govern performance of various applications and devices. For instance, there are no large, reliable datasets available for several key 'performance determining' metrics in energy applications, such as diffusivities in battery electrodes, carrier recombination rates in photovoltaics, and molecular adsorption energies for catalysis. On the other hand, there are reasonably 'large' datasets (> 100,000 datapoints) available on some properties, such as, bulk formation enthalpies, computed band structures, and crystal structures across wide chemical spaces. Thus, if key chemical, compositional, and structural trends can be captured in available large datasets and subsequently transferred (or re-learnt), it will enable the use of deep learning and graph based neural network models in smaller datasets as well. Hence, my talk will explore the utility of current transfer learning (TL) approaches that are available for computational materials science and identify optimal ways to employ TL-based strategies. Specifically, TL involves training a neural network model on a larger dataset and subsequently retraining a fraction of the model on a smaller dataset. I will quantify the accuracy, transferability, and efficiency of TL models compared to models that have been trained from scratch. Finally, I will focus on TL models that can generalise over multi-properties during pre-training and can efficiently be re-trained on small datasets, which pave the way towards creating more general, foundational models, in the near future.

Key words: Materials properties, transfer learning, machine learning, computational data, predictive models

CMS_104

Simulation of thermal profiles and microstructure evolution of as-build Inconel 625 alloy in laser powder bed fusion additive manufacturing

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Abstract

Inconel(IN)625 alloy offers outstanding high-temperature mechanical properties and corrosion resistance. Its exceptional combination of properties makes it a popular choice in aerospace, solar power plants and marine applications. Manufacturing desired parts of IN625 with high geometric complexity is difficult by conventional manufacturing route.
Laser powder bed fusion (LPBF) additive manufacturing (AM) emerges as a compelling solution for creating parts with intricate geometries while maintaining a high-quality surface finish. However, the microstructure that forms in LPBF is notably heterogeneous due to the rapid and uneven thermal profiles. As a result, it is necessary to select LPBF process parameters with care to obtain the desired microstructures without the presence of harmful phases. Optimizing parameters through trial-and-error experimental methods in LPBF-based AM is difficult because of the numerous process parameters and the complex heat transfer conditions that exist during the printing process. Consequently, mathematical modeling of the underlying physical phenomena becomes beneficial for optimizing parameters in the LPBF of Inconel 625 alloy components.

In this research, a simplified 3D heat source model was created using the finite element method (FEM) to study the thermal cycles during LPBF of IN625. The model employs a simplified strategy, where all elements within a layer melt concurrently, in order to minimize computational time. A multi-phase field modelling (MPFM) approach was used to simulate microstructure evolution and forecast segregation behaviors of various alloying elements using the thermal boundary conditions obtained from the FEM simulation. The influence of thermal gradients and cooling rates on the morphological and elemental segregation characteristics of the developing microstructure during the additive manufacturing process was investigated. The primary dendritic arm spacing (PDAS) and the elemental segregation behaviour were analyzed using both experimental techniques and modelling. The findings demonstrated a good correlation with experimental observations. Through a meticulous comparative analysis, an ideal set of laser powder bed fusion (LPBF) process parameters was determined for fabricating components from Inconel 625 alloy with minimal defects and without adverse microstructural constituents.

Key words : Laser Powder Bed Fusion (LPBF); Finite Element Method (FEM); microstructure evolution; Multi-phase field modelling (MPFM); elemental segregation
CMS_105

Atomistic Simulation of Grain Boundary Segregation and Migration in Aluminium-Magnesium alloy

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Abstract

Grain Boundaries are the locations in the microstructure where the atomic arrangement of two meeting crystal lattices is remarkably disturbed. Compared to the bulk grains, grain boundaries have higher energy and a substantial effect on the mechanical and functional properties of the material. Again, for the same ensemble of atoms, free energy is higher in polycrystalline materials compared to single crystals due to the presence of grain boundaries. To reduce this free energy, the solute atoms of an alloy tend to segregate preferentially at the grain boundaries and other defective sites. We employ atomistic simulations to study the segregation behavior of magnesium in the aluminum-magnesium alloy, which is of immense technological importance. Tubular bi-crystals have been created along different cubic axes, *viz*., <001>, <110> and <111>. Different radii of curvature of grain boundaries have also been considered. These variations help us understand the segregation of solute atoms based on atomic packing and grain boundary curvature. Semi-Grand Canonical Monte Carlo (SGMC) computations have been employed along with isobaric-isothermal ensemble (NPT) as hybrid Monte Carlo/Molecular Dynamics (MC/MD) simulations to understand the site preference for replacement of Al by Mg atoms. Annealing studies have been performed at various temperatures to better understand the concept of migration of grain boundaries under the condition of solute segregation at the grain boundaries. Segregation energy has been calculated for the samples and is co-related with the segregation of solute atoms and grain boundary migration.

Keywords: Atomistic Simulation, Semi-Grand Canonical Monte Carlo, Grain Boundary segregation, Grain Boundary migration, Al-Mg alloy

CMS_017

Effect of segregation on phase transformations and deformation behaviour: continuum and atomistic modelling

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Abstract

Segregation to defects plays a key role in microstructural evolution as well as deformation behaviour. In this talk, we show how continuum (phase field) models can be used to understand the effect of dislocations on mechanisms of phase transformation in binary systems that undergo phase separation. Specifically, we show that segregation can lead to spinodal decomposition along the dislocation in systems that are nominally outside the spinodal composition. Further, we also show the key role played by pipe diffusion in the choice of phase transformation mechanism. We indicate the phase transfer mechanism maps and predict systems in which such an effect can be expected to be observed.

In the second part of the talk, we show how atomistic (Molecular Dynamics and Monte Carlo) models can be used to understand segregation to defects and their subsequent effect on deformation behaviour. Specifically, we show the effect of segregation to dislocations and stacking faults on deformation behaviour in Cu-Al alloys. We show, in spite of abundant stacking faults, the Suzuki strengthening can only account for 10 to 25% of the strengthening and nearly 75 to 90% of the strengthening is attributable to segregation to dislocations. This combined MD and MC study can explain some of the strain aging observed in commercially pure Cu and Cu-8 at.% Al alloys.

Key words: Cottrell atmosphere, Suzuki effect, nucleation and growth, spinodal decomposition, deformation behaviour, dislocations, Cu-Al alloys, Fe-based alloys

CMS_022

Expediting additive manufacturing with ICME

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Abstract

Integrated Computational Materials Engineering (ICME) accelerates the integration of Additive Manufacturing (AM) into the industry by addressing emerging challenges. These challenges include rapid identification of optimal process parameters to prevent defects and optimizing material compositions to meet the property requirements of AM-fabricated components for high-demand applications. This presentation showcases an ICME framework aimed at expediting the optimization of processing parameters and the development of material solutions for both single and multi-material additive manufacturing. By addressing the relationships between process, structure, and properties, this framework enhances component performance, reduces manufacturing defects, and optimizes material compositions. Consequently, it significantly lowers development costs and time in AM. By leveraging predictive modeling of microstructures and properties, and enabling composition and process optimization, ICME plays a pivotal role in the rapid adoption and industrialization of AM technologies.

Key words: ICME, additive manufacturing, multi-materials additive manufacturing

CMS_044

Phase Field Study on Morphological Evolution of Hexagonal Anisotropic Inclusions

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Abstract

The mechanical properties of steels are significantly affected by the presence and morphology of non-metallic inclusions such as oxides and sulfides. Irregularly shaped inclusions, unlike spherical particles, can concentrate stress within the material, potentially leading to crack initiation and propagation. This can adversely impact the steel's ductility, toughness, and fatigue strength, which are critical for structural applications. Understanding the evolution of inclusion morphology is thus crucial for optimizing material performance. This study employs a phase field model to simulate the morphological evolution of hexagonal anisotropic inclusions (such as that of alpha-alumina) in steel, focusing on various inclusion shapes influenced by interfacial energy anisotropy and supersaturation levels.

Phase field models are employed to describe the microstructural evolution of materials by using order parameters to represent the system's free energy. In these models, the free energy is expressed as a function of the order parameters and their spatial derivatives. We use an existing extended Cahn-Hilliard formulation, in which, the free energy density for hexagonal systems is derived through Taylor series expansion, incorporating both bulk and interfacial free energy contributions. Specifically, in this study we use the free energy expression that includes an aberration term, which is expanded into a polynomial to account for interfacial energy contributions in different spatial dimensions. The chemical potential and evolution equations are derived from the free energy functional. The Cahn-Hilliard and Allen-Cahn models describe the time evolution of composition and structural quantities, respectively.

Wulff constructions are used to graphically represent the equilibrium shapes of inclusions. The study finds that lower supersaturation levels lead to plate-like hexagonal morphologies, whereas higher supersaturation levels result in dendritic structures. This is attributed to the point effect of diffusion, that is, the system's tendency to reduce energy by adding atoms to areas of high surface energy at the corners of the morphology. The simulations also address other inclusion shapes, such as hexagonal prisms and bi-pyramids, which align with experimental observations. Additionally, octahedral and polyhedral morphologies are explored.

In conclusion, the phase field simulation can provide a comprehensive understanding of the morphological evolution of hexagonal anisotropic inclusions in steel. By adjusting interfacial energy parameters and supersaturation levels, the study successfully reproduces various inclusion shapes and their equilibrium configurations observed in experiments. This work contributes valuable insights into the relationship between material processing conditions and inclusion morphology, and can help in optimizing steel's microstructure for structural applications.

Keywords: Phase Field Modelling; Steel Making; Alumina Inclusions; Morphology Evolution

CMS_061

Phase Field Modelling of Chromium Nitride Precipitation in FeCrMnN steels

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Abstract

Phase field simulations of Cr_2N precipitation in Fe-Cr-N and Fe-Cr-Mn-N systems were performed using Cahn-Hilliard and Allen-Cahn expressions at different aging temperatures. Thermodynamic and kinetic data of elements were derived using CALPHAD approach. Numerical model was developed based on semi-implicit Discrete Fourier Transform (DFT) method. Growth of Cr_2N precipitates in the austenitic matrix gets delayed by addition of Mn content due to the strong stability of austenite phase at aging temperatures. The diffuse interface thickness reduces the diffusion of elements into precipitate and hence reduce the growth rate of precipitate for higher time steps. Reduction in concentration gradient between GB/precipitate, reduces the growth rate of precipitate.

Key words : Phase Field modelling, chromium nitride, Diffusion, CALPHAD :

CMS_057

ICME-based approach to establish a processing map for the IN718 welding

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Abstract

Welding process optimisation is inevitable in the aerospace industry. Several experimental trials and resources are needed to identify the optimum welding conditions. Simulation-guided approaches will accelerate the optimisation of the welding process with limited resources. The current study focused on the welding process (TIG & EB) optimisation of the IN718 superalloy using an ICME approach. The macroscale simulation establishes the thermal field in the material during the welding process. The thermal conditions were correlated with kinetic calculations to identify the microstructure variations in heat affected zone and verified using physical simulation. The thermal cycles in the fusion zone are used for microstructure simulation using the phase field method. The segregation of elements in the fusion zone is established using the phase field simulation and correlated with the experimental data. A parametric study is conducted by varying the welding conditions, such as current and welding speed; the phase field simulation is carried out based on the macroscale parametric study. A processing/segregation map was established to guide the welding process of superalloys.

Keywords: FEM simulation; Welding; Phase-field simulation; ICME; Superalloy

CMS130

A Multi-scale Computational Framework for Simulating Internal Friction in Steel: Decoupling Different Microstructural Loss Mechanisms

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Abstract

In a viscoelastic (or anelastic) material, damping is characterized by the dissipation of mechanical energy. The mechanism of damping originates from internal friction. The internal friction response of a material is characterized by mechanical spectroscopy, and a clear experimental linkage between microstructure and internal friction responses was established. However, due to complex microstructures, decoupling of microstructural inputs to internal friction was not possible experimentally. To overcome this, a robust multiscale simulation framework comprising kinetic Monte Carlo (KMC) and molecular dynamics (MD) simulations was developed. Extensive in-house kMC codes were developed to capture diverse activated processes related to the internal friction response in bcc-steel. The simulation methodology comprised of three stages: (i) determination of diffusion barrier using the nudged elastic band method (NEB) using MD, (ii) simulation of defect migration with KMC, and (iii) estimation of elastic strains through MD simulations. KMC was used to access longer time and length scales which were inaccessible with classical MD. Multiscale KMC-MD simulations were utilized to simulate different relaxation/loss peaks corresponding to interstitial migration, dislocation density and solute-dislocation interaction. The simulation scheme helped in decoupling the role of different microstructural inputs on the internal friction response of bcc-steel. More importantly, KMC-MD simulations provided insight into the atomistic mechanism behind different internal loss peaks. In summary, a multiscale KMC-MD framework was developed to simulate defect migration, which governs the internal friction and other properties of the material.

Keywords: Internal Friction, Steel, Diffusion, Molecular Dynamics, Kinetic Monte Carlo.

CMS_109

Phase Transformation via dislocation-interaction in Refractory High Entropy Alloys (HfNbTaTiZr) at different strain rates – A Molecular Dynamics simulation study

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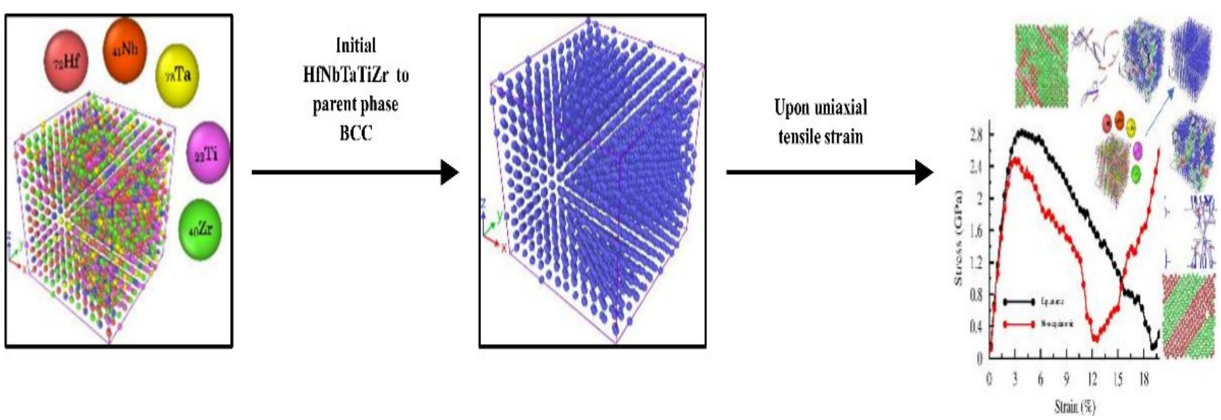
Abstract

The interplay of different transition metals, introduces a newly developed class of alloys; known as Refractory High Entropy Alloys (RHEA). It possesses exceptional microstructural hardness, and numerous unique characteristics like high melting point (>2000˚C), high strength and ductility at higher temperatures etc. Some novel applications of RHEAs includes advanced nuclear reactors, thermoelectric devices for waste heat recovery, hydrogen production and storage, and many more. Research on such futuristic materials (RHEAs) with multiple applications in highly demanded areas, has now become a research hotspot. Phase transformation can illustrate, how the mechanical behaviour changes, subjected to variation in elemental concentrations and strain rates. Here, a comparison between two compositions: equiatomic and non-equiatomic HfNbTaTiZr at three different uniaxial tensile strain rates, has been studied computationally through MD-simulations.



Significant differences between these compositions, helps us to understand the underlying mechanism during phase change. Starting from 100% BCC parent phase, it transforms to atoms in FCC and HCP phases, through an intermediate amorphous phase. This eventually results in unstable and stable stacking faults (SFs) for both equiatomic and non-equiatomic compositions,
CMS_55

respectively. As dislocations glide through the lattice, a major increase in the fraction of FCC and HCP phase atoms are observed. Surface defects (SFs) obstructs the gliding motion of dislocations which results in increasing the yield strength in plastic regime. This is known as strain hardening, predominantly observed in non-equiatomic composition at lower strain rate. After critical observation and interpretation, a conclusion can be derived as follows: Firstly, Transformation from BCC to FCC phase occurs through amorphization at about 10% strain while FCC to HCP occurs through dislocation dynamics. The dislocation-dislocation interaction is responsible for strain hardening. This increases its yield strength in the plastic regime; thereby strengthening the RHEA. This comparative study provides some interesting insights, showcasing non-equiatomic RHEA acquires greater strength even at lower strain rate, which is useful for high-end applications.

CMS_055

Development of a Heat Transfer and Solidification Model for Continuous Casting using OpenFOAM®: A CFD Approach

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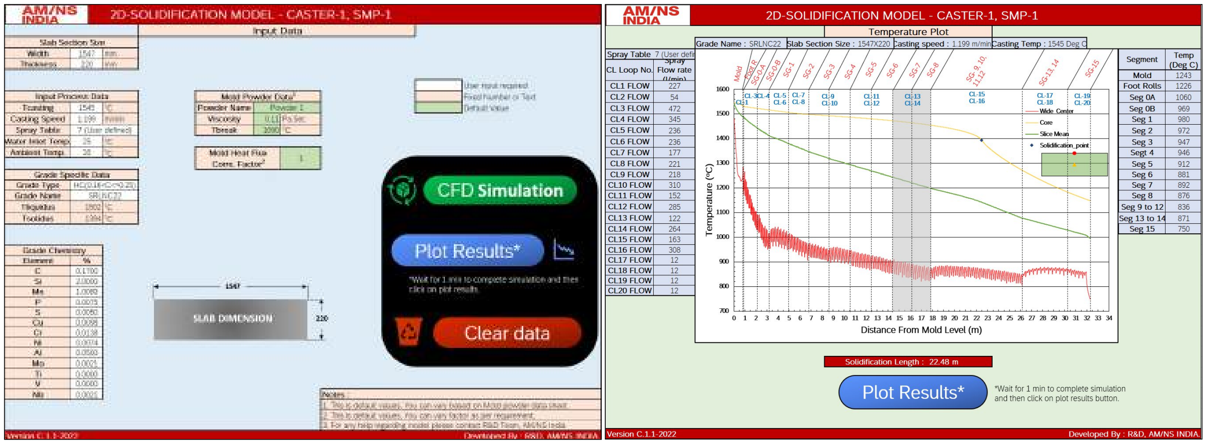
Abstract

The continuous casting process involves complex heat, mass, and metallurgical phenomena. It is very difficult for metallurgists and process engineers to predict the behaviour of the involved complex production process and optimize parameters before using them in real production. Additionally, accurately measuring the slab temperature along the length of the continuous caster on the shop floor is practically difficult, which is crucial for solving slab quality issues. Traditionally, new product development and process optimization rely on numerous plant-scale physical trials, which are time-consuming and money intensive.

In this work, a first-principle-based two-dimensional heat transfer and solidification model for continuous casting of liquid steel was developed using the open-source computational fluid dynamics (CFD) software OpenFOAM®. OpenFOAM® offers significant advantages over commercial software, including cost-effectiveness, flexibility to integrate additional physics for simulating complex processes, and parallelization capabilities. This approach facilitates the creation of a digital twin for complex processes like continuous casting. The model is validated against actual plant data and enables the evaluation of the effects of different casting conditions, such as casting speed, superheat, and primary and secondary cooling flow rates, slab size, grade chemistry on the thermal and solidification profiles of the strand. The model can also be utilized for virtual training of caster operators. A graphical user interface (GUI) has been created using Excel and VBA script for deploying the model at caster for ease of operation team. The implemented GUI of the model is illustrated in Figure 1.

CMS_021



(a) (b)

Fig. 1: Graphical user interface (GUI) layout (a) Input Data (b)Output Temperature Plot

Key words : Continuous casting, Solidification Model, Primary and Secondary cooling, OpenFOAM

Proactive Detection and Mitigation of Channeling Events in Blast Furnaces using Advanced Analytics

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Abstract

Ensuring the stable and efficient operation of blast furnaces is a critical challenge in the iron and steel industry. One such phenomenon that can disrupt blast furnace performance is "channeling", where the ascending gases become disconnected and rapidly escape the furnace without adequate heat exchange and reactions with the burden material. Channeling events can lead to severe consequences, including rising top temperatures, damage to gas cleaning facilities, and deterioration in blast furnace performance metrics like increased fuel rates, etc.

A framework for "Channeling Prediction in Blast Furnaces (CPBF)", which leverages advanced machine learning techniques to enable early detection of channeling has been developed. This helps mitigation of the factors contributing to channeling events. The proposed approach combines spatial and temporal data analysis with the progression of operational data to enable early detection of channeling occurrences. The CPBF framework employs a two-pronged approach, incorporating both unsupervised and supervised machine learning techniques. In the unsupervised phase, the model utilizes clustering algorithms, such as K-Means, K-Medoids, and DBSCAN, to identify abnormal events (e.g., slips, hangs, and drops) and label the 24-hour periods preceding these events as "abnormal batches". Conversely, "normal batches" are identified based on production and availability criteria.

In the supervised phase, the identified abnormality signals are used as the target variable, and different machine learning and deep learning classification algorithms including ensemble models are trained to predict the occurrence of channeling events with a lead time of 1, 2, and 4 hours. These predictive models leverage a comprehensive set of features, such as stave rib thermocouple readings, top gas pressure, uptake temperature, exit gas composition, cold blast flow rate, blast pressure, oxygen flow rate, skin flow temperature, wall pressure, event logs (or radar data), production rate, and availability.

The machine learning-driven CPBF framework represents a significant advancement in the field of blast furnace monitoring and control, providing operators with a powerful data-driven tool to visualize, detect, and mitigate the root causes of channeling events. This innovative approach enhances the overall efficiency and reliability of the iron and steel production process, with the potential for widespread adoption in the industry.

MPR_034

Fluid flow and heat transfer during injection molding of PET

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Abstract

Injection molding, a most common processing method for thermoplastics, is a cyclic replication-based molding process ideally suited to produce mass components with extreme repeatability. The thermo-mechanical conditions inside the cavity affect the morphology and properties of the final component, with thermal contact resistance (TCR) at the polymer/mold interface being a critical factor.

A 16 kN pneumatically operated vertical injection molding machine (experimental setup) was designed and fabricated to estimate polymer/mold interfacial heat flux transients during the cyclic process. The PET (Poly Ethylene Terephthalate) melt from the heated barrel is injected into the mold cavity under pressure. The mold filling time, velocity, and shear rate profiles of the melt were assessed by the time delay in the response of the adjacent K-type thermocouples placed in line with the melt flow direction. Experiments were conducted at a melt injection temperature of 280°C and the maximum shear rate at the wall during mold filling was found to be 45 s^{-1}. The study also examined the wettability of polyethylene terephthalate (PET) melt on steel substrates, considering surface roughness and temperature. Contact angle measurements showed temperature had a greater impact on wetting than roughness. Surface free energy of steel decreased by 22% as roughness increased from 0.21 µm to 3.8 µm. After the filling stage, the melt cools down to the ejection temperature by rejecting heat to the mold. By utilizing the recorded temperature history of the mold, an inverse heat conduction problem (IHCP) was adopted to estimate the spatio-temporal heat flux transients at polymer/mold interface and thus the mold surface temperature. The interfacial heat flux transients were then used to simulate the cooling behavior of the polymer melt. The peak heat transfer coefficient (HTC) was found to be 5775 W/m^2K at a dimensionless interface temperature ratio of 0.75. The air gap at the interface evolved with an exponential fit, starting at 4 µm at peak HTC and increasing to about 100 µm by the end of solidification. Peak heat flux corresponded with polymer skin formation on the mold, while peak HTC marked the start of air gap nucleation. Accurate HTC values are essential for reliable simulation of the temperature distribution in the solidifying part, as incorrect values can lead to defects.

Cooling rates affected the opacity of solidified PET melt, quantified by image analysis in MATLAB. Opacity declined sharply at lower cooling rates before stabilizing at higher rates, with three solidification regimes identified: increased crystallization at cooling rates below 8°C/min,

CMS_075

amorphous characteristics at rates above 199°C/min, and a transitional regime at intermediate

rates. No significant difference in mean pixel intensity was observed between PET melts solidified at different substrate temperatures.

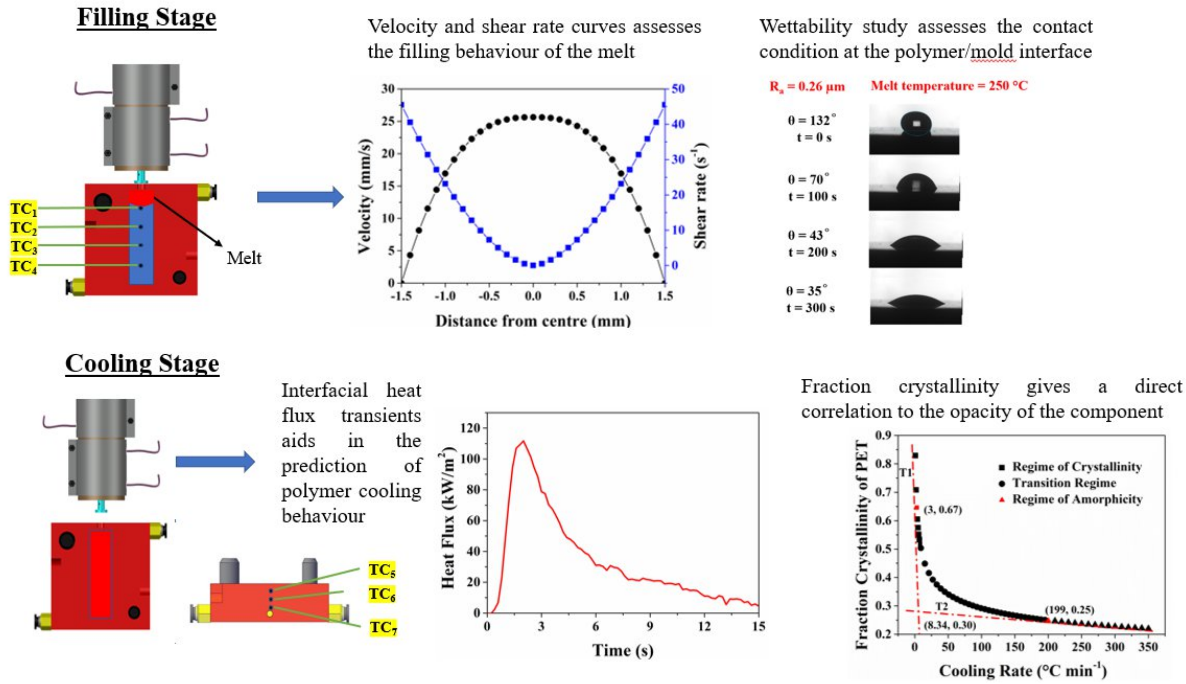

Fig. 1 Graphical representation of the fluid flow and heat transfer during injection molding of PET.

Key words: injection molding; shear rate; wettability; heat flux transients; crystallinity; amorphicity; cooling rate

CMS_075

Solidification Transport phenomena and Microstructure Evolution in Al-7%Si-MWCNT composite: An Eulerian Multiphase flow CFD model

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Abstract

In this study, a comprehensive Computational Fluid Dynamic (CFD) study is performed to understand the effect of the Multi-Walled Carbon Nano Tubes (MWCNTs) addition on the solidification micro mechanisms of Al-7% Si alloy. The work also encompasses a comparative study of the evolution of eutectic silicon, with and without the addition of MWCNTs. The numerical model includes several stages such as optimization of melt stirring conditions to achieve homogenous mixing of MWCNTs within the Al-Si alloy melt, simulation of melt flow through the resistance heating melting furnace sprout, filling of the liquid melt within the cast iron mould and subsequent solidification of the composite melt. The above mentioned CFD model deals with the optimization of the mixing temperature of the composite slurry in the stirring stage, followed by calculation of the sprout exit flow velocity as well as viscosity of the composite-liquid melt during pouring within the cast iron mould. The six phases included in the said multiphase model are liquid phase, dendritic aluminium, equiaxed aluminium, eutectic silicon, MWCNTs, and air. The four evolved phases are quantified by the volume fraction of the evolved microstructure. Further, the grains are considered as volume-equivalent sphere envelope for the equiaxed microstructure, volume-equivalent cylinder envelope for the dendritic microstructure, and volume-equivalent ellipsoid envelope for the eutectic silicon microstructure. The results suggest 650 ℃ as the optimum melt temperature to mix the MWCNTs within the Al-Si alloy melt as well as for die filling. The results reveal that MWCNTs addition to the liquid melt significantly affects the dendritic and equiaxed grain evolution. The addition of MWCNT leads to grain refinement for all three phases namely, dendritic, equiaxed, and eutectic silicon. In addition to this, the model also calculates the solutal Si rejection while solidification of primary Al grains.

The simulation results obtained showed a good agreement with the experimental characterisation of the solidified composite specimens. The volume fractions of the primary aluminium and the eutectic silicon are confirmed by X-ray diffraction (XRD), whereas grain size predictions are validated via grain size measurements of the optical micrographs of the composite specimens. The addition of the MWCNTs lead to grain refinement and redistribution of the eutectic silicon, which in turn increases mechanical properties of the newly developed composite material and makes it worthier for structural, aerospace, and automobile applications compared to presently used cast Al-Si alloys.

Key words: CFD, Solidification, Casting, Composite, MWCNTs, Eutecti

CMS_097

Modelling effect of microstructure on hole expansion ratio of dual phase (DP) steel by RVE approach

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Abstract

In the automotive industries, Dual Phase (DP) steels have become a favoured material for the car body parts due to their excellent combination of high strength and strain hardening capability leading to superior formability offered by its unique microstructure of hard martensitic islands in a soft ferritic matrix. However, DP steels are among the high strength grades which suffer from low stretch-flangeability which is often measured by hole expansion ratio (HER). During the production of DP steels, the volume expansion and shape change accompanying the austenite to martensite transformation is accommodated by the deformation of surrounding ferrite grains. The extent of the deformation in ferrite grains ultimately affects the mechanical properties of DP steels. Ferrite grains can also exhibit a short-range deformation limited to the vicinity of the ferrite/martensite interface. While qualitative prediction of HER in various DP steels using a Representative Volume Element (RVE) approach in a conventional plasticity framework has been studied by many, the effect of martensite island size on the transformation strain and HER values remains largely unexplored. Conventional plasticity models can not predict such size effects and a length scale dependent theory such as Conventional Mechanism-based Strain Gradient plasticity (CMSG) is necessary to model such effects. In this work, CMSG theory has been employed for DP590 and DP780, to study the effect of transformation strain and microstructure on the HER value. Our results indicate that smaller martensite islands are suitable for improved HER and this has been compared with results reported in literature.

Key words: High Strength Steel (HSS), Strain localization, Representative volume elements, Size effects

MFR_077

CFD Modeling of Twin-Strand Slab Caster Tundish

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Abstract

In the steel making process, the presence of non-metallic inclusions can significantly degrade the quality of the final product. Efficient removal of these inclusions during the steel making process and specifically in continuous casting process is crucial. The problem is more severe in the twin-strand tundish, where uneven flow distribution of molten steel causes variations in slab quality and potential operational disruptions. These issues can be mitigated through optimized tundish design and improved flow profiles. This study focuses on optimizing flow modifiers in a twin-strand slab caster tundish to enhance the flow distribution of molten steel, resulting in improved inclusion flotation, using Computational Fluid Dynamics (CFD) analysis.

The CFD model was developed for a twin strand slab caster tundish and studied with different flow modifiers to observe flow patterns and inclusion trajectories. The model was built using ANSYS Fluent commercial software with poly-hexcore meshing. The SST $k-\epsilon$ model was used for turbulence, and the Discrete Phase Model was incorporated for inclusion tracking. Various flow modifiers, such as dams, weirs, and turbulence inhibitors, were introduced into the model to evaluate their impact on inclusion behaviour. The simulations revealed that the strategic placement and design of these modifiers could significantly enhance inclusion flotation. For instance, dams create low-velocity zones where inclusions can float to the surface more efficiently, while turbulence inhibitors reduce high-energy eddies that entrain inclusions deeper into the molten steel. Various configurations, such as existing and higher dam heights, weirs at varying locations, and turbostoppers with cuboid and round shapes, were simulated. Based on CFD results, the optimized configuration of flow modifiers is proposed to improve inclusion flotation and improve the overall steel quality.

Key words: Computational Fluid Dynamics (CFD), Inclusion flotation, Twin-strand tundish, Flow modifiers, and Flow profile.

CMS_085

Heat transfer model for Stelmor cooling of wire-rod and prediction of properties

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Abstract

Wire rod cooling process on Stelmor is modelled to predict the temperature profile and the phase transformation. A numerical heat transfer model is considered which considers the effect of phase transformation during the cooling process. In this work we have used the semi empirical model of Kirkaldy and Venugopalan for the computation of isothermal transformation curves to evolve various phases during the cooling process. The phase evolution is governed by the Avrami equation. Furthermore, we have included the effect of geometry of wire rod as it plays important role since the wire density along the lateral direction increase towards the edge that changes the heat transfer coefficient. Using this model, we can predict the occurrence of recalescence start and end position, the fraction of each phase formed and physical properties such as UTS and hardness.

Key words : wire-rod, Stelmor, heat transfer

References:

1. P. K. Agarwal and J. K. Brimacombe, Metall. Trans. B, 12B (1981) 121.
2. P. C. Campbell, E. B. Hawbolt and J. K. Brimacombe, Metall. Trans. A, 22A (1991) 2791.
3. M. Avrami, J. Chem. Phys, 9, (1941) 177.
4. D. P. Koistinen and R. R. Marburger, Acta Metall., 7 (1959) 59.
5. J. S. Kirkaldy and D. Venugopalan, Phase Transformation if Ferrous Alloys, D. A. R. Marder and J. I. Goldstein, eds., AIME, New York, NY, 1983, pp. 128-48.
6. A. Lindemann and J. Schmidt,J. Mater. Process. Technol. 169 (2005) 466–475.

CMS_028

Three-dimensional Modelling of Gas-Solid-Fines Flow in an Ironmaking Blast Furnace

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Abstract

The ironmaking blast furnace is a counter-current reactor[1] in which iron ore in the lump, sinter, or pellet form and coke is charged from the top and the hot air is injected from the tuyeres located around the periphery at the bottom. As the hot blast air enters into the coke bed it forms a recirculating zone known as the raceway[2]. The coke particles burn in this zone and as a result, reducing gases are generated. These reducing gases while moving up reduce the downward descending solid burden of iron ore. Over the years it has been found that the injection of pulverised coal fines into the blast air can reduce the coke consumption [1]. However, the unburnt pulverised coal, and coke fines generated by the mechanical degradation of it, reduce the permeability of the coke bed in the dropping zone affecting the production and smooth operation of the furnace[2].In addition, the molten metal/slag also flows discretely[3] from the cohesive zone, making the blast furnace a complex multiphase reactor. Thus, it is imperative to study the gas, solid and fine flow behaviour & interactions in three dimensions in the presence of the cohesive zone.

In this work, the gas, solid fine flow behaviour in 3D in the presence of the cohesive zone is investigated. All three phases i.e. gas, solid and fines are modelled as a continuum. The impact of various operational factors, including gas flow rate, solid flow rate & size, fine flux & size, tuyere opening size, and selective tuyere shutdowns is presented. The analysis is substantiated by validation using data from the literature. This model forms a basis for implementing the heat and mass transfer phenomena for the full-scale ironmaking blast furnace.

Keywords: Three-dimensional modelling, Raceway, Cohesive Zone, Selective Tuyere Shutdowns

References:

[1] Y. Omori, Joint Society on Iron and Steel Basic Research, The Iron and Steel Institute of Japan, Blast Furnace Phenomena and Modelling, Springer Netherlands, Dordrecht, 1987. https://doi.org/10.1007/978-94-009-3431-3.

[2] Smita Kamble, Ferdin Donbosco, Govind Gupta, Effect of raceway shape and size on gas and fines flow behaviour in a packed bed, *Metallurgical and Materials Transactions B*, April 2022, Vol. 53, pp 2117-2131, DOI: 10.1007/s11663-022-02512-7

[3] Venkat Arunchaitanya GADI & Govind Sharan Gupta, Discrete Liquid Flow Behavior in a 2D Random Packed Bed, *ISIJ International*, Vol.63 (2023), No. 5, pp. 810-821, https://doi.org/10.2355/isijinternational.ISIJINT-2022-529

CMS_097

Dynamic simulation-based approach to develop process model to predict metal recovery in industrial operation

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Abstract

Non-ferrous metals are indispensable for a modern sustainable society and are a functional necessity for every object used in day-to-day life. Treating these metals at high temperatures in pyrometallurgical reactors requires a thorough understanding of thermodynamics, process flows, and reaction mechanisms. The challenge intensifies when processing secondary non-ferrous scrap, which may contain 20-30 elements or even more and produce thousands of compounds under furnace conditions. Given the complexity of the charge mix, it is paramount to digitally simulate the metallurgical processes which can predict the output from the reactors close to reality. Modern thermodynamic modelling tools enable us to understand the process dynamics and determine the optimal operating point for the desired output. This paper focuses on thermodynamic modelling of a processes active in the furnace to recover valuable metals from copper scrap. The type of furnace to be used to process the raw material is SMS group in house tilting refining furnace (TRF) which is a flexible unit that enables melting, refining, and casting in the single unit. The developed model offers a detailed insight into the process mechanisms within the furnace, thereby allowing better control over the output.

Key words: Non-ferrous metals, Copper, recovery, simulation, tilting refining furnace

NFM_049

3D Continuous caster model using reduced order modelling

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Abstract

Defects in continuous casting of steel lead to downgrading or rejection of steel products which affect productivity. Severe defects such as breakouts also lead to downtime of the caster. Prediction and prevention of these defects are of utmost importance for optimum operational performance and improved product quality. Traditional three-dimensional (3D) numerical methods have helped to simulate and visualize the complex thermofluidic interactions occurring in caster to predict the thermal and thermo-mechanical state of the solidifying strand. This has immensely facilitated in optimizing the casting process and have often been reported in literatures. However, such models are computationally expensive and fall short in real-time predictions. In recent days, data-based models have shown promises in identifying complex combinations of various physical phenomena using historical data and numerical algorithms. In the present work, a Reduced Order Model (ROM) has been developed for a slab caster using Computational Fluid Dynamics (CFD) simulations and Fluent ROM Builder software. The model predicts thermal and thermo-mechanical state of the caster within the operating range and has been validated with existing thermo-fluidic solidification models. The analysis of thermo-mechanical data can help to predict occurrence of cracks in the surface and sub-surface of the slab. The present model will enable real-time analysis of the process parameters, alleviate the computational burden posed by higher order CFD models and open up new avenues for process control and prediction of defect in the caster.

Keywords: Reduced order models, continuous casting, numerical modelling, defects, thermo-mechanical

CMS_014

Improvement in steel cleanliness in central strand of a billet caster using water modelling

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Abstract

In continuous casting, the size and design of tundish has changed significantly, over the years. Multi-strand, billet casters are now commonly used in large integrated steel plants for achieving higher productivity, but have difficulty in controlling the flow dynamics in the tundish. JSW Steel, BPSL operates a 13 T, 3-strands billet caster. This tundish has trapezoid shaped turbo stopper and have side dam of only 90 mm height. The close proximity of central strands to the ladle shroud results in increased amount of inclusions and have inferior internal soundness. It is expected that, there is possibility of improvement the steel cleanliness in the existing practice and used tundish designs. With an aim to improve the steel cleanliness in central strands, water modelling studies carried out on 0.5 scale perpex model using Froud no. similarity. Based on water modelling results, Trapezoid shaped turbo stopper was replaced with circular turbostopper, inverted V dam introduced at central strand and height of side dam was increased from 90 mm to 130 mm. Full scale plant trial has been taken at JSW Steel, BPSL. Plant trials demonstrated reduction in inclusion area percentage of 53 % at billet stage. These reductions were achieved without any adverse effects on the internal structure of the billet, confirming an improvement in the steel cleanliness at the central strands.

Key words **:** Steelmaking, Continuous casting, Water modelling, Tundish, Billet

ISM_160

Development of Packed-bed Solver using OpenFOAM®: Application to Straight-Grate Iron Oxide Pellet Induration Furnace Simulation

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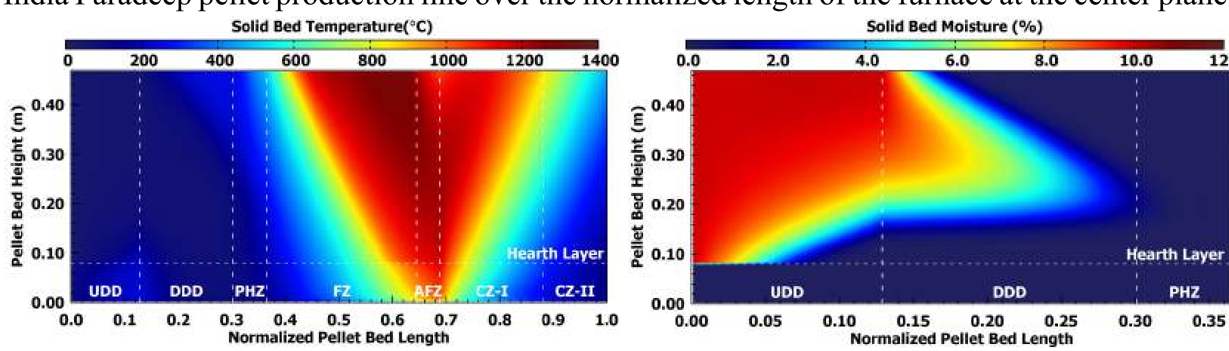
Abstract

Commercial Computational Fluid Dynamics (CFD) packages lack the flexibility to integrate additional physics for developing packed-bed simulation tools for complex metallurgical processes, such as pellet induration furnaces, sintering, Direct Reduced Iron (DRI) modules, and blast furnaces. These solutions are also unsuitable for online deployment in plant operation control rooms. As a result, many researchers have developed models using in-house codes, but these models often lack computational efficiency, parallel processing capabilities, and robustness. This work leverages the flexibility and parallelization potential of open-source codes by developing a comprehensive packed bed solver using OpenFOAM® to simulate the straight-grate iron oxide pellet induration furnace.

The induration furnace is designed for efficient heat and mass transfer between the pellet bed and the flowing gas. The model includes various physicochemical phenomena, such as gas-solid heat and mass transfer, drying and condensation of moisture, carbon combustion, limestone calcination, and the kinetics of LOI removal from hydrated iron ore. The model has been validated against experimental and numerical data from the literature and extensively validated against plant-scale Thermo-Car test conducted at AM/NS India Paradeep pellet plant. The model facilitates the evaluation of the effects of changes in different furnace operating parameters on the thermal and chemical state of the pellet bed. Figure 1 illustrates the thermal and moisture contours of AM/NS India Paradeep pellet production line over the normalized length of the furnace at the center plane.



(a) Thermal contour (b) Moisture contour

Fig. 1: Model results for AM/NS India Paradeep pellet production line

Key words : OpenFOAM® Solver Development, Mathematical Modelling, Packed Bed Simulation, Straight-Grate Pellet Induration Furnace

CMS_023

Thermodynamic Assessment of ZnO-Nb2O5 Quasi-Binary System

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Abstract

Zn-Nb-O is a potent system for several functional applications. E.g. batteries. Effective exploitation of the system requires comprehensive knowledge on phase diagram and thermodynamic properties. The most robust method to serve this purpose is CALPHAD (CALculation of PHAse Diagram), which requires thermodynamic description of the system in the form of a database readable by a CALPHAD software. The existing database, SSUB, in the Thermo-Calc software [1], lacks sufficient information on Nb-O-Zn system, especially in the ternary domain, e.g., In ZnO-Nb_2O_5 system, certain experimentally reported compounds [1,2] are not assessed. In the present work, description for ZnO-Nb_2O_5 quasi-binary domain is generated as a part of Zn-O-Nb ternary system by thermodynamic assessment procedure, a domain of CALPHAD approach. Both thermochemical and phase-equilibria data are collected from the literature and critically analysed. The thermodynamic description for the end members were collected from SSUB database. Appropriate thermodynamic modelling of the phases is done followed by optimization using Thermo-Calc software. A database file is compiled and the respective phase diagram is calculated. Experimental datapoints have been superimposed and they align extremely well with the calculated diagram, indicating the accuracy of descriptions generated.

Key words: Phase diagram, Thermodynamic assessment, CALPHAD, phase-equilibria, Thermodynamic model.

References:

[1] A.J. Pollard, Note on the System Niobium Oxide-Zinc Oxide, 1960.
[2] R.R. Dayal, THE BINARY SYSTEM ZnO-Nb,O, n.d.

CMS_033

Gas aspiration in ladle shroud and its impact on tundish process perfpormance: a physical and mathematical modeling study

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Abstract

A modern-day tundish not only acts as a reservoir but also has become a crucial reactor for non-metallic inclusion floatation, thus improving the steel products' quality. Tundish hydrodynamics plays an important role in determining the inclusion floatation efficiency, hence, various flow modifiers such as pouring boxes are commonly used. In general, tundish macro-mixing characteristics, determined *via* the residence time distribution (RTD) curve, are employed to assess its ability to float out inclusions qualitatively.

In continuous casting of steel, during shrouded teeming of molten metal from a ladle to tundish, gas (air and/ or argon) aspiration occurs due to the presence of imperfect mounting ladle shroud onto the collector nozzle, in addition to the presence of structural irregularities at the joint. The aspired gases travel with the downflowing melt in the ladle shroud, and upon exiting the shroud, penetrate to a certain distance in the tundish, before eventually rising towards the steel-slag/ air interface due to buoyancy. The phenomenon of gas aspiration and the resulting two-phase flow in the ladle shroud have been extensively investigated. However, the possible influence of gas aspiration in the ladle shroud on the tundish hydrodynamics and associated phenomena have not been discussed at length.

The present study aims to investigate and re-evaluate the role of gas aspiration in the ladle shroud on the tundish hydrodynamics and macro-mixing characteristics *via* physical and mathematical modeling. To this end, fluid flow and RTD in a full-scale, two-strand bloom casting tundish have been investigated numerically and experimentally. Prior to using the numerical model (volume of fluid-based two-phase turbulent flow model) to make predictions, the model has been validated with experimental measurements. The numerical results in conjunction with the physical modeling results indicated that the gas aspiration altered the mean flow and turbulence in the vicinity of the shroud outlet and caused early reversal of the shroud jet due to the buoyancy of the aspired gases. These increased the flow intensity near the water-air interface, resulting in the reduction of plug flow volume from 13.75% to 7.69% with an increase in the gas aspiration rate from 0% to 10%. Thus, the increase in the gas aspiration rate is expected to reduce the tundish's inclusion floatation efficiency. Most importantly, however, the gas aspiration drastically cuts down the interaction between the shroud jet and the pouring box due to the early jet reversal, making the specific design and shape of the pouring box redundant.

Keywords: Residence time distribution, steel cleanliness, air aspiration, volume of fluid, two-phase flows
CMS_056

To Study the Effect of Shell and Solid Elements used in Stretch Forming Simulations of Thick Austenitic Stainless Steel Sheets.

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Abstract

Austenitic stainless steels are widely used for engineering applications due to their strength combined with relatively good formability. Forming of sheets with thickness above 2-3 mm is a challenging process because of high degree of spring back and issues with formability. For an effective forming result accurate prediction through FEA becomes necessary. The core of finite element analysis (FEA) is breaking down parts into individual pieces (or finite elements) to be able to solve the analysis. Using the correct type of element and applying mesh properly is very important to the results of the simulation. This paper focuses on two main type of elements that are used in FEA i,e. shell elements and solid elements. For FE simulations of sheets metal forming generally shell elements are used because in thin sheets one dimension is much smaller than other two dimensions. Shell elements decouple the deformation on the surface and the deformation in through thickness direction, allowing for a simple and efficient simulation of thin sheets. In this study we have used an austenitic stainless steel sheet of 4 mm thickness hence in this case the stress distribution through the thickness plays a pivotal role. Therefore solid elements will also be used to incorporate the through thickness stresses for accurate forming predictions. Solid elements are the most common type of element but are also the most resource intensive element to use. Solid elements can represent practically any geometry and do not carry the inherent geometry simplification used by shell elements. Solid elements will always give the most accurate geometric representation and stress results. In this study numerical simulation of stretch forming is performed on a 4 mm thick austenitic stainless steel sheet using the finite element code ABAQUS with shell and solid elements in order to compare the computational efficiency of these types of elements. The results highlight the potential of considering solid elements in case of a thick sheet to get an accurate prediction through numerical simulations.

Keywords: Finite Element Analysis (FEA), Shell element, Solid element, Stretch Forming, ABAQUS.

References:

[1] J. Coer., H. Laurent and M.C. Oliveira., 2018. Detailed experimental and numerical analysis of a cylindrical cup deep drawing: Pros and cons of using solid-shell elements: International Journal of Material Forming , 11, p.357-373.

MPR_378

J. Adam., J. Rotter., 2013. Solid or shell finite elements to model thick cylindrical tubes and shells under global bending: International Journal of Mechanical Sciences, 74, p.143-153.
[2] L. Caro., M. Schill., K. Haller., 2020. Damage and fracture during sheet-metal forming of alloy718: International Journal of Material Forming, 13, p.15-28.
[3] T. Stoughton., J.W. Yoon., 2011. A new approach for failure criterion for sheet metals: International Journal of Plasticity, 27, p.440-459.
[4] M. Anderson., F.Bridier., J. Gholipour and P. Wanjara., 2016. Mechanical and Metallurgical Evolution of Stainless steel 321 in a Multi-step Forming Process: Journal of Materials Engineering and Performance.
[5] K. Prasad., S. Panda., S. Kumar and M. Sen., 2017. Microstucture, Forming Limit and failure analysis of Inconel 718 Sheets for Fabrication of Aerospace Components: Journal of Materials Engineering and Performance, 26, p.1513-1530.
[6] Y. Cho., J. Yee., 2021. Modelling of Ductile Damage Fracture for SS275Structural Steel Sheets:Appl.Sci., 11, 5392.

MPR_378

Optimization of heat treatment parameters through CALPHAD based simulation to achieve high performance Al6061 alloy

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Abstract

Heat treatment parameters has a significant effect on the microstructure and mechanical properties of the alloys. Optimization of heat treatment parameters through thermodynamic simulation software is a time saving and cost-effective techniques. In this work, heat treatment parameters of Al6061 alloy were efficiently designed through CALPHAD technique. Phase fraction simulation demonstrate that a good compressive performance was attributed to numerous precipitates such as Mg_2Si, Al_2Cu and Mg_5Si_6 respectively, that possess the strong coherent with Al matrix. It is also notable that number of metastable phases decreases gradually with the increase in aging heat treatment temperature. The optimal aging treatment parameter for the alloy is 180º C for 12 hours, and the yield strength reaches at this time to 416 MPa. Precipitation strengthening (279 MPa) have higher impact in resulting yield strength as compared to gran boundary strengthening (1.0 MPa), solid solution strengthening (31 MPa) and work hardening (32 MPa) respectively.

Key words: Al6061, ICME, yield strength prediction, strengthening mechanism.

CMS_077

Improvement of Zinc utility for Ductile iron pipe surface coating using Arc spray simulation

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Abstract

DI pipe largely replaced cast iron pipe as the prominent material in the water industry. Experimental research and industrial case histories concluded that ductile iron possesses competitive corrosion resistance compared to steel when exposed in corrosive underground service environments. However, DI pipe does not fail in the same way or at the same rate as pipe made of other materials. DI pipes are Zinc coated externally to provide sacrificial corrosion prevention. Zinc coating serves as a metallic barrier from moisture that reaches the surface of the coated object. Zinc is more electrochemically active than iron, hence prevents the formation of small anodic and cathodic regions on the surface of the metal delaying the corrosion of iron. Zn coating on DI pipes is carried out using Zn wires having diameter 3.17 mm and purity 99.99%, see Fig. 3. The wire is kept at some distance and current is passed through them. An electric arc gets generated causing metal to melt in the closed vicinity of arc. Compressed air is passed to produce atomized metal droplet. It is frequently used in industries for dense coating with more bond strength.

Industries reportedly declared that the Zn coating process has only 65% Zn utilization where rest 35% is a wastage. Considering the wastage an estimate reveals that the projected loss is around 18 Cr INR yearly. Literature review demonstrates that arc spray involves complex physical process such as interaction of molten metal droplets with surrounding through convection, impingement of molten metal droplets on substrate, and phase change of droplets involving latent heat release. Predominantly researchers have divided the problem in three sections viz: flow inside the gun, flow in the spray domain and splat formation. In this perspective the main aim of the present study is the real time estimation of zinc coating thickness formed on the rotating substrate so that, the spraying distance, orientation of spray gun, pipe rotation, auxiliary air pressure and its associated parameters can be optimised to reduce the wastage of zinc. To address the issue at TSMD, the following approaches have been finalized:- a) Design study and optimization of arc spray gun geometry b) Optimization of splat formation and particle flow on the substrate using numerical simulations c) Corelation of the above study with Zn coating parameters online during production d) Experimental approach to validate numerical simulation results e) Final recommendations to modify the line parameters expectedly to meet reduced Zn wastage.

CMS_095

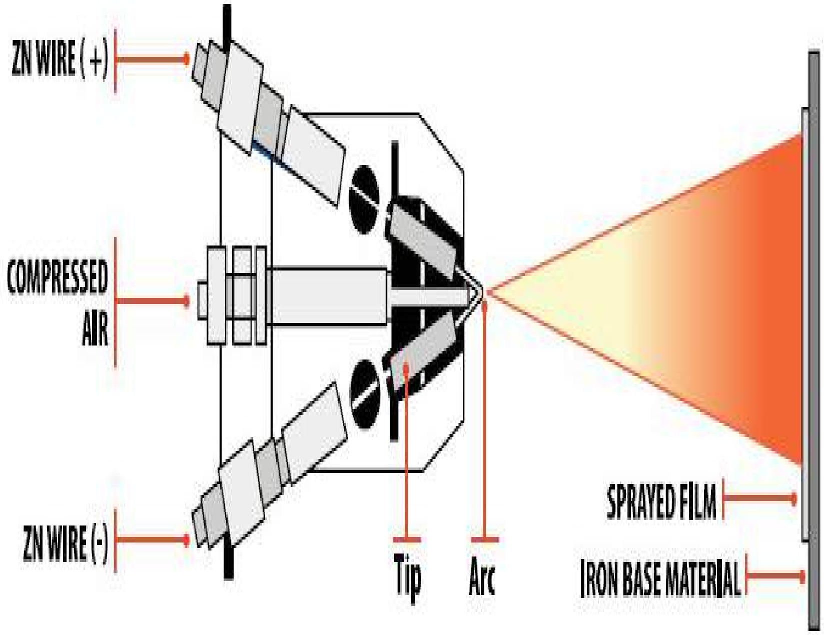

Fig.3. Zn coating of DI pipes by Arc spray method, schematic diagram

Key words : Atomized, Impingement, Splat formation

CORROSION, ELECTROCHEMICAL & BATTERIES

Oral Abstracts

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[COMPANY NAME]
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A novel route to fabricate Bilayer Electrolyte for Solid-State Sodium-ion Battery

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Abstract

Solid-state sodium-ion batteries (Na-SSB), the next-generation energy storage system, are progressively developing. High interfacial resistance between electrode-electrolyte interface and poor tolerance to sodium dendrites are the two biggest bottlenecks in developing Na-SSB. However, designing a dense/porous bilayer electrolyte and integrating the electrode in a monolithic architecture has emerged as a viable solution[1], [2] The strategy not only reduces the interfacial resistance but also allows a high active material loading leading to an increased energy density of the cell. The main challenge during conventional synthesis is the loss of the electrolyte's porous structure. Therefore, a novel methodology for designing bilayer electrolyte using a cold sintering process (CSP) was investigated. CSP lowers the densification temperature, resulting in a relatively more porous structure with sufficient mechanical strength compared to the conventional method. In this study, the coin cell was fabricated with Mg-doped NZSP as an electrolyte, $Na_3V_2PO_4$ (NVP) as a cathode and Na-metal was used as an anode. NVP precursor was infiltrated into the porous scaffold of the solid electrolyte. The electrochemical performance of the cell with varying electrode loading will be discussed.

References

[1] Y. Lu, J. A. Alonso, Q. Yi, L. Lu, Z. L. Wang, and C. Sun, "A high-performance monolithic solid-state sodium battery with Ca2+ doped Na3Zr2Si2PO12 electrolyte," Adv Energy Mater, vol. 9, no. 28, p. 1901205, 2019.

[2] T. Lan et al., "Room-temperature all-solid-state sodium batteries with robust ceramic interface between rigid electrolyte and electrode materials," Nano Energy, vol. 65, p. 104040, 2019.

CEB_025

Effect of sintering technique and microstructure on the ionic conductivity of Co-doped Na3Zr2Si2PO12 solid electrolyte for all solid-state sodium ion batteries

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Abstract

Solid electrolyte is an important functional ceramic in all solid-state batteries (ASSBs) but its ionic conductivity is one of the great challenges for commercialization of ASSBs. Grain size, grain boundary area, impurities, thickness of solid electrolyte and its compatibility with electrodes are the crucial parameters which affect electrochemical properties of all solid-state batteries. Sodium superionic conductor (NASICON) based solid electrolyte got immense attention in the research due to its high ionic conductivity, good air and thermal stability and easy processability. Co-doping at Na and Zr simultaneously can be elegant strategy to achieve optimized Na-ion concentration and better control of bottleneck size. Aliovalent substitution in Zr site creates vacancies due to charge disbalance and this charge disbalance is compensated by substitution of aliovalent element in Na site. The present work is focused on the effect of conventional sintering (CS) and spark plasma sintering (SPS) processes on the ionic conductivity of La and Zn co-doped $Na_3Zr_{2-x}Zn_xLa_{0.66x}Si_2PO_{12}$ ($NZZLSP_x$). Here, the difference in grain and grain boundary conductivity has been reported for conventional and spark plasma sintered samples. The relative density of sintered samples has increased in both the sintering processes on co-doping. The density of spark plasma sintered pellets was increased from 3.15 to 3.33g/cm^3 whereas from 2.76 to 3.07g/cm^3 for conventional sintering upon doping. Such significant change in density after La and Zn co-doping may be due to the doping of higher density elements or formation of higher density secondary phase. Rietveld analysis of XRD patterns of the samples reveal the main phase along with impurity phases such as $Na_2ZrSi_4O_{11}$ and $ZrSiO_4$ present in the sample. For both the sintering processes, the highest ionic conductivity is obtained in $NZZLSP_{0.04}$ sample which is 0.252 mS/cm for conventional sintering and 0.172 mS/cm for spark plasma sintering. It is observed that there is a huge difference in highest grain conductivity obtained after doping between CS (0.589mS/cm) and SPS (6.19mS/cm) pellets. Such significant difference in grain conductivities may be due to the grain size as the grain size of SPSed pellets are smaller than the conventionally sintered pellets.

Keywords: Solid electrolyte, Spark plasma sintering, Ionic conductivity, NASICON, Impedance spectroscopy

CEB_030

Electrodeposited Sb-Sn-Cu ternary alloy negative electrode for lithium-ion batteries: effect of composition on lithiation behavior and structural integrity

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Abstract

Tin antimony-based ternary alloys have emerged as promising negative electrode materials for lithium-ion batteries owing to their higher gravimetric (2–3 times because of intermetallic formation) and volumetric capacities (6–8 times higher as Sn and Sb are denser than graphite) compared to graphite. Furthermore, these metallic alloys are highly conductive and do not require the addition of any conductive agents. They can also be electrodeposited owing to their conductivity and do not require any binder, as in the powder-coating process. Therefore, not only the material but also the cell design (devoid of binder and conductive agent) enhances the volumetric capacity to a large extent. These alloys (SbSnCu) are easy to electrodeposit, and based on the bath composition (Sn- or Sb-rich), different phase mixtures can be synthesized under similar electrodeposition conditions. These alloys undergo active-active-inactive chemical buffering during lithiation to mitigate the stress caused by volume expansion. Therefore, the phase combination with more lithiation/delithiation steps can better resist the volumetric expansion during cycling.

In this study, it was found that Sb-rich alloys exhibit a greater number of lithiation/delithiation peaks than Sn-rich alloys, indicating better buffering during volume expansion/contraction. It also shows that lithium-inactive copper, which is inactive to Li and deforms plastically to mitigate volumetric stress, acts as a better stress buffer in Sb-rich alloys than in Sn-rich alloys because of the difference in lithiation profiles. The combination of these two phenomena (better buffering through a greater number of lithiation peaks and better use of Cu as a stress arrester) imparts more structural stability to the Sb-rich SbSnCu alloy, which is reflected in its electrochemical performance. The Sb-rich alloy delivered a specific discharge capacity of 374 mAh g^{-1} at 200 mA g^{-1} even after the 100^{th} cycle, while the Sn-rich sample failed to retain its initial capacity, delivering only 113 mAh g^{-1} after the 100^{th} cycle. Structural instability and delamination of the active mass were identified as the main reasons for the drastic capacity fading in the Sn-rich sample. In contrast, the Sb-rich alloy maintained its structural stability, losing only 20 % of its pristine capacity in the last 80 cycles. These findings highlight the importance of composition in optimizing the performance of Sb-Sn-Cu ternary alloys as negative electrodes for lithium-ion batteries.

Keywords: Lithium-ion batteries, Negative electrode, Sb-Sn-Cu ternary alloy, Electrodeposition
CEB_032

Effect of rGO on LTO anode electrochemistry for Li-ion batteries

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Abstract:

A high-performance energy storage device is becoming more vital as the demand for electric vehicles (EVs) and hybrid electric vehicles (HEVs) rises in response to their low environmental impact. Nowadays the most promising energy storage technology are the Lithium-ion batteries (LIBs). Spinel Lithium Titanate $Li_4Ti_5O_{12}$ (LTO) is considered a promising anode candidate for high-power LIBs due to its high safety and long cycle life, and the negligible volume change during lithiation. However, the slow Li^+ ion diffusion coefficient ($< 10^{-11}$ cm^2 s^{-1}) and its inherently low electrical conductivity (5.41×10^{-14}S/cm) significantly limit its high-rate performance in LIBs. Nevertheless, the problem could be solved by creating LTO/carbonous composites. Among the possible carbon materials, graphene is believed to be one of the best choices, because of its extraordinary properties like large surface area, ultrahigh electrical conductivity, and excellent mechanical flexibility. As graphene has superior electronic conductivity, it may enhance the poor electron transport mechanism of LTO. Again, it is expected that the LTO-graphene composite would perform better for lithium storage than the pure LTO due to the short Li^+ solid-diffusion distance in the LTO-graphene composite. In this work we had used the reduced graphene oxide (rGO) obtained from coal. India is the second largest producer of coal with the all India Production of coal during 2023-24 being 997.25 MT. Therefore, converting coal into rGO and using it in energy storage may be the best use of coal. However optimising LTO-rGO ratio is of utmost importance. Though a faster, shorter, and more conductive electron transport channel might be offered by the inclusion of rGO, however, it might not be possible to create a continuous conductive network with a low rGO content and a higher rGO percentage may result in the production of an SEI film, and the resulting thicker rGO covering could prevent Li^+ from diffusing. All things considered, in this work, we aimed to develop an optimal compositions of LTO-rGO composite anode for LIBs through a simple, cost-effective method, and environment-friendly process, which won't limit its large-scale applications.

Again, the lengthy charging time of LIBs compared to the time required to refill an Internal Combustion Engine Vehicle is a hurdle to the adoption of Li-ion-based EVs. The EV industry believes that raising the current rate (C-rate) would shorten charging time, however this raises the battery degradation rate. As a consequence, a thorough examination of battery performance at higher C-rates is essential. Consequently, the LTO-rGO anode's battery performance tests at various C-rates were carried out. With limited study and varying results, the present work will certainly aid in understanding the effect of rGO proportion and C-rate on the electrochemical performances of LTO-rGO anode. The results of the present work can be used to design dynamic efficient charging protocols for charging LTO-rGO anodes-based LIBs.

Keywords: Li-ion Battery, Lithium Titanate, reduced Graphene Oxide, Electrochemistry.

CEB_38

Quasi-Solid State Electrolyte For High Energy Density Aluminium-Air Batteries

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Abstract

As per the Paris Accords, there is an urgent need for alternatives to fossil fuels to limit the global temperature to 1.5ºC. In order to achieve this, high-energy density energy storage systems that will fulfil the demands of consumer electronics, electric vehicles, and portable devices are required to be developed in a sustainable manner. Different battery systems are already available on the market, including Li-Ion batteries (LIB) and Lead acid batteries. Due to environmental toxicity, exploring alternatives to LIB is necessary. Metal Air batteries are a potential alternative, especially among the available options; aluminium, being an earth-abundant metal, shows promising results when used in air batteries due to its high theoretical specific capacity (2980 mAh/g) and high volumetric energy density (8.1kWh/kg). Most metal-air batteries employ liquid-based acidic or alkaline electrolytes. Such electrolytes are challenging to handle because of leakage issues, which prevents such technologies from being commercially viable. In our study, we have employed Kaolinite as a quasi-solid-state electrolyte in a mixture of NaOH and KOH with different mass ratios to reduce the HER. The obtained open circuit potential was -1.2V to -1.5V over 2 hours, which shows the stability of the battery. From galvanostatic discharge data, a specific capacity of around 1000-1500 mAh/g and an energy density of about 1.5kWh/kg and up to 3.1kWh/kg was observed. Cyclic voltammetry and Tafel plot show the stable reaction in the operating range starting from -1.5V, making the combination of metal-air batteries a step closer to commercialization.

Keywords: Energy devices, Metal-air battery, Quasi solid-state electrolyte, Energy density, specific capacity.

CEB_049

Investigation of Cobalt-Free Cathode in Lithium-Ion Batteries (LIB)

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Abstract

The escalating demand for lithium-ion batteries is driven by the proliferation of portable electronic devices and electric vehicles. The limited reserves of cobalt, hazardous working conditions, and generation of toxic waste underscores the urgency for sustainable alternatives to cobalt-based cathode materials. However, cobalt's scarcity, price volatility, and geopolitical concerns pose significant challenges. This study investigates manganese as a viable replacement for cobalt in lithium-ion battery cathodes.

With its low production cost, high availability, and high rate capability, manganese emerges as a promising solution. Specifically, this research focuses on Lithium Manganese Oxide (LiMn2O4) as a cobalt-free cathode material. The electrochemical properties of LiMn2O4, synthesized via co-precipitation and ball milling (10 hours, respectively), are thoroughly evaluated. Experimental findings suggest that LiMn2O4 holds promise as an excellent substitute for cobalt-based cathode materials. However, challenges such as cycle fading and capacity loss are observed. To address these issues, aluminum doping is performed. The resulting material, Lithium Manganese Aluminum Oxide (LiMn2-xAlxO4; x=0.01), demonstrates significant improvements. Additionally, LMNO material is also compared with LMO cathode material. Certain amount of Nickel in LMNO is showing high initial capacity as compared with LMO. Composition of final products is Li1.2Mn0.6Ni0.2O2 as LMNO and for better understanding here LMO is LiMnO2. This also follows the coprecipitation method of carbonate and hydroxide separately and tried out several processing techniques to optimize the best output. Vacuum stirrer is used to make slurry of battery material by mixing NMP and PVDF as binder. Glove box is used to make coin cell battery under argon atmosphere. Moisture is avoided from slurry making to production of coin cell. Characterization techniques like SEM, XRD and battery tester is used for test the material and electrochemical performance respectively. Charging capacity and discharging capacity was measured under different C rate. This research provides valuable insights into the feasibility of sustainable alternatives to cobalt-based cathode materials in lithium-ion batteries.

Keywords: Cobalt-free cathode, LIB, LMO, LMNO, Coprecipitation.

CEB_069

Preparation of Lithium Cobalt Oxide Cathode Material from spent Li-Ion Batteries

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Abstract

The increasing demand for lithium-ion batteries (LIBs) has led to significant environmental concerns due to the disposal of spent batteries Lithium-ion battery recycling has emerged as a critical process to address these concerns by recovering valuable materials, reducing environmental pollution, and minimizing resource depletion. Regenerating lithium cobalt oxide (LCO) from spent LIBs offers a sustainable solution by recovering valuable materials and reducing waste. Our study represents a novel process for the regeneration of LCO from spent LIBs. involving purification, and re-Lithiation of spent LCO materials. The regenerated LCO demonstrated comparable electrochemical performance, including capacity, cycling stability, and rate capability, to that of commercially available LCO. This approach not only provides a cost-effective method for material recovery but also aligns with circular economy principles, contributing to the sustainability of the battery industry. The findings suggest that regenerated LCO can serve as a viable alternative to virgin materials, reducing the environmental footprint and raw material dependence in LIB production.

CEB_091

Enabling Advanced Material Research for Fuel Cells, Electrolyzes, and Metal-Air Batteries through Innovative Reactor Systems

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Abstract

The development of new materials for fuel cells, electrolyzers, and metal-air batteries is crucial for advancing energy storage and conversion technologies. To support this research, precise and versatile experimental setups are required. This study presents a detailed analysis of innovative reactor systems, specifically designed to facilitate the study and development of materials for these applications. The developed metal-air battery reactors are constructed with chemically resistant PMMA bodies and are designed to accommodate a variety of metal-air chemistries, including aluminum-air and zinc-air batteries. These reactors facilitate straightforward assembly and disassembly, which is essential for iterative testing and material modifications. The air-cathode performance is rigorously assessed using the developed electrochemical cell setups, which include provisions for precise control of gas flow and electrolyte management, critical for achieving reliable and reproducible results.
The developed electrochemical cell setups incorporate features such as gas-tight seals and adjustable electrode holders, enabling accurate and reproducible studies of air-cathode performance. These setups are compatible with both two-electrode and three-electrode configurations, allowing for comprehensive electrochemical analysis, including cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and chronoamperometry. The precise control over gas flow and electrolyte management enhances the reliability of data obtained from these systems, making them invaluable for investigating the electrochemical behavior of novel catalysts and electrode materials.

The developed water-splitting reactors feature a zero-gap design that minimizes ohmic losses by reducing the inter-electrode distance, thereby optimizing the efficiency of hydrogen and oxygen evolution reactions. The design also incorporates serpentine flow fields to enhance reactant distribution and manage thermal gradients across the electrodes, which are pivotal in studying high-performance catalysts and membrane electrode assemblies (MEAs).

These reactor systems have been utilized in various studies, providing researchers with the capability to systematically investigate and optimize new materials and catalysts under controlled conditions. This has led to significant advancements in understanding the electrochemical performance and durability of materials, particularly in the context of oxygen reduction reactions (ORR) and hydrogen evolution reactions (HER).
This abstract underscores the role of these reactor systems in advancing material science, offering researchers the tools necessary to explore and develop next-generation materials for clean energy applications.

CEB_095

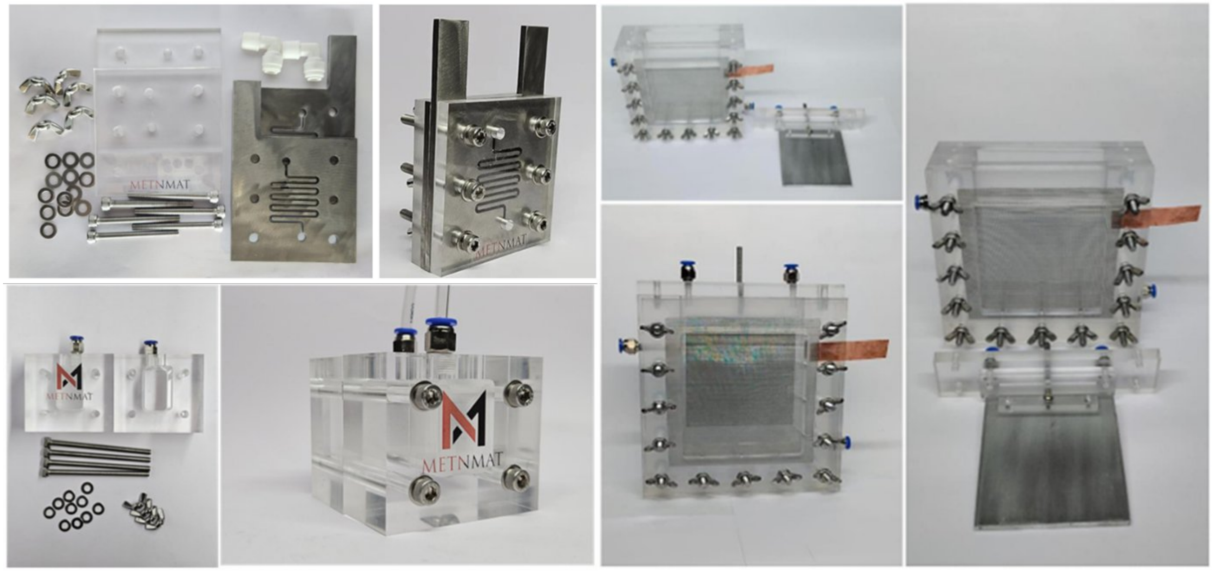

Fig 1: Fabricated Zero-Gap Water Splitting Reactor and Fuel Cell Reactors

Keywords: Hydrogen evolution reaction (HER), Oxygen reduction reaction (ORR), Water Splitting, Electrolyzer, Fuel cells, Metal-air batteries

Cold sintering assisted densification for NASICON-type solid electrolyte for sodium ion battery

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Abstract

The cold sintering process (CSP) is a potential method that enables densification at relatively lower temperatures. Sintering of ceramic electrolytes requires high temperature and longer time and is therefore, very energy-intensive. Moreover, high processing temperature causes material volatilisation as well as the formation of secondary phase(s), deteriorating the properties of the electrolyte. $Na_3Zr_2Si_2PO_{12}$, a promising NASICON-type solid electrolyte for sodium-ion batteries, also suffers the same problem of Na and P loss and formation of unwanted secondary phases (ZrO_2) due to its high temperature sintering at 1250 °C. In the present work, the CSP method is investigated for the sintering temperature of magnesium-doped NZSP, which successfully resulted in the highly-dense pellets at a lowered sintering temperature of 1150 °C. X-ray diffraction, scanning electron microscope and impedance spectroscopy were used for the phase analysis, morphological study and ionic conductivity determination. The obtained data was compared further with samples prepared using the conventional route. A coin cell was fabricated using a dense electrolyte prepared with optimised processing conditions, iron-doped $Na_3V_2PO_{12}$ and Na-Metal as cathode and anode, respectively, to evaluate its electrochemical performance.

CEB_026

High energy density and Fast Charging Lithium-ion battery for EV application

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Abstract

Graphite has been widely used as an anode material for lithium-ion batteries due to its stability and ease of use. However, it suffers from lower energy density, slow current rate capability, and safety issues related to thermal runaway. To address these limitations, significant efforts have been made to improve its performance. One promising approach is to replace the conventional graphite anode with silicon, which offers nearly ten times higher energy density and improved safety. Nevertheless, the major challenge with silicon anodes is their substantial volume expansion (300%) during lithiation, which hinders their commercial viability.
This study explores the use of a silicon@C-graphite composite anode to enhance the energy density of graphite anodes without sacrificing durability. The silicon incorporated into the graphite is porous and synthesized through a novel two-step chemical etching process of a 50-50 Al-Si alloy, which effectively accommodates the volume expansion during lithiation. The resulting porous silicon-graphite composite anodes were prepared using an environmentally friendly water-based slurry. Our findings demonstrate that batteries utilizing this composite anode exhibit excellent cycle stability and significantly higher energy density compared to conventional graphite anodes, making them a promising solution for next-generation lithium-ion batteries.

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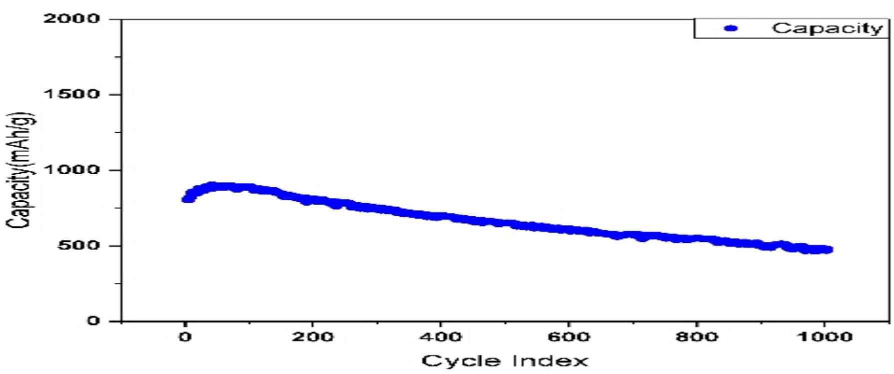

Fig. 1: Cycle life vs Capacity curve

Key words: Porous Silicon, Composite, Capacity, stability

CEB_028

High-throughput screening of Li-ion and beyond Li-ion battery cathodes for electrochemical ion-capture and desalination from aqueous medium

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Abstract

The increasing salinity of freshwater sources, driven by rising sea levels and human activities, demands efficient water conservation and management of industrial brine. Desalination offers a solution by transforming waste brine into a resource, extracting valuable minerals like Li, essential for lithium-ion batteries (LIBs), while producing clean water. Due to the growing demand for Li and its uneven global distribution, desalination provides a sustainable method for extracting Li from unconventional sources such as geothermal brines, seawater, and industrial wastewater. It also facilitates the extraction of other minerals like Na, K, Mg and Ca from seawater.

Traditional desalination methods, including thermal evaporation and reverse osmosis, have high energy costs and limitations. Hence, we focus on electrochemical desalination using intercalation electrodes as an energy-efficient method capable of selectively extracting specific ions (or multiple ions) from varied brine compositions to produce clean water. The most common intercalation electrodes, olivine-$FePO_4$ and spinel-MnO_2, face issues such as slow intercalation kinetics and poor structural stability. While much of the research in this field has focused on overcoming these shortcomings, our approach explores alternative electrode frameworks with superior properties, leveraging the similar working principles of electrochemical desalination and LIBs. LIB and beyond LIB cathodes, which intercalate seawater-abundant cations like Na^+, K^+, Mg^{+2}, and Ca^{+2}, are promising candidates for potential desalination electrodes. However, most of these batteries use non-aqueous electrolytes, and the stability of these battery cathodes in water is not well understood.

Utilizing high throughput computational data generated using density functional theory based calculations, we construct multi-element Pourbaix diagrams to assess their thermodynamic stability in water (at different salt concentrations in water) and calculate the intercalation voltage of water-stable frameworks. We filter frameworks based on the optimum operating voltage for aqueous electrolytes and compare them to identify electrodes that can intercalate either multiple ions or selective ions. Our high-throughput computational study proposes promising candidate electrodes for experimental trials, advancing electrochemical desalination for sustainable mineral extraction and water purification.

Key words: electrochemical desalination, sustainable mineral extraction, water purification
CEB_031

Design and fabrication of redox flow batteries for enhanced energy and power performance

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Abstract

Redox flow batteries (RFB's) are one of the most promising electrochemical energy storage systems considered to be suitable for a wide range of grid energy storage applications. The realm of energy storage, redox flow batteries are increasingly recognized for their safety, scalability, and extended cycle life, making them a promising solution amidst the growing market demands. An essential aspect of improving their viability is the optimization of flow field design, which is critical for efficiently distributing electrolytes across electrodes while decreasing the energy required for pumping. In this context, the new design includes end plates and gaskets to improve safety, extend life, and promote ease of assembly with fewer components than traditional RFB cells flow channels. This work mainly emphasizes two different cell designs which includes the electrolyte flow velocity and pattern which is of critical importance to increase the overall battery performance. The work focus is based on the critical examination of the design patterns and structural optimization of various flow fields, including serpentine, interdigitated, parallel, spiral, and pin-based configurations. It then addresses the challenges and strategies associated with scaling these flow fields for larger applications. The present work also highlights the remaining obstacles and explores future prospects for developing highly efficient flow fields for battery stacks.

Keywords: RFB, electrochemical energy storage, cell design, battery performance, electrochemical performance.

CEB_065

Synthesis of High-Performance Composite Materials via Upcycling of Lead-Acid Battery: Electrochemical Characterization

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Abstract

The rapid growth of the energy storage market has led to an increased demand for lead-acid batteries, resulting in significant amounts of hazardous lead-containing scrap. To address the environmental concerns associated with lead and to enhance the specific capacitance of lead-acid batteries, this work proposes a greener, cost-effective, and short-loop route for upcycling spent lead-acid batteries. The proposed method involves a desulfurization process followed by the synthesis of composite materials. Recovered active materials from spent batteries were integrated with annealed MXene into a recycled material matrix. Structural characterization via X-ray diffraction (XRD) confirmed phase purity and crystallinity, while scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) demonstrated uniform MXene dispersion within the matrix. Electrochemical evaluations, including cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) tests conducted in a 1M H_2SO_4 electrolyte, revealed substantial improvements in electrochemical performance. Notably, the RM3 (recycle material with 3% annealed MXene) electrode exhibited a specific capacitance of 176 Fg^{-1} at 0.25 Ag^{-1} and 112 Fg^{-1} at 1 Ag^{-1}. Additionally, RM3 demonstrated excellent energy and power densities of 13 $Whkg^{-1}$ and 650 Wkg^{-1} at a current density of 1 Ag^{-1}, respectively. This innovative approach not only mitigates the environmental risks associated with lead but also enhances the energy storage performance of lead-acid batteries, contributing to a more sustainable and circular economy in battery technology. Furthermore, this study highlights the effectiveness of MXene, a two-dimensional nanomaterial, as a strategic platform for upcycling materials from spent lead-acid batteries

Keywords: Lead acid battery; MXene; Electrodes; Electrochemical; Recycling

CEB_080

Exploring Fluoride Frameworks as Potential Calcium-ion Battery Cathodes

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Abstract

Calcium-ion batteries (CIBs) are emerging as promising next-generation energy storage devices, offering a viable alternative to lithium-ion batteries due to their high theoretical energy density, enhanced safety, and lower costs from the natural abundance of calcium. However, the progress of CIBs has been hindered by the scarcity of suitable cathode materials. Given the similar ionic radii of Na^+ and Ca^{2+}, structures effective in intercalating Na^+ might also be capable of intercalating Ca^{2+}. In this presentation, we explore transition metal fluorides (TMFs) with weberite and perovskite structures, known for their ability to intercalate Na^+, as potential CIB cathodes. Using first-principles calculations, we investigate weberite and perovskite TMFs of compositions $Ca_xM_2F_7$ and Ca_xMF_3, respectively, where M = Ti, V, Cr, Mn, Fe, Co, or Ni. We systematically assess key cathode properties, including ground state structure, average Ca-intercalation voltage, thermodynamic stability at 0 K, theoretical capacity, and Ca^{2+} migration barriers. Importantly, our calculations identify $Ca_xV_2F_7$ and $Ca_xCr_2F_7$ weberite frameworks as promising Ca-cathodes, demonstrating their potential through computed ground state structure, average voltage, thermodynamic stability, and migration barriers. On the contrary, despite their appealing voltage and thermodynamic (meta)stability, none of the perovskite frameworks are identified as viable Ca-cathodes due to their high Ca^{2+} migration barriers. Our investigation not only unveils potential Ca-cathodes but also paves the way for further advancement in transition metal fluoride-based intercalation Ca-cathodes, expanding the chemical space for next-generation Ca-based energy storage technology.

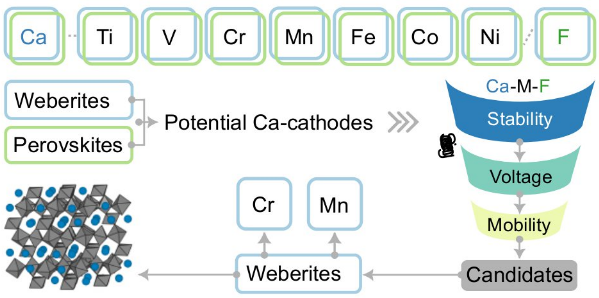

Fig. 1: Computational exploration and discovery of fluoride-based weberites and perovskites as cathode materials for calcium-ion batteries.

Key words: transition metal fluorides, calcium-ion battery, cathodes, density functional theory

CMS_37

Lithium-Ion Battery Resource Management: An Effort to Synthesized Electrode Material from Waste

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Abstract

The lithium-ion battery is considered the most successful energy storage device in the past few decades. Lithium-ion batteries (LIBs) have been extensively used in portable electronic devices, electric vehicles, and in large energy storage devices as well. However, after the end of the life of LIBs, a large amount of e-waste /or battery waste is generated every year. The battery waste contains many valuables. Currently, a small amount of waste is processed for recycling of valuables. However, the battery waste must be recycled fully for sustainable resource management of energy materials. Here we present the recycling of LIBs cathode and anode and the reuse of the regenerated electrode materials for the development of lithium-ion batteries. Additionally, the preparation of lithium iron phosphate (LFP) from the steel industry by-product, cold rolling mill (CRM) iron oxide is also presented.

Keywords: Lithium-ion batteries, LFP, Energy material, cold rolling mill iron oxide, Regeneration

CEB_013

In-situ in-operando XRD to understand battery cell performance under non-ambient conditions

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Abstract

In-operando XRD is an important technique to understand the stability and lithiation behavior of electrode materials, and the associated volume and crystal phase changes, as the cell is cycled. Measurements can be carried out in in a coin cell geometry or in pouch cell configuration. Although synchrotrons are the preferred choice for in-operando measurements, there are numerous publications reporting in-operando measurements with laboratory XRD systems as well. However, there are very few reports of in-operando XRD under non-ambient conditions, particularly using laboratory XRD systems. In this work we developed Variable Temperature Electrochemical Cell (VTEC) – one for the coin size electrodes and another for pouch cell to perform in-operando experiments in -10 to 70C temperature range. Some examples of non-ambient in-operando measurements on LFP and NMC cells will be presented. In-operando measurements help to understand the cause of cell performance degradation at non-ambient temperatures. With the use of Mo or Ag radiation, pouch cells up to 5mm thick could be measured in-operando. Non-ambient in-operando XRD produces very large amount of data. Special software developed to analyze the in-operando data will also be presented.

DM_059

MXene- A potential anti-corrosion coating material for Mild Steel

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Abstract

MXenes, a new family of two-dimensional transition metal carbides, nitrides, and carbonitrides, have emerged as potential materials for improving corrosion resistance. Their distinct mix of high conductivity, mechanical strength, and chemical stability makes them great materials for protective coatings and composites. This study investigates the application of MXenes in corrosion prevention, with an emphasis on their incorporation into various polymer matrices and other coating systems. MXene can improve corrosion resistance by forming physical barriers that delay corrosive agent diffusion, providing cathodic protection via sacrificial anodic behavior, and improving mechanical properties that prevent crack propagation and coating degradation. Furthermore, MXenes' capacity to form passivating layers, as well as their self-healing capabilities, contribute to their efficiency in corrosion prevention. MXene can also be loaded with various corrosion inhibitor molecules to act as a carrier for inhibitor molecules and provide corrosion protection when needed. Through a comprehensive assessment of current research and experimental findings, this study demonstrates MXenes' potential to greatly extend the service life of metal substrates in severe conditions, opening the door for their usage in a variety of industrial applications.

CEB_012

Optimizing Passivation Layer Chromium Content for Enhanced Corrosion Resistance in Galvanized Steel Coils

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Abstract

The surface passivation treatment, involving a thin, typically invisible, corrosion-inhibiting film, is applied to hot-dipped galvanized steel coils. This treatment, most commonly a water-based chromate coating, prevents the formation of white corrosion products during transport and storage. The focus of this work is to understand the impact of the total surface Chromium content of the mixed chrome passivation layer on corrosion inhibition. The objective is to determine the optimal total surface Chromium content that provides the desired corrosion resistance. Over 100 galvanized sheet samples with varying total surface chrome content (5 to 70 mg/m^2) were studied. Varying surface Chromium content was produced using a roll coater by controlling its applicant roll speed and pressure under constant chromate bath parameters (bath chemical composition, bath temperature, pH) and operating parameters (peak metal temperature after coating, and drier temperature). The samples had a base metal thickness ranging from 0.6 to 3mm and Zinc coating thickness from 80 to 250 GSM. Corrosion performance was assessed by exposure to 5% salt fog (ASTM B-117 test procedure) accelerated corrosion tests to predict service life, with passing criteria set as <5% white rust after 120hrs. The study found that total surface chrome content significantly affects the onset of white rust formation, with both the pass percentage and the time to the start of white rust showing a linear increase with the total surface Chromium. Optimal corrosion resistance was observed at a total surface Chromium content around 50 mg/m^2. However, no relationship was established between the onset of white rust, Zinc coating thickness, and base metal thickness. This study contributed to reducing the use of chromium-based passivation chemicals.

Key words: Hot dip galvanized steel, Chromate passivation, total surface Chromium, Salt Spray Test

CEB_037

Effect of prior copper-coating on the microstructural development and corrosion behavior of hot-dip galvanized Mn containing high strength steel sheet

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Abstract

In the present investigation, the role of copper (Cu) pre-coating has been studied for the development of good quality corrosion-resistant hot-dip galvanized (GI) coating on high strength C-Mn steel sheets. The Cu pre-coated GI steel has a more pronounced texture coefficient (TC) of the preferred high atomically dense (0002) crystal plane of Zn coating as compared to the GI steel without pre-coating. It has been observed that the GI coating with Cu pre-coating shows excellent surface quality in comparison to the GI coating without Cu pre-coating, which exhibits many bare spots on the final coating. Further, the Cu pre-coated GI steel has revealed the development of a continuous iron aluminide (Fe Al) intermetallic interfacial layer that has a uniform distribution of dense and equiaxed Fe Al crystals at its interface with the substrate. It can also be noticed that the Cu pre-coated GI steel has a superior corrosion resistance when compared to the GI steel without pre-coating. This is ascribed to the Cu pre-coated GI steel forming a continuous compact interfacial layer with the maximum atomically dense (0002) crystal plane and a high-quality defect-free coating.

Keywords: High strength steel; Galvanized steel; Copper pre-coat; Fe-Al interfacial layer; Corrosion

CEB_051

High corrosion resistant and spot-weldable polyimide/polyetherimide composite coating for mild steel

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Abstract

Steel is used in many infrastructures due to its durability and affordability. However, steel is always prone to corrosion because of electrochemical reactions (a spontaneous process) in its service environment. The protection of steel structures from corrosion is essential to ensure its durability, strength, safety and to avoid economical loss. There are different methods or coating systems used to protect steel structures from corrosion. In the present study, secondary engineering polymer coating based on polyimide/polyetherimide coating has been developed to protect the steel substrates (mild steel) from corrosion. These polymers have very good film forming property and have better adhesion with the metal substrate due to hetero atoms present in their backbone.

Coatings based on different polymers are electrically insulating in nature which cannot be spot-weldable. However, the electrical conductivity of above coatings can be improved by the addition of conducting fillers (conducting carbon powder, carbon nanotubes, graphene, metal powders, and conducting polymers). Here, we have used conducting polymer and/or metal powders as filler in the polyimide/polyetherimide resin matrix to design the coating for mild steel. The above composite coating was applied on mild steel using an automatic bar coater to achieve a uniform coating thickness of ~10 µm. Composite coating coated steel substrates are spot-weldable, whereas substrates coated with pure polyimide (insulating in nature) are not spot-weldable. We achieved superior corrosion resistance on mild steel substrates (>200 h, 5% red rust) using the composite coating, where the corrosion resistance of the pure polyimide coating was ~120 h (5% red rust). Both pure polyimide and composite coating systems exhibited very good adhesion to the mild steel substrate. The coated steel has very good forming stability and can be painted (with good adhesion) with different paint chemistries.

Keywords: Corrosion, Coating, Polyimide, Conducting powder, Mild steel

CEB_073

Effect of particle size of graphene on the corrosion resistance of graphene incorporated zinc rich epoxy coating system

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Abstract

Exotic physical properties of graphene such as high electrical and thermal conductivity and higher surface area have attracted researchers to use graphene as filler material in composite coating systems to enhance their properties. Graphene has potential to improve the corrosion resistance of coatings by enhancing the electrical connectivity between Zn particles and also acting as a barrier to diffusion of water molecules. However, enhancement of the above properties depends on the morphology of graphene particles and no effort has been made to study the aspect in detail till now. In the present investigation the effect of particle size of graphene nanoplatelets (GNP) on the corrosion resistance of GNP-zinc rich epoxy coating has been studied. Graphene nanoplatelets of different surface area 150, 300 and 500 m^2/g procured from Sigma Aldrich (xGNP) were incorporated into zinc rich epoxy (ZRE) and coated on maraging steel substrate. Characterisation of graphene nanoplatelets and coated samples were done using scanning electron microscope, Raman spectroscope and X-ray diffraction technique. Corrosion behaviour of the coated samples was evaluated by salt spray testing, potentiodynamic polarization and electrochemical impedance spectroscopy. Unstirred 3.5% NaCl solution prepared with distilled water that has been exposed freely to the atmosphere was used as the corrosive medium. Prolonged tests were carried out for a period of 30 days. Corrosion tests clearly revealed the dependence of the GNP morphology on the corrosion behaviour of the coatings. Coatings with largest particle size showed highest corrosion resistance in all tests. The highest value of impedance modulus (at 0.1 Hz) was exhibited by SA150 as 4.61×10^6 $\Omega.cm^2$.The impedance decreased with increase in the surface area and decrease in thickness of the GNPs.

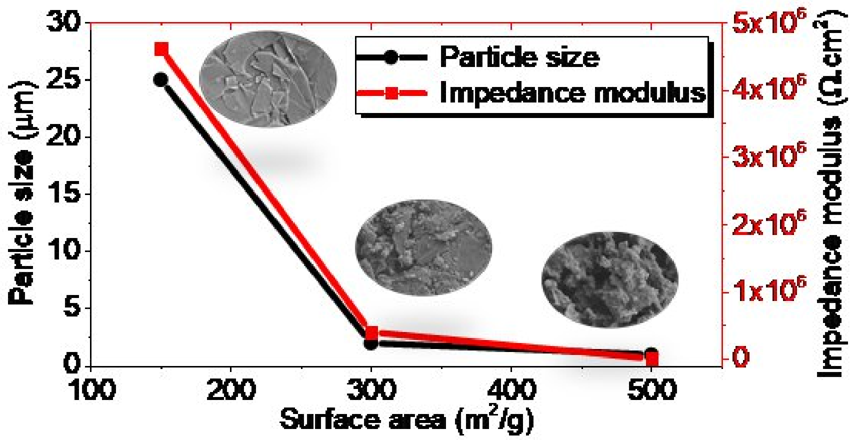

Fig. 1: Variation of impedance modulus of GNP-ZRE coatings with GNP morphology

Key words: Graphene nanoplates, corrosion resistance, impedance spectroscopy

CEB_077

Reduction and Nucleation Growth Analysis of Bimetallic Cu-Sn Electrodeposited in a Non-electroactive Pyrophosphate-based Bath

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Abstract

The enduring appeal of *Cu-Sn*-based intermetallics, widely recognized as bronze, arises from their remarkable versatility across diverse applications. When employed as coatings on stainless steel, *Cu-Sn* confers numerous advantages, such as enhanced aesthetics, superior corrosion resistance, reduced surface tension, improved weldability, and increased ductility. However, the electroplating of *Cu-Sn* onto stainless steel using acidic baths is an expensive process due to the inherent instability of acidic solutions. Additionally, the short lifespan of these baths necessitates the use of costly additives. In this study, we propose an innovative method utilizing a stable, cost-efficient basic pyrophosphate-based electrolyte bath to deposit *Cu*, *Sn*, and *Cu-Sn* coatings. *X-ray* diffraction analysis reveals that the *Cu-Sn* coatings on stainless steel are primarily composed of $Cu_{13.7}Sn$ and Cu_3Sn phases, with a minor presence of *elemental-Sn*. Notably, the *Cu-Sn* bath exhibits a high current efficiency of *92%* and demonstrates exceptional long-term stability, maintaining its integrity for over a year even under ambient air exposure. To further elucidate the nucleation and growth mechanisms, we undertake a comprehensive investigation employing cyclic voltammetry and chronoamperometry. The Scharifker–Hills model is utilized to analyze the nucleation and growth steps, while a detailed examination of the cyclic voltammetry results enables us to unravel the complex diffusion kinetics during deposition.

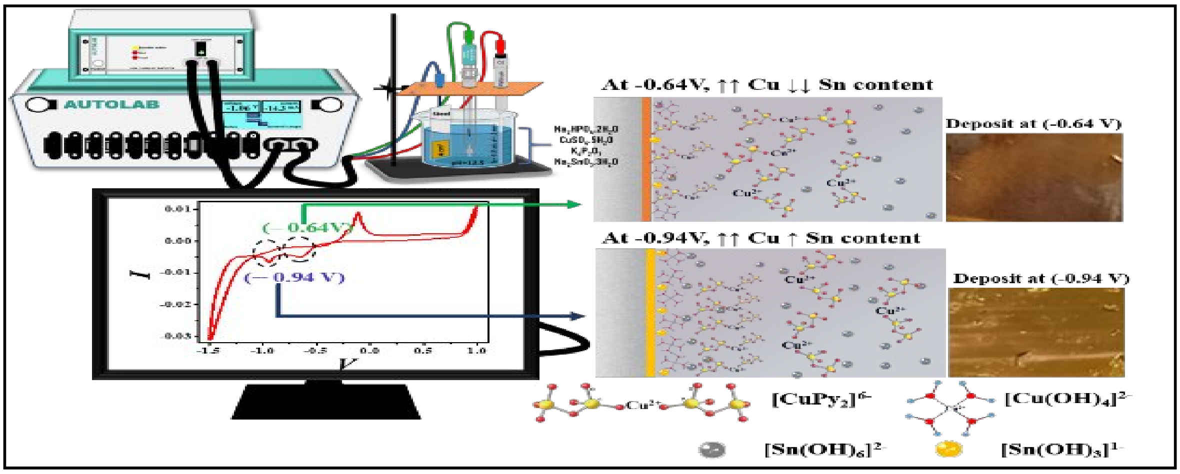

Fig. 1: Graphical abstract

CEB_098

Keywords: Potassium pyrophosphate; Pulse-galvanostatic; Speciation analysis; Reduction potential; SH model.

References:

1. Vijendra Kumar, * Debasis Nayak, Karabi Das, and Siddhartha Das." *Innovative Electrodeposition of Bimetallic Cu-Sn in a Stable Nonelectroactive Pyrophosphate-Based Bath: Reduction and Nucleation Growth Analysis.*" J.Phys.Chem.C 2023,127,20360−20371.

Study regarding the effect of Copper doping in Cobalt sites of PrNi0.5Co0.5O3-d oxygen electrode

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Abstract

Energy consumption is increasing day by day due to the increase in population, industrialization, etc., So we have to look forward to some better technologies as we are capable of producing and consuming adequate energy due to an abundance of energy resources and industrial diversification. But the challenge is to obtain this technology with a minimum amount, Cost-effectiveness, non-hazardous nature etc. An electrochemical device with a high energy conversion efficiency that can theoretically produce electricity directly and continuously is called a solid oxide fuel cell, or SOFC. It is continuously fed with a reversible solid oxide fuel cell (RSOFC), which can function well in electrolysis and fuel cell modes. Thus, when operating in fuel cell mode, an RSOFC performs the same activities as a SOFC, producing electricity through the electrochemical reaction of air (oxygen in the air) and fuel (hydrogen, hydrocarbons, alcohols, etc.). In the electrolysis mode, an RSOFC works as an electrolyzer (also known as a solid oxide electrolysis cell, or SOEC) when coupled with a fossil, nuclear, or renewable energy source to produce hydrogen (from water) or chemicals like syngas (from carbon dioxide and water mixtures). When a pure electronic conductor is used as an oxygen Electrode material, the reaction is limited to the triple phase boundary where the gas, electrolyte, and electrode meet. Still, when an MIEC material like LSM-YSZ is used, the oxide ions, along with the electrons, can be conducted through the electrolyte, which enhances the reaction area to an extent. New oxygen electrode materials are required since the oxygen electrodes are facing serious delamination issues. $PrNi_{0.5}Co_{0.5}O_{3-d}$ is a promising oxygen electrode material with an excellent electrical conductivity value of around 300 Scm^{-1} at 700◦C. Doping Cu in the cobalt sites has improved the structural integrity, lowering the cost, improved thermal stability, etc. So, in this work, $PrNi_{0.5}Co_{0.4}Cu_{0.1}O_{3-d}$ and $PrNi_{0.5}Co_{0.1}Cu_{0.4}O_{3-d}$ oxygen electrode materials are prepared using the solution combustion synthesis, and then the power characterizations and Electrochemical analysis are done.

Keywords: Reversible Solid Oxide Fuel Cells, Electrolyzers, Conductivit

The Impact of the Current Collectors on the Electrochemical Performance of the Pseudocapacitive Material: Sr2FeCoO6

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Abstract

This work reports the synthesis of Sr_2CoFeO_6, double perovskite, via a wet chemical method. X-ray diffraction (XRD) analysis and Rietveld Refinement confirmed the successful formation of pure, single-phase perovskite structure with $Pm\bar{3}m$ space group. Transmission electron microscopy (TEM) shows the irregularly shaped polycrystalline particles. Furthermore, the Brunauer–Emmett–Teller (BET) analysis showed that the particles have An average surface area of 3.01 m²/g and an average pore diameter of 37.8 nm. Current collectors, namely carbon Toray paper, carbon cloth, nickel foam, and nickel strip, were selected to evaluate the electrochemical properties of Sr_2CoFeO_6. The morphology of the current collectors was captured using a Scanning Electron Microscope (SEM). The electrochemical performance of bare and loaded (with Sr_2CoFeO_6) current collectors was assessed through cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) testing, and electrochemical impedance spectroscopy (EIS) under similar measurement conditions. The findings showed that Sr_2CoFeO_6 displays varying energy-storing capabilities in different current collectors. The high specific capacitance of the sample is observed over the carbon cloth and nickel foam to be 105.7 and 93.3 F/g, respectively, while bare carbon cloth shows very high capacitance. By comparing the performance of different current collectors, we have identified the key factors influencing the material's performance. This study will enhance our understanding of its potential applications in energy storage and other pertinent areas.

Hierarchial phase transformation affecting the corrosion performance in super duplex stainless steel

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Abstract

In the present study, the phase transformation behavior and their consequent effect on the electrochemical properties of super duplex stainless steel is explored by double loop electrochemical potentiokinetic reactivation (DLEPR) test, within the aging temperature range of 923K-1073K for different time period (~ 600-18000 sec). The prolonged aging treatment at the fixed temperature of 973K and 1073K imparts the significant changes in the microstructural development from duplex ferrite-austenite microstructure to multiphase structure consisting of ferrite, primary and secondary austenite and sigma phase. The gradual evolution of sigma phase and secondary austenite at the expense of ferrite phase randomized the orientation relationship with larger spread around 40˚<110> misorientation axis. The growth of the aforementioned phases with aging plays the important role in degrading the corrosion performance of investigated steel, as identified by the higher DOS value. Interestingly, for the overaged specimens, having the higher sigma fraction and coarser sigma size, there is a drop noticed in the DOS value which indicates the phenomenon of healing occurring in this specimen. Besides the phase fraction and size, the coherent nature of sigma is studied through electrical conductivity test and further correlated with the corrosion resistance properties. The finer coherent sigma is primarily responsible for the localized attack whereas the coarser incoherent sigma affects the overall corrosion of the aged specimens.

Keyword: Super duplex stainless steel; Phase transformation; Sigma phase; Electrical conductivity; DLEPR; Corrosion.

Internal Friction and Hydrogen Embrittlement of Steel

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Abstract

Internal friction of a metallic material is associated with the dissipation of mechanical energy. This dissipation can happen through multiple relaxations or losses in the presence of various microstructural parameters. The latter include the nature and concentration of interstitials, crystallographic orientation, the presence of dislocations and residual stresses, etc. This study used tailored microstructures, and bulk plus local internal friction measurements, to establish a clear experimental linkage between microstructure and internal friction responses. The present work was extended to multiscale modeling consisting of kinetic Monte Carlo (KMC), and molecular dynamics (MD). Multiscale modeling was employed to understand the atomistic mechanism of defect migration and its role in the internal friction loss spectrum of the material. In particular, relaxations arising from hydrogen-dislocation interactions were studied. It was found that dislocation relaxation in the Cottrell atmosphere of hydrogen gives rise to an internal friction peak known as Snoek Köster (SK) peak. The SK peak showed a strong dependence on hydrogen type and concentration as well as on dislocation configurations. Further, this study was expanded to understand hydrogen diffusion in the presence of different microstructural defects. It was noticed that hydrogen interactions with microstructural features have a significant role in hydrogen embrittlement. In addition, hydrogen charging experiments were performed on dual-phase steel, followed by mechanical and microstructural characterization. A combination of experiments and simulations was essential in defining the mechanistic origin of hydrogen embrittlement. In the end, a correlation was developed between internal friction and hydrogen embrittlement.

Keywords: Internal Friction, Hydrogen, Diffusion, Microstructure, Multiscale Modeling.

Studies on electrocatalytic behavior of La0.5M0.5FeO3 (M = Ca, Sr, Ba) Perovskite

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Abstract

The present work investigates the electrocatalytic activity of $La_{0.5}M_{0.5}FeO_3$ (M = Ca, Sr, Ba). The EDTA-citrate-assisted solution combustion technique was adopted to synthesize the powder. The Phase analysis of the powder indicated the synthesis of phase pure perovskite. The morphological study indicated the powder agglomerated powder consisting of spherical nanoparticles. Intra-agglomerate porosity was observed in the micrographs. The surface area of the studied calcined powders was found in the range of 15 m^2/g to 19 m^2/g. The change in the oxidation state of Fe and, hence, the oxygen non-stoichiometry of the samples was measured using iodometric titration. The oxygen nonstoichiometry and the oxidation of the state of B-site iron depend on the chemistry of the divalent cation substituted at the A-site. The electrocatalytic activity of synthesized samples for oxygen evolution reaction was investigated using linear sweep and cyclic voltammetry study in an alkaline medium. The electrochemical parameters, namely Overpotential, Tafel slope, electrochemically active surface area, Specific activity, and Mass activity, were studied as a function of A-site cation substitution. The observed variation of the electrochemical parameters is correlated with the oxygen nonstoichiometry of the samples. The study revealed that the electrochemical activity of the powder follows the trend $Ba^{+2} < Ca^{+2} < Sr^{+2}$.

Keywords: Oxygen evolution reaction, LSV, CV, Oxygen non-stoichiometry.

References:

[1] M. Zhang *et al., Mater. Today*, vol. 49, no. October, pp. 351–377, 2021, doi: 10.1016/j.mattod.2021.05.004

Development of passive nickel coating on ICSS1218-321 austenitic stainless steel to overcome liquid metal embrittlement

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Abstract

Liquid metal embrittlement (LME) is a phenomenon that occurs when a solid metal or alloy loses its ductility and strength after being coated with a liquid metal. LME may occur in a brazing operation involving high-strength materials such as stainless steels, nickel alloys or age-hardened alloys, when the materials are stressed and come into contact with molten brazing filler metal. During vacuum brazing, LOX-Kerosene thrust chambers suffered failure due to the formation of a crack in the flexures of the hardware made of Ti-stabilized austenitic stainless steel ICSS-1218-321. Detailed metallurgical investigation was carried out to determine the cause of failure and mechanism responsible for hot cracking in the flexures during brazing. The failed part of the flexure revealed extensive grain boundary cracking near the fracture edge. Crack propagation along the grain boundaries was observed with inter-granular fracture features and presence of Cu-Ag eutecticin the crack region at fracture edge. These observations established that the hot cracking resulted from liquid-metal embrittlement due to formation of eutectic of Ag and Cu during brazing. Further, Gleeble^{TM} thermo-mechanical simulator (TMS) was used to simulate the failure condition inICSS-1218-321 steel with varying strain rate and thickness of braze coating.

To avoid LME during brazing, simulation experiments were performed in TMS with varying strain rate and nickel coating thickness. 10-20μm nickel coating over ICSS-1218-321 steel acting as a passive layer which protects from LME upto 20% of strain. Detailed metallurgical analysis was performed on samples tested in TMS. Crack portion of flexure along with fractograph and microstructure are shown in Figure 1a-1c. Presence of Cu-Ag eutectic in TMS tested sample (with braze coating) is shown in Figure 1d & 1e.This study provides an insight on detrimental effect of liquid metal embrittlement in the manufacturing processes and suggests remedial measures to avoid recurrence of such failures.

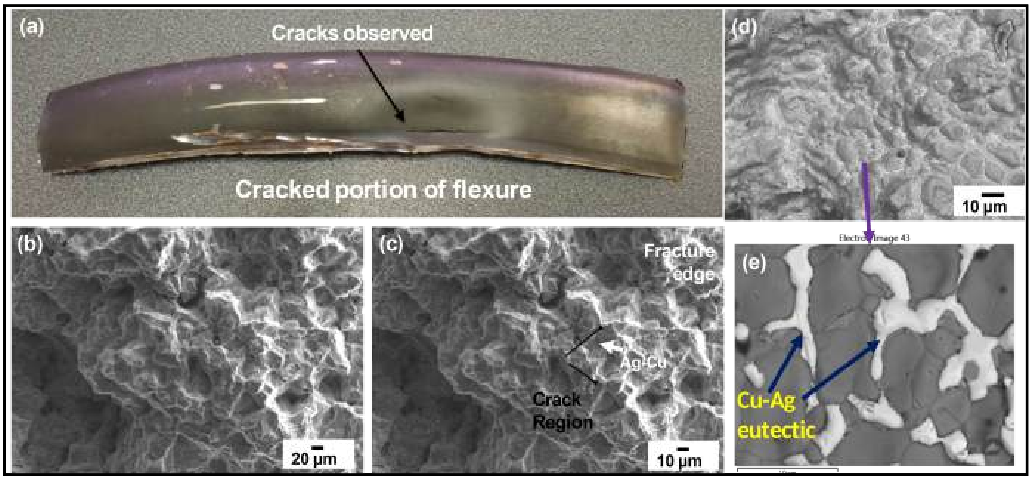

Fig. 1: (a) Failed flexure during brazing b) Fractograph of cracked portion of flexure c) SEM images of intergranular cracks at fracture d) & e) Fractograph of TMS tested sample.

Key words: Liquid metal embrittlement, brazing, thermo-mechanical simulator, passive coating.

Corrosion Evaluation of Sanicro-25 in EuCl3-LiCl-KCl Molten Salt by Electrochemical Techniques for Pyrochemical reprocessing applications

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Abstract

The spent metallic fuels from the future Fast breeder reactors in India will be reprocessed by pyrochemical reprocessing. Electrorefining is the main fuel separation step of the pyrochemical reprocessing. LiCl-KCl molten salt at 500°C is being used as the electrolyte for the electrorefining process. During the electrorefining, fission products like lanthanides dissolve in the salt. In order to ascertain the effect of other fission product ions in molten salt on the corrosion of structural materials, a 1 wt.% $EuCl_3$ containing molten LiCl-KCl salt being used in the present study to evaluate the corrosion behaviour of Sanicro-25 using electrochemical techniques. The corrosion behaviour of Sanicro-25 is monitored for about 200 h by electrochemical techniques like open circuit potential(OCP), linear polarization resistance and electrochemical impedance spectroscopy (EIS). The corrosion species dissolved in the salt are monitored by cyclic voltammetry at W electrode. The OCP of the Sanicro-25 is changed towards noble potential with an intermittent change to the active potential, which indicates the tendency to form protective films over the surface. However, the formed protective films are found to be dissolved during further exposure to the molten salt. The examination of the sample after the corrosion test that indicated the dissolution of the sample. It was further confirmed by the cyclic voltammetric examination, wherein the appearance of a new couple of redox peaks corresponding to both Ni and Fe are seen. The linear polarization resistance, measured at various exposure intervals, decreased with the increase of molten salt exposure indicating higher corrosion of the sample. The Nyquist plot consists of two semi-circles with an incomplete semi-circle at the lower frequency end, indicating the existence of three-time constants and formation of intermittent oxide film. These studies provide a comprehensive understanding of the corrosion processes of alloy steels by electrochemical techniques for corrosion monitoring in high-temperature eutectic LiCl-KCl molten salt with $EuCl_3$ for pyrochemical reprocessing application.

Key words: Sanicro 25; $EuCl_3$-LiCl-KCl molten salt; Corrosion; Electrochemcial techniques.

Effect of microstructure morphology on corrosion behavior of high carbon wire rods used as reinforcement in concreate structure.

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Abstract

Abstract: High carbon wire rod strands are essential in constructing pre-stressed concrete girders for roads, rivers, and railway bridges, as well as PT slabs for high-rise buildings, flyovers, slabs, domes, silos, and hangers. A critical property of these strands is their ability to retain tension, counteracting tensile stresses in concrete effectively. This research investigates a newly developed high carbon wire rod variant produced via the conventional BF-BOF route, continuously cast and hot-rolled at the Visakhapatnam Steel Plant. The study focuses on the impact of microstructural morphology on the mechanical properties and corrosion behavior of these wire rods, as corrosion significantly affects the durability of concrete structures. Specifically, chloride infiltration into concrete over time can weaken the wire rods, reducing their lifespan. Experiments utilized conventional electrochemical methods to examine the corrosion behavior of the wire rods in a 3.5 wt.% NaCl environment. The study measured the material's free corrosion potential and anodic/cathodic behavior in NaCl solution at room temperature and analyzed corrosion propagation using potentiostatic polarization scans (Tafel plots). Chemical composition was determined with an Optical Emission Spectrometer (OES), microstructural morphology was observed using a Leica optical microscope, and mechanical tests were conducted to assess strength and hardness. Results indicated that the steel exhibits a ferritic microstructure with a uniform distribution of pearlite particles and a fine grain size of approximately 10-12 µm. The wire rod steel showed a Vickers hardness of around 500-600 HV, an ultimate tensile strength (UTS) of approximately 1150-1300 MPa, and a reduction in area (RA) of 30-32%. The corrosion resistance of these wire rods was found to be 3 mpy, influenced by their microstructural morphology.

Keywords: high carbon wire rod strands, corrosion behavior, free corrosion potential, potentiostatic polarization scan.

Development of Ultra-High Strength Corrosion Resistant Uncoated Non-Stainless Steel

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Abstract

This study presents a novel, uncoated, ultra-high-strength steel (UHSS) with exceptional corrosion resistance and mechanical properties, exceeding conventional stainless-steel alternatives. This innovative steel incorporates corrosion-resistant alloying principles inspired by weathering steels like Corten steel, unlike existing UHSS which rely on post-production coatings. The study meticulously optimizes the alloy composition and processing regimen, including heat treatment, to achieve a synergistic effect on both mechanical performance and corrosion resistance. This approach enhances the service life of steel products, minimizes the need for additional protective coatings, and reduces environmental impact and production costs. The optimized alloy composition includes Cu, Cr, Mn, and Si. Copper promotes the formation of a protective passivation layer of anhydrous Cu-oxide on the steel surface, contributing to the weathering effect. Chromium, manganese, and silicon work together to create a non-porous oxide layer, further strengthening the passivation layer and providing high corrosion resistance. Rigorous testing methodologies validate the effectiveness of this innovative alloy composition. Accelerated salt spray tests demonstrate the remarkable corrosion resistance of the newly developed steel. Conventional DP780 steels exhibit visible rust formations after 24 hours, while the novel steel samples (CRS1, CRS2, and CRS3) remain rust-free. Electrochemical corrosion tests conducted on CRS1 and CRS2 demonstrate a significantly lower corrosion rate (approximately 10 times lower) compared to uncoated DP780 steel, highlighting the enhanced service life of the newly developed steel in the same corrosive environment. The addition of small copper and zirconium to the steel composition does not compromise its ductility or formability, unlike coated steels. This research opens new possibilities for uncoated UHSS, offering exceptional corrosion resistance and strength while minimizing the environmental impact and production cost associated with traditional coating methods. This development holds significant potential for various applications in automotive, construction, and other industries demanding high strength and long-lasting performance in demanding environments.

Samples	Beta A V/decade	Beta C V/decade	I_{corr} A/cm^2	E_{corr} mV	Corrosion Rate (mpy)
DP780	419.2e^{-3}	208.6e^{-3}	84.10e^{-6}	-793.0	38.41
CRS1	40.10e^{-3}	562.2e^{-3}	7.970e^{-6}	-449.0	6.642
CRS2	37.60e^{-3}	350.4e^{-3}	8.140e^{-6}	-482.0	3.719
CRS3	41.90e^{-3}	437.0e^{-3}	5.300e^{-6}	-458.0	2.421

Table1: Tafel experiment results showing the superior corrosion protection in CRS1-CRS3 steels as compared to conventional DP780 steel.

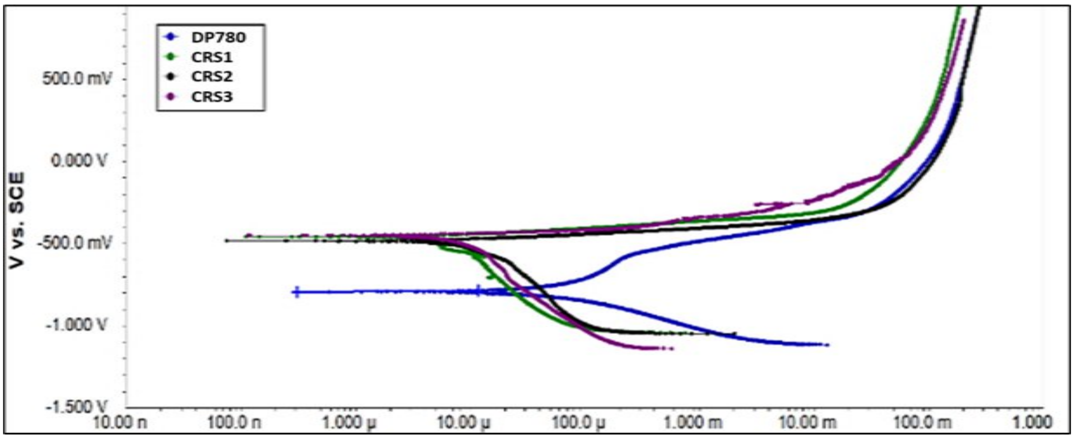

Figure 1: The plot of Tafel electrodynamic corrosion rate simulation experiment

Key words: Continuous annealed Martensite Steel, High strength corrosion resistant steel

Corrosion Resistance and Cut Edge Protection Performance of Coated Steel

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Abstract

Hot dip galvanizing is a widely used industrial process to produce coated steels. Metallic coatings over steel substrate protect steel by sacrificial corrosion, barrier protection, and natural weathering effect. Over the years various coatings have been developed and successfully engineered to protect steels in different applications & environments. This work focused on understanding coated steel's corrosion resistance and cut-edge protection behaviors. The coating was done via four different methods namely conventional galvanized, galvalume, ZMA (ZnMgAl) & batch galvanizing coatings. Cut edge-protected and unprotected coated steel samples were exposed to the neutral salt spray (5% NaCl) environment (SST) and cyclic corrosion tests for different exposure times. Before and after corrosion tests, the samples were studied using the characterization methods of scanning electron microscope (SEM), and X-ray diffraction (XRD). The microstructure and phase were compared with unexposed samples and co-related to the corrosion resistance performance of the various coated steel. Unlike a galvanized coating, the galvalume and ZMA coatings result in a multi-phase structure. Industrial Zn-spraying is being done in manufacturing to protect material in severely corrosive environments. The coating with Mg content showed better corrosion resistance and cut-edge protection over other coated products. Cross-sectional elemental analysis using EDS after different periods of exposure showed a decrease in Fe content and peaks of other elements observed which confirms to the exposed steel being self-healed. Such property was observed best in Zn-Mg-Al among the 3 alloy coatings whereas was minimal for Zn-Al (galvalume) alloy coatings. The phase fraction of protective and insoluble corrosion product simonkolleite (Zn5Cl2(OH)8.H2O) is observed more in Zn-Mg-Al alloy coatings which is attributed to a decrease in pH due to precipitation of Mg(OH)2. Overall, it can be concluded, the alloy coatings with Mg content can be used without Zn-spray over cut edges and help reduce significant cost and processing time.

Key words : Hot-dip galvanizing (HDG), Zn-Mg-Al alloy coatings, Cut Edge Protection

Effect of alloying on corrosion and toxicological properties of austenitic stainless steels

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Abstract

Austenitic stainless steels are widely used for fabrication of utensils and cookware because of their excellent combination of mechanical and corrosion properties. Besides chromium (Cr), these stainless steels are conventionally alloyed with nickel (Ni) as a major constituent element, where Ni stabilizes the austenitic phase. Due to rising costs of Ni, stainless steel makers worldwide have been in search of suitable alternative austenitic stabilizer. Recent toxicological research has shown that Cr and Ni ions released from the stainless steels are potentially carcinogenic and can lead to several problems for human skin like epidermis swelling, reddening, eczema and itching sensations. These factors have led to the development of Ni-substituted/ Ni-free manganese (Mn) containing austenitic stainless steels.

Manganese stabilizes the austenitic phase, much like Ni, and also costs far less than Ni; these being the prime reasons for its use in place of Ni. There has been some research work on the corrosion behavior of Mn-substituted stainless steels (Brigham and Tozer 1976, Bandy and Van Rooyen 1983, Baba et al. 2002, Condylis et al. 1970, Shams et al. 1972 & 1973, Lunarska et al. 1975, and Lim et al. 2001). Nevertheless, a lack of clarity exists in the published literature as to the role of Mn on the corrosion resistance of austenitic stainless steels. Some of the studies indicate that Mn is beneficial to pitting and crevice corrosion resistance (Brigham and Tozer 1976), while a few of them (Bandy and Van Rooyen 1983, Baba et al., 2002) show that Mn is detrimental to the pitting resistance of stainless steels, but few go on to conclude that it is detrimental above certain level (Condylis et al. 1970, Shams et al. 1972 & 1973). With the Mn-containing stainless steels finding ever increasing use in utensil and cookware fabrication, there is a need to understand its specific role in corrosion of stainless steels in food media.

Accordingly, in the present work, an attempt has been made to study the effect of alloying elements on corrosion and toxicological properties of austenitic stainless steels in acidic food media. For this, three different austenitic stainless steels with varying Ni and Mn contents were subjected to immersion corrosion testing in different food acids with and without salt (at room and boiling temperatures). The corrosion rates were correlated with respect to alloying elements and chloride content in chosen food media. Further, the dissolution of metal ions during the immersion was analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES). The ICP results showed that metal ion dissolution increases with increase in chloride content and more so, in Ni-substituted austenitic stainless steels.

Effect of Surface Finish on the Corrosion Resistance of Stainless Steels

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Abstract

This study investigates the influence of surface finish on the corrosion behavior of AISI 304, AISI 439, and AISI 204Cu stainless steel samples in a chloride-containing environment. These grades were selected for their common outdoor use and to assess the impact of varying compositions, microstructures, and surface finishes. The different surface finishing processes applied to the stainless-steel surfaces yields different surface roughness levels and also can affect the chromium content in the oxide film. Rougher surfaces are more susceptible to localized forms of corrosion, such as pitting and crevice corrosion, than smoother surfaces. This effect can be related to the surface nucleation of metastable pits preceding pit propagation.

In the present study, four surface finishes (No. 1, 2B, 2E, and 2R/BA, as per EN10088-2) were subjected to electrochemical testing—Potentiodynamic Polarization measurement (ASTM G59) and Electrochemical Impedance Spectroscopy (EIS) (ASTM G106) - in a 0.5% NaCl solution. For alloys 439 and 304, the difference in pitting potentials between finer finishes (2B, BA) and coarse finishes (No. 1, 2E) was approximately +130 mV, whereas, for the 204Cu grade, a difference of only +30 mV was observed. These results showed that finer finishes in the 439 and 304 grades generally exhibited superior pitting resistance, as evidenced by higher E_{pit} values. Also, the pitting potentials observed for 439 and 304 grades in finer finishes were between +318 mV and +356 mV, indicating that the corrosion behavior of 439 grades exhibits a trend similar to that of 304 grades. Finer finishes in the 204Cu grade (2B, BA) showed a pitting potential of about +160 mV. Consequently, among the studied stainless steel grades, 204Cu demonstrated the highest corrosion rates and lowest pitting potentials, regardless of surface finish. EIS analysis indicated that all samples exhibited simple Randles-type behavior. The 2B and BA finishes in the 439 and 304 grades demonstrated lower double-layer capacitance (C_{dl}) and resistance (R_{dl}), suggesting a more stable and protective passive film. In contrast, 204Cu with 2B and BA finishes exhibited higher R_{dl} values, indicating potential barriers to charge transfer. Microstructural analysis of corroded 439 grade samples revealed that corrosion resistance was enhanced by Ti-based precipitation, whereas, for the 204Cu grade, the Cu-based precipitates increased susceptibility.

Keywords: Stainless steel, surface finish, electrochemical testing, microstructural analysis, corrosion

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.

Corrosion Analysis and Mitigation plan for Sour Gas Pipelines

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Abstract

Here in this paper, we have studied the reason of Gas pipelines corrosion used for supply of sour gases (by-product) from generating units to consuming units and the suitable solutions to enhance the life.

Energy Management at JSW Steel, Vijayanagar works is a centralized department that plays a vital role in Operations and Maintenance of large gas network of more than 65 KMs distributed geographically throughout the plant. It is responsible for optimization of various by-product gases generated during the process of Coke Making, Iron Making and Steel Making.

Corrosion mitigation is a focus area for every industry, and gas pipeline is one of the major affected segments, mainly due to Sour Gases. Various reasons were pointed out through thorough analysis for corrosion i.e. moisture & impurities stagnation, acidic nature of chemical as a contaminant in gases like Sulphur & Hydrocarbons. These impurities lead to corrosion of pipeline, further resulting in pipeline thickness reduction and gas leakages. The pipeline leakages may cause to gas poisoning and other health issues (toxic nature of gases) damage to property (due to inflammability) and the production loss.

Nature of corrosion are categorized as they range from pitting corrosion, uniform corrosion, galvanic corrosion, crevice corrosion and microbiologically influenced corrosion to name a few. The corrosion identified in this case is of nature of pitting corrosion.

To resolve the issue, various options were explored; one of them was internal protection of pipelines from corrosion. Various vendors who're expert in corrosion protection coating were explored. Corrosion Protection Coated samples with DFT of 1 mm were collected and tested in acidic environment for 30 days to ascertain the feasibility of pipeline coating for sour gas application. The sample with Vinyl Ester based Glass flake coating was intact and having resistance to corrosion. Gas pipeline life can be enhanced through internal coating to protect the pipe metal from acidic impurities and moisture.

Figure 1: Coated MS plate lab analysis

Key words : Corrosion, Pitting, Sour gases, Sulphur, Hydrocarbons, DFT, Glass flake

DIGITALIZATION

Oral Abstracts

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Prediction of Blaine Number of the Output of Ball Mill D&G Circui

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Abstract

The iron bearing material fed into the Blast Furnace is primarily in the agglomerated form of pellets and sinter, the former becoming more and more used in modern furnaces. In order to make the pellets, the crushed iron ore is further ground into very fine powder, typically in a ball mill along with flux and fuel. The quality of pellets produced, mainly its mechanical strength and metallurgical properties is critically dependent on the fineness of particles achieved during the grinding process which is measured as total surface area per unit mass and reported as the Blaine Number. In this work, a model has been developed to predict the Blaine Number in real-time as a function of raw material properties as well as grinding process parameters. The strength of this model lies in its comprehensive consideration of various input parameters. These include both physical and chemical properties of the raw materials, as well as crucial process conditions such as feed rate and rotational speed. Several machine learning algorithms were employed and finetuned to predict the Blaine number, and their performances were compared. Among the algorithms tested, Random Forest Algorithm produced the best results delivering the most accurate predictions. The model achieved an impressive accuracy level of around 90%, showcasing its reliability and effectiveness. The model is deployed at Pellet Plant, TATA STEEL for real time prediction of Blaine.

Key words : Blaine number, Pellet, Machine Learning, Random Forest

DIN_057

Prediction of reduction degradation index in Sinter Plant using hybrid approach

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Abstract

This abstract presents a detailed analysis of developing a prediction model for the Reduction Degradation Index (RDI) of sinter to support smooth functioning of blast furnaces in the face of drastic changes in iron ore qualities. For the sake of promoting the permeability of a blast furnace burden and ensuring the smooth smelting process and maintaining consistency in sinter properties has become a challenge for steel manufacturing industries, leading to irregularities and disturbances in the blast furnace ironmaking process. Our work aims to predict the RDI well in advance using plant process parameters.

A prediction model for the Reduction Degradation Index (RDI) of sinter has been developed using the Random Forest algorithm, achieving an accuracy of 76%. The model predicts the RDI with a lead time of four hours, providing instantaneous predictions upon receiving relevant chemical and process parameters. Various input features, including chemical compositions and process control indices, are utilized to enhance the model's accuracy. Additionally, the model suggests the optimal range of controlled parameters to achieve the best RDI value. This allows for proactive adjustments in the sintering process, thereby improving the efficiency and stability of blast furnace operations.

The model leverages a range of input features, including chemical compositions and process control indices such as particle size fractions, elemental compositions (FeO, MgO, CaO), basicity, and various process control metrics. These parameters are sourced from the Production Planning Management System (PPMS) and the PI Vision system. The Random Forest feature importance matrix identifies these parameters' impact on RDI, guiding optimal control ranges for improved efficiency and stability in the sintering process.

The user interface, developed with ReactJS, offers a responsive platform for real-time data interaction. The backend, built with NodeJS, manages data integration and processing via the NodeJS script through PI Web API and PPMS database. All data, including input parameters and RDI predictions, are stored in an MSSQL database, ensuring effective data management. This model's ability to provide early RDI predictions highlights its innovation and practical benefits for industrial applications.

Keywords: Sinter, Random Forest algorithm, RDI prediction, PPMS, PI WEB API, MSSQL.

DIN_068

Digitalization of Coke Dry Quenching (CDQ) plant: Real-Time Optimization through Advanced Automation and Soft Sensing of Solution Loss Carbon

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Abstract

This paper presents a novel approach to optimize Coke Dry Quenching (CDQ) plant operations by integrating auto control system and real-time soft sensing of solution loss carbon. The system combines sophisticated compensation logic to optimize cooled coke discharging, gas circulation fan, and dilution air injection with a digital soft sensing approach to estimate solution loss carbon in real-time. This integrated system enables automatic control of circulation gas & dilution air volume, and coke discharging rate, ensuring that key process parameters, such as discharging coke temperature, CO concentration, and boiler inlet gas temperature, remain within allowable ranges. The advanced storage level management system adjusts the cooled coke discharging rate based on pushing rate from coke oven, minimizing fluctuations, and reducing process upsets. The soft sensing approach leverages process calculation-based methodology and silo level data to provide accurate estimates of solution loss carbon, which is critical for optimizing coke productivity and energy efficiency. This integrated system minimizes temperature fluctuations inside the chamber, resulting in longer refractory life, and maximizes heat recovery volume by burning excess CO gas, while reducing the risk of explosion. This digital solution offers significant financial benefits, including improved coke yield, and showcases the potential of digitalization and advanced process control to transform CDQ plant operations.

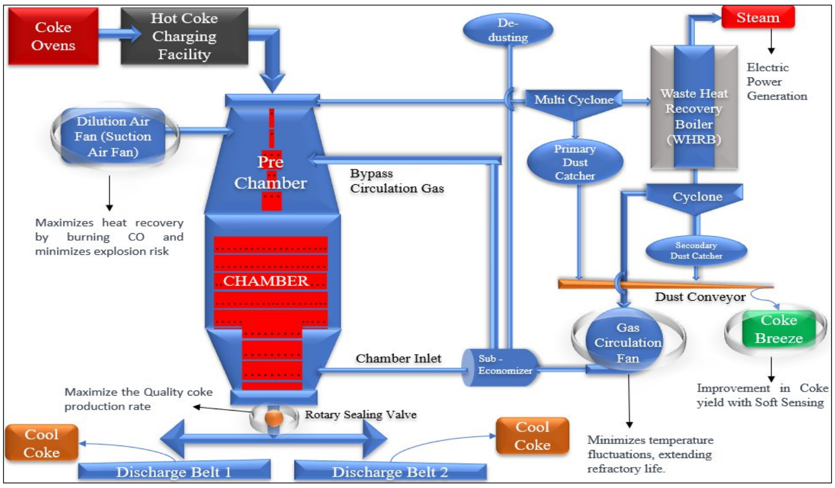

Figure. 1: Process Flow Diagram of Coke Dry Quenching

Keywords: Coke Dry Quenching, CDQ, Solution Loss, Dilution Air, Gas Circulation Fan

DIN_013

Prediction of hot metal temperature in Blast Furnace using hybrid approach

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Abstract

Blast Furnace play a crucial role in the steel industry in terms of cost as well as production rate. For the operational aspects there are major process parameters such as Hot Blast rate, Moisture, Fuel rate, Oxygen rate, Top gas temperature and pressure and Hot metal temperature etc. Out of this Hot metal temperature is very key process parameter to define the efficiency and productivity of the furnace. Hot metal temperature have direct impact on the fuel rate. If hot metal temperature is below 1470^0C it lead to decrease the productivity of steel melting shop where as if hot metal temperature is beyond range (1530^0C) than it lead to more fuel consumption in Blast Furnace. Predicting hot metal temperature well in advance can give the operator a buffer time to change the process parameters to improve furnace conditions.

A hot metal temperature prediction model is developed based on the machine learning concept. Random forest regression model provided the best accuracy for the complex Blast Furnace process. A Gaussian function is used to weight and average past furnace operating parameters to reflect their impact on current hot metal temperature. Tuyere injection parameters have the maximum impact on hot metal temperature which is also reflected from random forest feature importance matrix.

Developed the RIST-RAFT model to provide operators with real-time suggestions for controlling input parameters, ensuring that the hot metal temperature stays within the desired range (1480^0C to 1520^0C). Hot metal temperature prediction model provides the future prediction of hot metal temperature and RIST-RAFT model provide suggestion to control the temperature. By controlling hot metal temperature fuel rate per tonne hot metal decreases.

Keywords: Hot Metal temperature, Blast Furnace, RIST-RAFT Model, Prediction Model, Random forest regression,

DIN_054

Vision-Based and Thermal Vision-Based Inspection and Analytics for Blast Furnaces and Steelmaking Shops in Steel Plants

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Abstract

The steel production process, particularly within Blast Furnaces (BF) and Steelmaking Shops (SMS), demands precise control over temperature, material distribution, and structural integrity to ensure the highest quality and efficiency. Traditional monitoring techniques, relying on periodic inspections and limited sensor data, often fall short in providing the continuous, real-time insights necessary for proactive management. This paper explores the transformative potential of integrating Automation and the Internet of Things (IoT) with Vision and Thermal Vision-based inspection systems to enhance process control in both BF and SMS operations. State-of-the-art approaches in this field leverage advanced imaging technologies, such as high-resolution cameras and thermal imaging sensors, strategically placed around the blast furnace and within the SMS to capture real-time data on critical operational parameters. In the Blast Furnace, these systems focus on monitoring temperature profiles, refractory lining integrity, and raw material distribution. In the SMS, the focus shifts to continuous casting operations, ladle integrity, and slag detection. Machine learning algorithms, including deep learning techniques, are employed to analyze visual and thermal data, identifying patterns that correspond to normal operations or potential anomalies in both BF and SMS. Convolutional neural networks (CNNs), for example, are utilized for real-time image processing to detect irregularities in the furnace lining or ladle wear in SMS, while thermal imaging helps identify hot spots, cooling inefficiencies, or slag overflow that could compromise operational integrity.

In addition to anomaly detection, these systems support predictive maintenance by analyzing historical data alongside real-time inputs to forecast potential failures. Predictive modeling and time-series analysis anticipate issues such as refractory wear in the Blast Furnace or ladle erosion in SMS before they lead to critical failures. IoT-enabled sensors further enhance this predictive capability by providing continuous feedback on temperature, pressure, and material flow, allowing for dynamic adjustments to both furnace and SMS operations to maintain optimal conditions.

The integration of these advanced technologies into Blast Furnace and SMS operations is expected to yield significant benefits, including reduced downtime, improved safety, and enhanced energy efficiency. The paper will explore anticipated case studies from leading steel plants where Vision-based and Thermal Vision-based systems are projected to be implemented, with the expectation that these technologies will lead to measurable improvements in operational performance. For instance, the deployment of a thermal vision system in Blast Furnaces is anticipated to reduce unplanned shutdowns by approximately 30%, while the

DIN_084

implementation of vision-based analytics in SMS is expected to improve the accuracy of slag detection and material charging by around 15%.

This exploration highlights the critical role of Automation and IoT in modernizing process control for both Blast Furnaces and SMS operations. By adopting state-of-the-art Vision and Thermal Vision-based inspection systems, steel plants can achieve a new level of operational efficiency, safety, and sustainability, setting a benchmark for the future of steel production.

Key words : Automation, IoT, Vision-Based Inspection, Thermal Vision, Predictive Maintenance

Real-Time Data Integration and Predictive Modeling in BF-5 of ISP through Process Digital Twin

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Abstract

The implementation of digital twin technology in blast furnace operations marks a pivotal advancement in industrial process optimization. This paper details the development and deployment of a process digital twin for Blast Furnace-5 at SAIL-ISP. This digital twin system harnesses real-time data from Sensors & Automation SCADA System to simulate and predict furnace behavior, thereby enabling real-time monitoring, process optimization, and predictive maintenance

Central to this digital twin system are its key components: the visually enriching digital dashboard, in-depth process overview modules, and in-house implemented advanced process models. These models include the Burden Calculation Model, Heat Balance Model, Tuyere Health Monitoring Model, Burden Distribution Model, Shaft Track Model, Stave Condition Monitoring Model, Cohesive Zone Prediction Model, Deadman Cleanliness Index Model, and Heat Flux Model. Each model plays a critical role in precisely tracking and optimizing various operational parameters of the furnace, resulting in enhanced efficiency, minimized downtime, and superior product quality.

Furthermore, the blast furnace process simulator provides a robust platform for operators to test different scenarios and optimize performance without disrupting production. The system's reporting capabilities offer detailed visual representations and comprehensive reports on numerous operational, quality, and techno-economic parameters.

In summary, the integration of process digital twin system in the blast furnace operations at SAIL-ISP have helped in achieving technological innovation, operational efficiency, and productivity improvements.

Key Words: Digital Twin, Process Models, Blast Furnace, Digital Dashboard, SAIL-ISP

DIN_021

Blast Furnace hot metal temperature prediction using machine learning techniques

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Abstract

Digitalization in the steel industry is driving significant improvements in efficiency, quality, and sustainability. Prediction models are one of the efficient digital tools adopted to enhance risk management and resource optimization. Blast furnace is a primary and process efficient iron making route adopting many technology advancements. Maintaining or extending the life of the blast furnace through effective maintenance and technological upgrades, steel producers can achieve greater efficiency, reduced costs, and a more sustainable and reliable operation. Hot metal temperature (HMT) is critical parameter that indicates the quality of molten iron, energy utilisation, thermal stability, hearth life and thus the longevity of blast furnace.

Accurately monitoring hot metal temperature is a challenging job and mathematical modelling using first principles can increase complexity due to the effect of many operational parameters. Predicting the HM temperature allows operators to adjust process parameters such as blast furnace operations, refining, and casting techniques to maintain desired temperatures for optimal processing conditions.

In this work, a statistical analysis was performed to study the effect of different parameters such as blast temperature, blast volume, ore to coke ratio, blast moisture, fuel injection rate, oxygen enrichment etc. on hot metal temperature and correlations were established. By using machine learning techniques such as multi linear regression (MLR) and random forest (RF), a prediction model was developed and validated with the plant data. The model accuracy was found to be more than 75 % with ± 5 °C deviation. Key findings highlight the significant impact of blast parameters on thermal conditions within the furnace and their implications for process control and optimization.

Key words : Hot metal temperature, prediction model, random forest, ML

DIN_075

A computational soft sensor for prediction of realtime media wear rate of grinding mill

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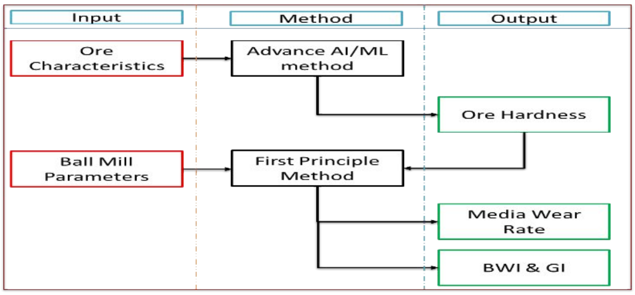
Abstract

Optimizing grinding mill performance in iron ore pelletization necessitates overcoming challenges such as grinding media wear. During grinding operations, media wear occurs unpredictably, necessitating frequent mill stoppages to check media level and top up quantity. To overcome such problem, a novel hybrid methodology has been developed, amalgamating AI and machine learning for ore hardness prediction and first-principle mathematics for media wear kinetics modeling. This comprehensive approach integrates ore physical and chemical characteristics, a plurality of grinding operation parameters, and design variables of the grinding mill as input parameters. By accurately forecasting media wear rates and recommending timely media top-ups during grinding operations, the methodology enhances product size quality and reduces specific power consumption by 3 to 5 percent. Moreover, the methodology uniquely determines media wear separately for cascading and cataracting phenomena of media motion inside the mill, providing intrinsic insights into grinding phenomena and its media wear causes. This advancement provides significant improvements in the efficiency and cost-effectiveness of the grinding process for iron ore pelletization.

Keywords: Grinding Media, Wear Kinetics, cascading and cataracting motion

[1] M. J. Chegeni, Journal of Mining and Environment (JME) Vol. 10, No. 1, 2019, 151-161.
[2] A. Azizi et al., Iranian Journal of Material Science Vol 13, No.2.



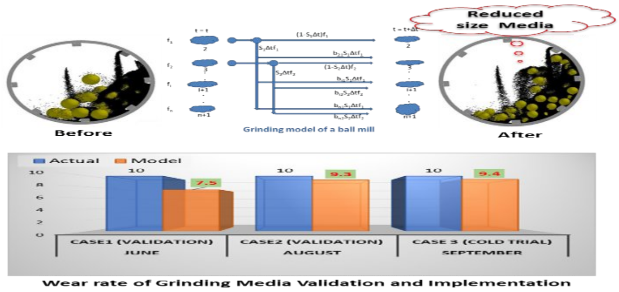


Fig 1: Approach for real time media wear rate
Fig 2: Results of media wear rate

DIN_100

Digital Twin Solution in Green Anode Manufacturing

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Abstract

Mahan Aluminium Smelter of Hindalco Industries located in Madhya Pradesh, India, utilizes AP30 technology with a designed capacity of 360KTPA for Aluminium production. The process follows the Hall- Héroult method employing carbon as the anode material. The carbon anode, a critical component in the electrolysis cells is manufactured using a blend of calcined petroleum coke and coal tar pitch to produce green anodes. These green anodes undergo baking in an anode bake oven before deployment in the Potlines. Consistently maintaining high-quality anodes is essential for Potline efficiency and energy consumption. In recent years, sourcing high-quality coke has emerged as a significant challenge, complicating efforts to produce superior anodes using varied coke types from different suppliers with varying specifications. Furthermore, the absence of real-time coke granulometry monitoring and continuous paste quality assessment contributes to increased rejection rates of paste and anodes, thereby escalating the Cost of Poor Quality (COPQ) associated with green anodes.

To tackle these challenges, a digital twin of the green anode plant has been created to forecast anode quality using different coke types. This digital twin utilizes hourly predictions and recommendations derived from historical data and operational insights, enabling real-time adjustment of parameters. It integrates several machine learning models such as decision trees, K-means clustering, and random forest regression. Live data is captured and displayed on a dashboard that includes hourly graphs, analysis of deviations, root cause identification, and actionable recommendations.

The implementation of digital twin has led to enhanced anode quality and increased process stability through timely predictions and actionable recommendations. This system enables proactive management of raw material variability and paste quality, thereby reducing the Cost of Poor Quality (COPQ) associated with green anodes.

The digital twin deployed at the green anode plant of Mahan Aluminium Smelter showcases considerable potential in optimizing production processes and elevating product quality.
Keywords: Digital Twin, Machine Learning, Fault Trees, Clustering, Optimization

MPR_156

Digital transformation in Aditya Smelter: Enhancing productivity and sustainability in Aluminium smelting

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Abstract

Aditya Aluminium, a state-of-the-art AP-30 smelting facility with a capacity of 370 KTPA, ranks 2nd globally in metal purity among AP-30 s smelters. Located in Odisha, India, the facility emphasizes precise control over various parameters to ensure metal quality and competitiveness in the energy-intensive aluminum smelting process. Any deviations can lead to significant energy and productivity losses.

The smelting process is significantly energy intensive which involves potlines with electrolytic cells where alumina, derived from bauxite, is dissolved in molten cryolite and undergoes electrolytic reduction using carbon anodes, producing aluminum and emitting carbon dioxide.

Aditya Aluminium has embraced digital initiatives to enhance data generation capabilities, crucial for sustainability and competitiveness in the industry 4.0 era. The key pillars of digital transformation include data democratization, reducing paper-based processes by over 75% using OAC/APEX platforms, adaption to cutting edge digital tools and technology of industry 4.0, AI-ML and focus on people upskilling.

Advanced potline process control servers (ALPSYS) and real-time monitoring systems ensure data accuracy and readiness for analysis. Automated analytical reports and smart analytical dashboards provide critical insights, enabling faster decision-making on the shop floor.

Predictive, prescriptive and descriptive analytical models, such as bath temperature and CVD analysis allows forecast future conditions and recommend actions to maintain optimal chemical and thermal balances in potlines, improving productivity and reducing failure risks.

Use of online shuttle planning to generate 3-pots combos (Shuttle) based on lab reports (LIMS) and tapping weights recommendation is another significant achievement that has guided to optimize the metal purity-volume enhancement and also eliminate human practices to generate shuttle reports.

Vision analytics for anode carbon block surface defect detection in green anode plant and baking furnaces is another innovative application. Advanced image processing and high-resolution cameras inspect and analyse anode surfaces, ensuring only high-quality blocks are used, thereby saving energy by eliminating the need to bake defective anodes.

ML modelling and exploratory data analysis of anode baking furnaces (ABF) have optimized the baking process, improved sectional performances of baking pits, leading to optimized HFO consumption and improved anode quality (Lc). Smart condition-based monitoring setups for

critical equipment like CT fans, compressors, crushers, and ID fans provide detailed vibrational analysis, oil quality monitoring, and predictive action recommendations. These IIoT devices monitor machinery health in real-time, predicting potential failures and reducing unplanned downtime and maintenance costs.

Online air flow monitoring and compressor performance tracking using mass-thermal flowmeters have significantly reduced auxiliary power consumption. Continuous monitoring allows for prompt detection and resolution of inefficiencies, ensuring optimal compressor operation, minimizing energy waste, and enhancing overall power management, leading to substantial energy savings and improved operational efficiency.

In conclusion, the digital transformation of Aditya Aluminium's smelter operations represents a fundamental shift in management and optimization. This transformation has resulted in significant improvements in productivity, process optimization, asset reliability, customer centricity, and reduced human intervention. By leveraging advanced technologies and data analytics, Aditya Aluminium is well-positioned to maintain its competitive edge and ensure long-term sustainability in the aluminum smelting industry.

Keywords: State-of-the-art, Aluminium Smelting, Data democratization, Exploratory Data Analysis, Smart Condition based Monitoring, Auxiliary Power Consumption, AI-ML Modelling, Digital Transformation, Anode Quality, Metal Purity, Vision Analytics, Energy Intensive, Asset Reliability, Process Optimization, Customer Centricity

DIN_103

Overcoming industrial challenges with regard to robotised handling and digital support of flow control systems in the steel industry

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Abstract

The steel industry is in a transformative phase with the advent of digitalisation, robotics and automation technologies. RHI Magnesita has developed automation-ready flow control systems as well as new digital solutions as expansion to the flow control offering and rolled these out to the steel industry with the corresponding robotic cells. This paper explores how these advances contribute to a safer working place, improved process stability and a more attractive working environment in the steel industry for future workforce talents. In a showcase, we focus on a novel bottom-up approach that improves processes related to ladle slide gate operation through digitalisation, integration of slag detection sensors and advanced mechanical design. The result is the development of decision support systems that provide operators with real-time insights, empowering them to make informed decisions, address process deviations and optimize refractory utilization over time.

In addition, the paper also examines how advances in robotics and automation contribute to a safer working environment in the steel industry. One area of focus in the area of flow control is the coupling process of hydraulic cylinders to the ladle slide gate and other media in the casting area, which traditionally requires multiple sequential, manually executed movements and exposes operators to a harsh and unsafe working environment. The innovative hydraulic cylinder with media-coupling technology proposes to combine these sequential movements into a single, integrated movement. This transformative change not only streamlines the manual coupling process, but also lays the foundation for the introduction of robotic automation. Another focus is the robotic handling of the flow control elements required for the steel transfer from the ladle to the tundish on the hot side of the continuous caster, such as the ladle cover, temperature sensors and steel samples. And further focus, is the robot-assisted handling of monotubes from the tundish to the mold for automatic exchange in order to extend the sequence lengths.

This paper describes and demonstrates industrial applications of how RHI Magnesita offers customers a portfolio of advanced technologies and solutions based on its in-house flow control systems, building on innovations in robotics & automation, sensor integration and digitalisation.

Key words: flow control, robotic handling, digitalisation

ISM_208

Digital transformation in Aditya Smelter: Enhancing productivity and sustainability in Aluminium smelting

Anish Das, Himan Kundu, Nikita Gayake , Vishal Bodhke ,Manish Shaw

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Abstract

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DIN_103

Leveraging AI for Operational Excellence: A Real Time Defect Prediction & Prescription at Continuous Galvanizing Line

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Abstract

The galvanizing process, crucial for enhancing the durability of steel products, is susceptible to various defects. These defects, arising from process parameter fluctuations, can lead to material degradation, production disruptions, and a decline in product quality. This research presents the development and deployment of a data-driven quality prediction model aimed at mitigating these challenges at GP-1, a galvanizing line at Tata Steel.

The model utilizes a comprehensive dataset encompassing real-time critical to quality process parameters and associated defects. This dataset spans over a year and captures data from various stages of the galvanizing process, including furnace parameters, strip temperature, and cooling zones. The model integrates a machine learning algorithm trained on this historical data to predict the occurrence of major defects with a focus on those arising due to process parameter variations.

The model leverages Pareto analysis to identify the most significant contributing defects, enabling targeted interventions. It also incorporates a prescriptive component, recommending adjustments to key process parameters based on predicted defect occurrences. By providing early warnings and precise recommendations, this model empowers operators to proactively mitigate defects, enhancing product quality and minimizing production disruptions.

The deployment of this model has a multi-faceted impact. It reduces the rate of product diversion due to process parameter variations, improving material utilization and reducing costs associated with scrap. Additionally, it enhances the consistency of the GP coil supplied by ensuring that products adhere to quality standards. The model also facilitates efficient process control by providing online monitoring of critical parameters and alerting operators when values exceed predefined limits.

This research contributes to the advancement of quality control in the galvanizing industry, showcasing the potential of data-driven approaches for improving process efficiency and product quality. Future work will focus on expanding the model's scope to include a wider range of defects and incorporating real-time data integration for continuous improvement.

Key words : Galvanizing, Defect Prediction, Machine Learning, Random Forest Classifier, Genetic Algorithm, Process Optimization, Quality Control, Real Time Process Control,

DIN_103

The Journey of Digitalization in Stainless Steel Industry for Transforming Traditional Manufacturing Processes into Smart Factories

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Abstract

Jindal Stainless Limited is embarking on a comprehensive digitalization project aimed at revolutionizing its production processes, boosting efficiency, and fostering sustainable growth through the integration of advanced digital technologies. This project encompasses the implementation of Industry 4.0 principles by leveraging cutting-edge technologies.

First, it aims to optimize operations by enabling real-time monitoring and analysis of production data. This will allow for more informed decision-making, quick identification of inefficiencies, and prompt corrective actions, which will free up human resources for more strategic roles and reduce the likelihood of human error.

Creating a smart, interconnected manufacturing environment is the overarching goal of the project. By integrating various production systems and enabling seamless communication between them, the project aims to create a cohesive and agile manufacturing process. This interconnected environment will facilitate better coordination, enhance flexibility, and enable rapid responses to changing demands.

We will implement several key initiatives in our digital transformation. The Plant Control Tower platform provides a comprehensive real-time dashboard for KPIs across various functions such as Production, Quality, Maintenance, Inventory, Energy, Safety, and Environment, with data aggregated from the work centre to the plant level. It features self-service historical data analysis for statistical insights and trend identification, real-time visualization and traceability for department-specific critical information, and an executive dashboard that automates data collection from multiple sources, replacing manual reporting processes.

The Digital Shop Floor initiative aims to eliminate paper trails by capturing event data electronically across all departments, such as Quality, Safety, Asset Utilization, Energy, Utilities, Productivity, and Operations. This centralized data collection enhances reporting accuracy and data quality by removing the reliance on paper logbooks. Additionally, the platform enables role-specific reporting, facilitating data-driven decision-making and improving overall operational efficiency.

The Planning Tool enhances production planning and scheduling, ensuring optimal resource utilization and alignment with demand. The Manufacturing Execution System (MES) implementation ensures real-time monitoring, data traceability, and control of production processes, standardizes procedures and maintains quality compliance and data hygiene.

DIN_066

Together, these innovations drive efficiency, accuracy, and responsiveness in the manufacturing environment.

The ultimate goal of this project is to enhance product quality and consistency by leveraging predictive analytics to detect and resolve potential issues before they impact production. Additionally, it aims to minimize downtime and extend equipment lifespan through predictive maintenance. Another key objective is to create safer workplaces using digital tools for real-time safety monitoring and improvements, replacing manual checks and paper records. Furthermore, it will implement a process-wise automatic CO_2 emission recording. This digitalization project is poised to transform Jindal Stainless Limited's production landscape, making it more resilient, agile, and capable of meeting future challenges in the stainless steel industry.

Keywords: : Digitalization,Real-time monitoring,Plant Control Tower,Digital Shop Floor,Manufacturing Execution System (MES)

Reliability Improvement of Ball Mill Through Digitalization

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Abstract

In the Alumina refining process, the 180TPH Ball Mill plays a pivotal role in the wet grinding of bauxite, which is essential for size reduction of feed material. This ball mill setup comprises several critical components, including a motor, gearbox, girth gear, mill, feed and discharge chutes, a lubrication system, starter panel and a power and control system. As a single-line equipment, the reliability of the ball mill directly impacts the plant's production capacity and overall operational efficiency.

Historically, the ball mill faced recurrent breakdowns, primarily due to bearing failures in either the mill or the motor. This resulted in significant production losses—averaging 45 tons per hour of hydrate alumina- which translated to financial losses of approximately Rs 82 lakhs daily. Maintenance costs surged to around 90 lakhs over the last three breakdowns, with a cumulative production loss of 22,000 MT.

To address these challenges, a Predictive Analytics system using Real-Time Monitoring of data (RTMS) was implemented to enhance the Ball Mill's reliability and availability. This system integrates several critical features: Vibration monitoring and analysis of motors, gearboxes, pinion, and girth gear bearings; Temperature monitoring for various components including motors, the ball mill, and Lubrication systems: lube oil quality analysis; motor current and mill feed trend analysis; and hydraulic oil flow and pressure monitoring. Additionally, the RTMS communicates with the existing PLC, providing real-time analytics through a user-friendly dashboard and SMS alerts.

The implementation of the RTMS has yielded a significant improvement in operational efficiency. Notably, the ball mill experienced no production loss or downtime in FY 23 & 24. This project has effectively reduced unplanned maintenance, optimized equipment performance, and transitioned the plant from reactive to predictive maintenance practices. The enhanced prognostic and diagnostic capabilities provided by the RTMS have not only improved the uptime of the ball mill but have also contributed to a more reliable and sustainable refining process, demonstrating substantial financial and operational benefits for the refinery unit.

Key words : Alumina Refinery, wet grinding, Ball Mill, Condition Monitoring, predictive maintenance, Digitalization, reliability improvement.

DIN_093

Digitalisation of Tandem mill stand motors for reducing stand tripping

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Abstract

Resistance Temperature Detector (RTD) is an instrumental device used to measure the temperature at different points in gearbox and motor bearing. At cold rolling mill (CRM) of Bokaro Steel Plant have 71 nos. of RTDs in gearbox and motor bearing. Whenever the temperature of any RTDs increases beyond 60°C, the stand is made to trip. In absence of analysis of temperature signal on historical basis the rising temperature trend is not captured and hence advance alerts cannot be generated.

To address the issue of not capturing the rising temperature trends and generating advance alerts, a new PLC system is developed for continuous monitoring and analysis of the temperature signals from the RTDs.

71 nos. of temperature transmitter for motor bearing temp through RTD is connected to PLC Pane as shown in Fig.:1. The temperature signals acquired through PLC & remote I/o is continuously analysed to provide advance alerts to all concerned executives through appropriate dashboard. SMS gateway system was integrated to send automated messages to multiple concerned recipients for warning, tripping temperature detections, and fault clear notifications if problem is resolved.

By implementing a system for Data Acquisition, Real-Time Monitoring with Alert System, temperature trends are monitored continuously, and potential issues are detected early, allowing for timely preventive actions and reducing the risk of unplanned shutdowns.

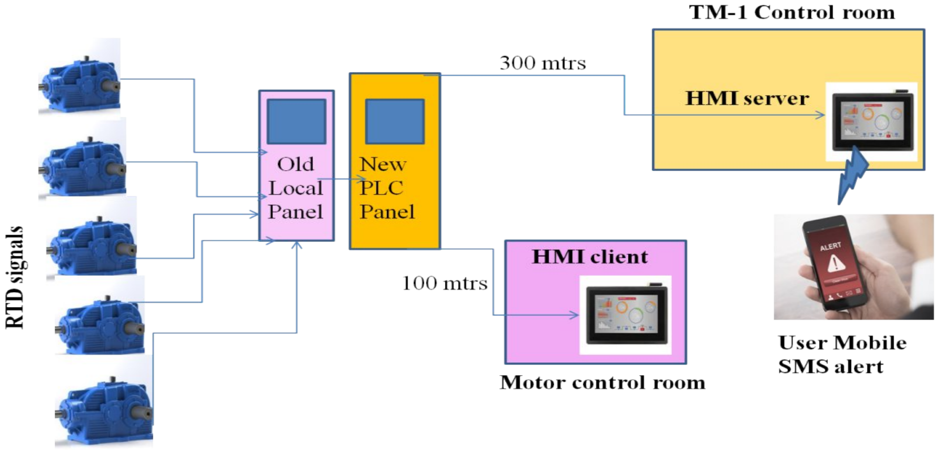

Fig. 1: An overview of OLD and New System

DIN_045

Development of a Hybrid Simulation and Machine Learning Model for Predicting Last Wash Soda and Operational Anomalies in an Alumina Refinery

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Abstract

In alumina refineries, the efficiency of the washing circuit, particularly in removing residual caustic soda from red mud, is crucial for optimizing soda losses and overall plant performance. This challenge is magnified when dealing with multiple bauxite sources, leading to significant process variability. This study proposes the development of a machine learning (ML) model to predict the last wash soda concentration in the residue stream of an alumina refinery utilizing conventional washers/decanters.

To start, a SysCAD model was developed to simulate the washing circuit, which was meticulously calibrated and validated to ensure it accurately reflected plant operations. Multiple iterations were performed to fine-tune the model. This validated SysCAD model, along with extensive plant data encompassing, bauxite composition, washer operating conditions, caustic ratios, and process temperatures, was then used to train the ML model. The objective is to predict the final wash soda concentration in advance, enabling operators to make timely process adjustments to mitigate the impact of bauxite variability and other operational shifts.

Additionally, this predictive model is designed to continuously collect and learn from new data. With sufficient future data, the model is expected to evolve to detect early signs of potential rake failures in the washer, further enhancing the reliability and operational safety of the washing circuit.

By integrating process simulation with advanced ML techniques, this approach offers a dynamic solution for real-time optimization and proactive maintenance. The research highlights the significant potential of data-driven models in improving both the efficiency and resilience of alumina refinery operations.

Keywords: Simulation, Predictive Modeling, Washing Circuit, Rake Failure Prediction, Machine Learning

DIN_082

Integrated Tool for Accelerated Materials Design & Development using AI & ML

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Abstract

Conventional methods, by which new materials are designed and developed, take a long time while incurring huge cost owing to the large number of experimental trials that are needed. With the advent of computational materials modelling and Artificial Intelligence (AIML) techniques, there have been efforts to gain insights into material systems, to capture complex trends, and to identify novel materials with desired properties. Further, the capabilities of AI are being explored to study microstructures for different purposes such as failure analysis, defect analysis etc and to establish process-structure-property correlations.

As a part of this work, an integrated tool for Accelerated Materials Design and Development (AMDAD), has been developed with a graphical user interface (GUI) that can perform all the machine learning operations starting from data collection, pre-processing, model fitting, optimization to the microstructure analysis on a single platform. AMDAD can significantly speed up the alloy design process, improve processing efficiency and provide complex processing, structure and property correlations.

A comparative study has been performed to benchmark the tool's performance with respect to several industry standard ML tools that are available for material science. Each tool has been evaluated through a consistent framework of criteria such as performance metrics (R^2, RMSE, training and inference time, resource utilization), usability metrics (ease of use, flexibility in data input, integration with other tools), and versatility metrics (range of supported algorithms, customizability, handling of various data types). The paper will summarise the capability of the developed tool and also elaborates the performance of AMDAD in comparison to other tools in terms of these metrics.

Keywords: Material Informatics, AIML, Software

CMS_119

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

CMS_096

Production parameter development and optimization in Additive manufacturing using Machine Learning & Artificial Intelligence.

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Abstract

Additive manufacturing (AM), also known as 3D printing, is a relatively new downstream manufacturing process used to produce intricate, high-quality functional parts and rapid prototypes from various ferrous and non-ferrous metals. This technology has gained widespread acceptance and experienced rapid growth over the past few years due to its numerous advantages. One key benefit of AM is the elimination of the need for moulds and additional tooling, as parts can be constructed layer by layer directly from a 3D drawing of the part. This process allows for the creation of internal features and passages that are impossible to manufacture using conventional methods. There are several 3D printing technologies available, with Laser Powder Bed Fusion (L-PBF) being one of the most common for producing high-quality, intricate metal parts. L-PBF involves up to 225 production parameters, with quality and productivity highly dependent on the correct selection of these parameters. Among the most critical parameters are laser power, scanning speed, hatch distance, layer thickness, and scanning pattern. Traditional experimentation techniques in manufacturing typically involve a trial-and-error approach, where one parameter is adjusted at a time while keeping others constant to observe the effects. This method is time-consuming, labour-intensive, and often fails to identify the optimal set of parameters due to its inability to account for interactions between different variables. Additionally, conventional methods can be costly and prone to errors, leading to suboptimal operating conditions that may not maximize productivity or quality. This paper presents a case study focused on systematically optimizing operating conditions to minimize defects while maintaining productivity. It involved following steps: Taguchi method (a design of experiment methodology) is used for design, conduct, analysis of experiments. Series of test blocks are built under various conditions as per TM design. Resulting properties such as density, roughness, porosity etc are measured. The data generated is fed into Artificial Neural Networks (ANN) software algorithm (a Machine learning technique) and predictive models are built. Predictive models are fed into a Genetic Algorithm (GA) –an Artificial intelligence (AI) algorithm, to determine optimum parameters. ANN is a software algorithm patterned after the operation of neurons in the human brain and is used extensively in such applications. GA is a search heuristic that mimics natural selection, using processes like mutation, crossover, and selection to optimize parameters and find the fittest solution.

By using this approach, significant time and resources are saved compared to conventional methods. This systematic and intelligent approach not only improves the quality and productivity of the manufacturing process but also provides a more reliable and repeatable method for parameter optimization.

Key words : Additive manufacturing, Laser powder bed fusion, Parameter development, ANN, Genetic algorithm, Taguchi method, predictive modelling, optimization, Industry 4.0

DIN_028

Optimization of a grinding circuit using physics-based and machine learning models

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Abstract

Mining and mineral processing is an energy-intensive industry, where optimizing key unit operations and processes is vital for enhancing profitability. Comminution operation, a crucial process in mineral processing plants, accounts for approximately 40% of the total energy consumption in a typical plant. Reducing power consumption while increasing throughput and maintaining product quality is both essential and challenging, especially as declining ore quality demands finer particle sizes and ultrafine grinding. Existing plants face significant hurdles in adopting new ultrafine grinding technologies due to high capital and operational costs.

A promising alternative is leveraging artificial intelligence and Industry 4.0 technologies to predict and optimize grinding circuit key performance indicators (KPIs) in real-time. We propose a novel framework that integrates physics-based and empirical models with machine learning (ML) and genetic algorithms to enhance grinding operations. It includes physics-based or semi-empirical models for three critical KPIs: mill hold-up (H), product particle size distribution, and power consumption. Existing models consider either product quality or power consumption only and not mill hold-up (H), which is also an important process variable.

The models for each KPI are validated with experimental data from a lab-scale ball mill. Subsequently, machine learning models are developed using simulated data generated from the physics-based models, to serve as soft sensors for online optimization. Integrating real-time sensor data with laboratory data and performing on-line data fusion and pre-processing are essential steps for providing accurate inputs to these models. Multi-objective optimization is performed using genetic algorithms to determine the optimal settings that maximize circuit throughput and minimize specific power consumption while meeting product quality specifications.

Finally, this framework can be implemented within a digital twin system, enabling continuous monitoring and real-time optimization of grinding operations. While tested in the context of ore grinding, this methodology is also applicable to other industries such as cement, pharmaceuticals, chemicals, and power utilities where comminution is an important operation, exemplifying the transformative potential of digitization and Industry 4.0 technologies in industrial processes.

Keywords: Comminution, Mineral Processing, Modeling, Optimization, Machine learning

DIN_060

Scrap motivated development of TRIP steels using interpretable machine learning

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Abstract

Scrap-compatible alloy design is important for the sustainable development of advanced high-strength steels with enhanced mechanical properties. This study describes a hybrid interpretable active learning framework for designing scrap-compatible Transformation-Induced Plasticity (TRIP) steels with improved yield and tensile strength by combining machine learning and experimentation. TRIP steels possess excellent strain-hardening characteristics leveraged through their underlying thermodynamic design principle, aiming to exploit misfit dislocations and additional interfaces generated by the gradual transformation of metastable austenite patches upon mechanical loading. However, limited tolerance of copper in steel scrap is one of the major deterrents in its utilization for developing advanced steels. Therefore, a hybrid interpretable active learning system is suggested for discovering the composition of high strength, high Cu tolerant TRIP steels based on steep scrap chemistry. We base our approach on the use of Machine learning (ML) with a focus on interpretable models and artificial neural networks. Machine learning has revolutionized the field of materials science, particularly in the design of novel alloy systems. However, the conventional 'black box' nature of ML models severely inhibits their applicability in developing alloy design insights for complex problems such as scrap steel based alloy design. Therefore, we combine the idea of the interpretation of continuous compositional pathways with active learning to search for novel high strength TRIP steels with high Cu tolerance based on scrap steel chemistries. In this direction, we propose a hybrid interpretable active learning framework for the composition discovery of high strength, high Cu tolerant TRIP steels based on steep scrap chemistry. The approach comprises of ML based techniques, thermodynamic calculations using CALPHAD and model informed experiments. This holistic approach aims to not only expedite the alloy development process but also lay the groundwork for a more intelligent and sustainable materials design paradigm.

DIN_062

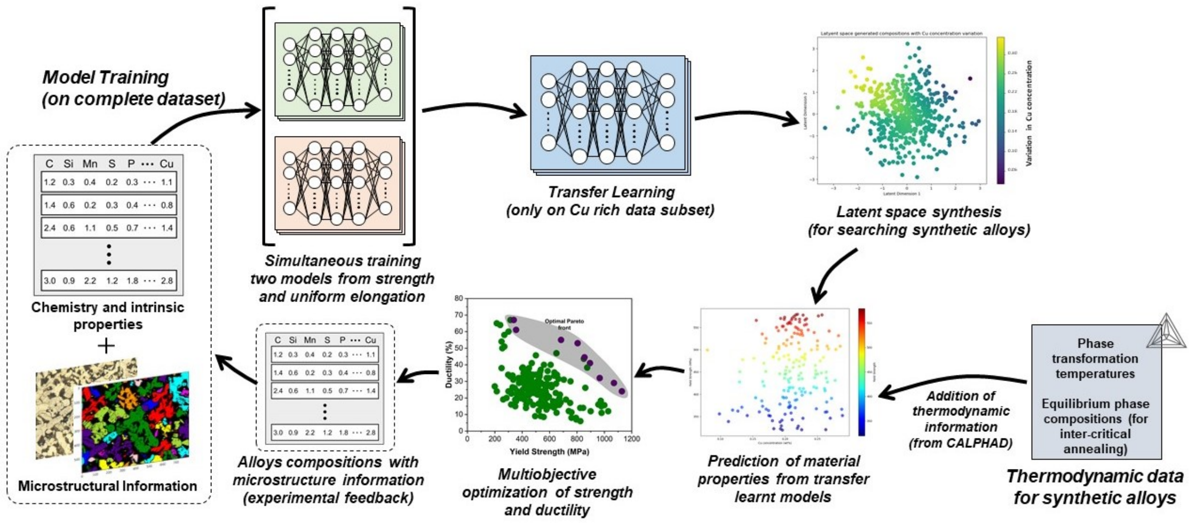

Fig. 1: Schematic representation of the hybrid active learning framework

Keywords: Steel scrap, TRIP steels, Machine Learning, CALPHAD, Artificial Neural Networks

Development of CCS prediction model for iron ore pelletization process through Machine Learning

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Abstract

In an integrated steel plant, the iron ore pellet properties affect the productivity and efficiency of the iron making units. The pelletizing process is very dynamic and is affected by many raw materials and process variables, which cause fluctuations in the cold and high temperature properties of the pellets. This mandates an increase in the frequency of sampling and testing, which involves tedious and long testing procedures leading to delay in corrective action. As part of advanced process control (APC), PP-3 has recently commissioned Optimizing Control System (OCS) from Metso which is essentially a simulation-based process advisor for pellet plant. It requires pellet cold crushing strength (CCS) property value as an input for internal calculations and subsequent process control. At pellet plant 3, CCS is tested twice in every shift. This value is available to the operators after a time lag of ~4 hours. This delay in tested CCS values causes delays any corrective action from OCS in case of deterioration in pellet properties. A CCS prediction model was developed based on gradient boosting machine learning technique in Python language to predict pellet CCS which can be used as an input to OCS. The model was developed with most important 12 input (process and composition) parameters which can be provided through a web-based application interface. The developed model achieved an R^2 of 0.72 and an average prediction accuracy of ~95.41%. Post deployment, the model helped in eliminating the time lag between sampling, testing to reporting of final property value which helped in better process control thereby reducing the standard deviation of the pellet CCS from 17.75 to 14.5. The model can also be used as an optimization tool for improving process performance and achieving better process control.

Key words: Iron ore pelletization, CCS prediction model, machine learning, gradient boosting.

DIN_090

Detection and analysis of clogging in a submerged entry nozzle using Deep Learning

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Abstract

The casting process involves the steel flow from the tundish to the mould through a submerged entry nozzle which protects the liquid steel from re-oxidizing with atmosphere. The flow rate is controlled with a stopper rod to maintain optimum casting conditions.

Nozzle clogging is the build-up of solid / semi-solid material on a refractory surface. Clogging impact is severe .It limits the productivity by interruption of the casting process, restricting the number of charges per tundish, affecting the quality of the produced steels, and consequently increasing the cast product customer rejections.

The problem statement identified was to detect clogging which was challenging. Clogging is typically defined through a deviation in stopper rod position and mould level. However, stopper rod position rise can be attributed to events other than clogging. What cannot be identified, cannot be quantified. And, what cannot be quantified , cannot be controlled. Clogging needs to be controlled as it affects both production and productivity downstream.
Preliminary analysis was done to identify percentage of missing values and identification of the repetitive event which best captures clogging. Qualitative analysis was done to establish clogging in terms of sensitivity analysis on lead parameters and unique identifiers of clogging. Quantitative analysis on clogging characteristics in terms of stopper rise and fall (using moving mean)and their delineations to quantify degree of clogging .

Qualitative identification of clogging was challenging leading to the requirement of a Machine Learning model for better classification . Classification required delineation of good and bad data(using moving standard deviation) in order to train the model.

A deep learning model (LSTM – Long Short-Term Memory) was successful in establishing superior model performance of accuracy, precision , recall and F1score above 0.9. The hyperparameters considered and their impact on the final model performance were also documented.
DIN_092

The model is used for root cause analysis in identifying the factors leading to clogging and dynamic intimation to the operator for corrective action within a single cast itself.

This lead to a combined savings of 3.5 Cr because it also helped in giving a probabilistic likelihood of sliver downstream which impacts product rejections.

Key words : Deep Learning; Machine Learning; clogging; submerged entry nozzle ;root cause analysis; casting ; production ; productivity

DIN_92

Transformative Integration of Industry 4.0 Technologies: Enhancing Efficiency, Safety, and Sustainability in Cold Rolling Mill-2 Operation

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Abstract

In the dynamic landscape of industrial operations, the integration of Industry-4.0 tools has become paramount for enhancing efficiency, safety, and overall performance. This abstract encapsulates the deployment and utilization of various cutting-edge **Industry-4.0 technologies** within the Cold Rolling Mill-2 department, showcasing a comprehensive approach towards operational excellence. A step towards automation is the deployment of a **dross skimming robot**, a robotic solution designed to streamline the dross removal process. By automating this labour-intensive task, operational efficiency is significantly enhanced vis-à-vis mitigating the safety risks associated with manual intervention.

Furthermore, the integration of **video analytics** has revolutionized safety protocols within the department. Leveraging advanced algorithms, this technology enables real-time monitoring of operational areas, identifying potential hazards and sending alarm to working personnel, thereby fostering a safer working environment. **IoT sensors** equipped with **edge analytics** and **cloud computing** capabilities have been strategically deployed for **predictive maintenance** initiatives. By continuously monitoring equipment health and performance metrics in real-time, potential malfunctions and downtimes are predicted and pre-emptively addressed, avoiding downtime of **689 hours** and minimizing production disruptions.

Addressing environmental sustainability concerns, a rolling oil concentration measuring device has been introduced to optimize rolling oil consumption at PLTCM. Through precise measurement and control of oil concentrations, resource utilization is optimized, contributing to **cost reduction of 6.1 million INR per year.** Moreover, the utilization of Generative Artificial Intelligence (Gen AI) and Natural Language Processing (NLP) technologies have revolutionized the planning and scheduling processes. By harnessing the power of AI-driven algorithms, complex data sets are being analysed, enabling informed decision-making and enhancing overall operational efficiency and agility. In conclusion, the amalgamation of these Industry 4.0 tools within the Cold Rolling Mill-2 department exemplifies a holistic approach towards **operational excellence, safety reinforcement**, **resource optimization**, and **strategic decision-making**.

Key words : Dross Skimming Robot, Predictive maintenance, Gen AI, IoT, AI/ML, NLP, Cloud-computing,

DIN_027

Machine Learning approaches for Efficient Tunnel Furnace Operation in TSCR

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Abstract

In the TSCR process, the tunnel furnace plays a crucial role, acting as a buffer and a reheating furnace, while reducing costs, energy consumption, and efficiency. Mixed gas is used for reheating the thin slabs of 50-70 mm thickness to temperatures between 1150-1170°C. The combustion system of the tunnel furnace operates in a closed loop, integrating thermocouples, flow control valves, pressure control system and Calorific Value (CV). This closed-loop system is designed to maintain precise temperature control and optimize fuel consumption. Thermocouples are used to measure the temperature at various points within the furnace, providing real-time data to the control system. Flow control valves regulate the flow of fuel and air, ensuring the correct combustion mixture with respect to CV, while pressure control system monitors the pressure inside furnace and gives feedback to damper opening.

However, the efficiency of this closed-loop system is highly dependent on the accuracy and reliability of the readings from the thermocouples and the performance of the flow control and pressure control system. Any abnormality in these readings can disrupt the entire loop, leading to suboptimal combustion conditions. For instance, if a thermocouple provides inaccurate temperature data, the control system may adjust the fuel and air mixture incorrectly, resulting in either excess fuel consumption or insufficient heating. Similarly, malfunctioning flow control valves can lead to imbalances in the fuel-air ratio, further affecting the combustion efficiency and increasing fuel consumption.

Thus, the integrity of the closed-loop system is crucial for the optimal operation of the tunnel furnace. Abnormalities may occur even if after regular calibration and maintenance of thermocouples, flow control valves, and control valves. Advanced monitoring systems and predictive maintenance strategies were used to identify such potential issues beforehand.

Key words: Thin slab caster, Tunnel Furnace, Machine Learning, Combustion system

DIN_094

Industry 4.0 in EPCM Sector – Minerals, Metals & Process Industry

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Abstract

Meinhardt EPCM (India) Private Limited, part of Meinhardt Group, is one of the reputed Engineering Consultant globally and follows the project delivery model from concept to commissioning based on "SPEED- PRECISION-SAFETY". To achieve this model, Meinhardt EPCM adopted various Industry 4.0 techniques in EPCM projects, especially in Minerals, Metals & Process industry. Some of the major techniques being followed are Project delivery through Building Information Modeling (BIM) to ensure clash free design and help in visualizing the construction schedule, Laser Scanning in brown field Projects, modeling and simulation, pre-fabricated modular construction to save construction time, mobile applications for safety management, cloud based real time collaboration, AI, IIoT, Discrete Element Method, etc.

Apart from the 3D modeling, technology had advanced and pushed the boundaries of design and engineering to higher dimensions, viz: 4D (time), 5D (cost), 6D (Energy) and 7D (Operations and Maintenance of the system).

Meinhardt EPCM and the project team had used various techniques like Industry 4.0, IIoT, Laser Scanning to upgrade the existing bulk material Ship Unloaders, Ship Loader, Bucket wheel Stacker and Reclaimer machines in fully autonomous modes of operation for loading, unloading, stacking & reclaiming Iron Ore including the anti-collision system in the Terminal for one of their clients. In one of the project, where the scope was for Concept level study for preparing the iron ore for dry grinding circuit, Meinhardt had effectively utilized 3D modeling to arrive at the bill of quantity for the entire systems, and thereby achieving required accuracy and saved time.

Meinhardt had also effectively used computational model / simulation techniques to propose the modifications in the ducting system of Iron Ore pellet plant, to support the client's effort to reduce carbon footprints and towards sustainability.

Meinhardt is also working towards Digital Twin (DT) in some of the projects which enhances the stakeholder's visibility multifold from blueprint to reality. This apart from 3D rendering and walkthroughs has the potential to interface the engineering data with the operational information.These techniques have enabled the EPCM sector towards a paradigm shift to arrive at a different business model and resulting in increased efficiency and productivity.

Key words: EPCM, Industry 4.0, Minerals, Metals, Iron ore, Beneficiation, Pellet plant

DIN_031

The Future of Metal Manufacturing:Embracing Industry 4.0 and Digital Technologies

By: Mr Harish Pathak
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Abstract

The metal industry is transforming significantly with the advent of automation and robotics, enhancing work safety, productivity, and consistency by replacing labor-intensive, hazardous tasks with automated processes. Digitalization, or Industry 4.0, leverages advanced technology and machine learning to optimize industrial processes, resulting in increased ROI, safer work environments, reduced worker strain, and enhanced precision. These advancements collectively save time, money, and energy, streamlining workflows and revolutionizing traditional practices.

Steps Towards Industry 4.0

New Equipment-Adopting newer equipment enhances digitalization and reduces the maintenance and labor demands associated with older technology. Although this transition requires substantial capital expenditure, the long-term benefits justify the investment.

Robots-Robots automate routine, repetitive tasks, enhancing safety by removing humans from hazardous areas and handling high-temperature materials, thereby mitigating health risks. Additionally, they can operate continuously without breaks, driving efficiency in the metal industry.

Digitalization of the Supply Chain-Smart supply chain software optimizes material procurement methods and predicts delays using AI, thereby enhancing efficiency and reliability.

Automation Using AI-AI is utilized to automate tasks, minimize scrap, and reduce costs. This process often involves simulation, eliminating the need for prototyping, which saves time and further reduces costs. Documenting procedures and creating a knowledge bank aids in training and knowledge transfer.

Challenges- Change management poses the biggest challenge when adopting automation with robots. Workers often fear job losses as robots assume tasks previously performed by humans. Consequently, training and upskilling workers to operate and maintain these automated systems are crucial.

Conclusion

The automation and robotics revolution in the metal industry is at an inflection point, driving efficiency, safety, quality, and innovation. The trend towards Industry 4.0 will persist, compelling every business to adopt these advancements to remain competitive.

Janyutech Private Ltd specializes in robotics, providing remotely operated vehicles and robotic arms that safeguard humans from hazardous conditions, enhance performance by reducing fatigue, and improve productivity and safety in the metal industry.

DIN_069

DRiSHyAM: DRones at SHopfloor (AI & Manless work)

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Abstract

At Coke Plant Kalinganagar Odisha India, two stamp charge coke oven batteries consume 2.11 million tons of dry coal to produce 1.57 million tons of gross metallurgical coke annually. This dry coal is a blend of around 6 different coal types ranging from Prime Hard Coking coals to Weak coking coals combining both imported and domestic coals, stacked at coal yard. Appropriate blending is ensured by 10 blending bins, each labelled with a certain type of coal. The quality of coal blend will govern coke properties subsequently facilitating smooth operations of Blast Furnace. Furthermore, since 49% of the hot metal cost is contributed by fuel cost which in turn is dominated by coke cost of around 79% it is necessary to prepare a blend with optimum cost. This project aims at developing innovative solutions in managing coals at stock yard and to implement the transition to digitalization. For this purpose, coal yard was mapped, land matrix was prepared, and each type of coal was assigned a specific site with ideal spacing between piles to prevent mixing. Three different methodologies were applied on the prepared land matrix, FIFO was incorporated into reclaiming pattern to prevent coal weathering, second anomalous coals were identified and fed into a designated anomalous blending bin to prevent quality dip, and third spillage coals were re-used. Simultaneously, drone-based photogrammetry Technology was used to capture coal pile height from a series of overlapping aerial images. In order to select the best reclaiming pile quickly, it was necessary to consider height when assessing each coal stockpile's volumetric tonnage in real time. Both quantitative and qualitative data of coals were represented in a real-time, interactive web-based dashboard. The outcomes of every methodology were in line with obtaining the lowest possible quality defect and the best possible coal blend cost. Drones used for coal yard management produced results for coal stockpile estimation that were more than 95% accurate. Coke properties and cost could be optimized through online real-time monitoring of both quantitative and qualitative coal data.

DIN_070

Fig. 1: Pictorial representation of capturing of images by drones

Key words: Coal, Drone, Photogrammetry, Digitalization.

Development of a Novel Analytical Database and Interactive Dashboard for Electrical Steel Defect Analysis

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Abstract

Electrical steel manufacturing involve various process units right from steelmaking to hot rolling, hot band annealing, cold rolling and final annealing and coating. There is a probability of defect generation peculiar to the processing line in each process of steel manufacturing. For defect analysis data cleaning, merging and visualization consumes lot of time and it is prone to manual errors. This work presents a novel solution utilizing various software tools developed in house to address these challenges. This project involves the development of an analytical database by automating data cleaning, merging, and labeling tasks, significantly reducing the time spent on these resource-demanding activities by leveraging advanced Python libraries. The data processed is stored in the SQL analytical database. The final output is an interactive dashboard developed with Power BI, providing visual insights into defect occurrence over time, defect distribution across different grades, and the impact of process parameter compliance on defect rates. This system facilitates improved defect tracking and analysis, contributing to more effective quality control and process optimization in electrical steel production.

Key words : SQL, Power BI, Python, Quality control, Data visualization

DIN_023

DIGITIZATION AND INDUSTRY 4.0

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Abstract

Digitization with Industry 4.0 is revolutionizing the logistics industry, enhancing efficiency, transparency, and reliability across both internal and external operations. This transformation is crucial given the logistics sector's role in facilitating the flow of goods and services globally, supporting both domestic and international trade.

Investment in digital transformation is substantial, with global spending projected to reach $1.6 trillion by 2023. The logistics and transportation segment specifically has seen remarkable growth, increasing from $54.92 billion in 2018 to $145.28 billion by 2025, reflecting a compound annual growth rate (CAGR) of 13%. Notably, 25% of this expenditure is directed towards digital transformation initiatives in leading organizations.

Historically, logistics systems have relied heavily on manual processes and paper-based documentation, leading to frequent errors, delays, and inefficiencies. The advent of digital technologies—such as real-time tracking and predictive analytics—is transforming these traditional methods. Digital tools now enhance not only the tracking of goods but **also In-Plant Movement (The Prime focus)**, where delays significantly impact Total Turnaround Time (TAT). Automation is crucial for addressing these delays by speeding up processes and providing real-time visibility, all while reducing costs.

An example of this digital shift is the "**Sampark**" project, designed to modernize traditional logistics systems with advanced technologies and streamlined processes. The Sampark system aims to enhance various aspects of logistics, from order management to truck loading to delivery, by incorporating real-time tracking at each stage. Key features of the Sampark system include **efficient yard and plant management, streamlined gate-in to gate-out processes, automated order allocation, improved Order Execution time, Queue reduction, historical fleet data, enhanced security and weighbridge automation**.

Digitization in logistics, driven by technologies such as IoT, big data analytics, and automation, is crucial to improving efficiency, transparency, and dependability. Industry 4.0 principles align closely with this transformation, focusing on real-time tracking (GPS), predictive analytics, and process optimization. **Project "Sampark"** exemplifies this shift by modernizing traditional systems, enhancing yard and plant management, and automating order processes.

DIN

This approach reduces turnaround times, improves collaboration, and cuts costs, reflecting Industry 4.0's emphasis on integrating advanced technologies to streamline operations and foster innovation in logistics.

By implementation of this Digitization, the **Sampark** system eliminates manual processes, accelerates In-Plant Turnaround Time, enhances process efficiency, improves collaboration, and increases safety with Improved Customer Satisfaction. This comprehensive approach results in significant improvements in logistics operations, highlighting the transformative impact of digitization in the sector.

Top of Form

Bottom of Form

Temperature monitoring in refractory-lined industrial structures of the steel industry towards Industry 4.0

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Abstract

Temperature monitoring in refractory-lined industrial structures is crucial for maintaining operational efficiency and safety in the manufacturing industry. In this paper, two such structures in the steel industry, the blowpipe of a blast furnace and the downcomer in a pellet plant, which are exposed to extreme temperatures, have been considered. The refractory lining of the blowpipe is prone to thermal cracking due to hostile operating conditions. This could result in any critical catastrophe, such as blowpipe bursts and untimely process downtime. Similarly, the downcomers in the pellet plant are prone to very high temperatures due to the burners used in pellet making. The thermal profile is monitored through thermal cameras. However, the backside of the refractory-lined downcomers is not accessible, and thermal cracking in the inaccessible areas could result in safety hazards. Thus, real-time monitoring is required to prevent any hazardous situation or sudden downtime. In this study, fiber Bragg grating (FBG) sensors were used to monitor the surface temperature. An optimal number of sensors were placed on the surface of the refractory-lines structures for temperature monitoring and preventive actions. One fiber can have up to ten FBG sensors, reducing the complex wiring and electrical hazards. An Artificial Neural Network based model was developed for the prediction of hotspots using simulation and real-time temperature data. ANN-based models can predict the critical zone of a large structure and create an alarm well in advance to take preventive action.

Keywords: Artificial Neural Network, blast furnace, blowpipe, Fiber Bragg Grating sensor, Industry 4.0, refractory-lined structures, and real-time temperature monitoring.

DIN_083

"System Driven Logistics Forecast Module to Generate Cost-Optimal Vessel Scheduling and Multi Modal (Rail/Road/Conveyor) Port Plant Linkages with AI Intervention"

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Abstract

In the era of Industry 4.0, Logistics 4.0 emerges as a crucial component, serving as the backbone for the seamless and efficient operation of modern industries. This paradigm shift integrates digital technologies, automation, and data-driven insights to optimize every aspect of the logistics process. The Flying Chital Multimodal Integrated Digital Logistics Management System is a pioneering platform that revolutionizes the logistics landscape with its comprehensive suite of services. This platform delivers logistics intelligence, connectivity, and real-time virtualization through an intuitive mobile application and web interface, ensuring access to logistics planning and operations anytime, anywhere, and across various devices.

India's leading steel producers, operating extensive integrated steel plants across the country, significantly depend on imported raw materials such as coal and limestone, sourced mainly from countries like Australia, USA, Indonesia, Mozambique, Russia (for coal), and UAE (for limestone). The logistics of transporting these raw materials from ports to plants involve complex processes with multiple stakeholders, including various management and handling groups, the Transport and Shipping (T&S) Division, and the Operations Team. The current logistics system lacks a predictive scheduling module within the SAP environment, resulting in inefficiencies such as elevated transportation costs, suboptimal inventory management, and reliance on manual coordination. ***These issues are further exacerbated by the lack of real-time visibility of incoming grades and blends, which is crucial for effective production planning.***

This paper proposes the development of an advanced digital platform powered by Artificial Intelligence (AI) and data analytics to optimize logistics planning and scheduling for India's steel producers. The proposed solution focuses on optimizing vessel scheduling and multi-modal port-plant linkages (via rail, road, or conveyor) using machine learning algorithms and predictive analytics. Key components of the platform include modules for vessel scheduling, multi-modal port-plant linkage optimization, inventory management, and integrated dashboards providing real-time visibility and reporting. The platform will leverage linear and mixed-integer programming models to optimize routing and reduce costs associated with vessel lightening, port handling, railway & road freight movement, including transportation through conveyor.

DIN_106

By facilitating data-driven decision-making and enhancing cross-functional coordination among stakeholders, the proposed digital platform aims to address the existing gaps in the logistics framework through effective planning aligned with the overall production and business strategy. The AI-driven approach will provide predictive insights on vessel schedules, port constraints, and inventory levels, ensuring seamless multi-modal (via ocean, rail, road, or conveyor) supply chain operations. This will ultimately lead to cost reduction, improved inventory management, and enhanced operational performance, aligning with the broader business objectives of India's major steel producers.

Keywords: Industry 4.0; Logistics 4.0; Mining 4.0; Multi Modal Supply Chain Optimisation; Digital Logistics Management; Smart Logistics; Real-Time Tracking; Flying Chital Integrated Logistics Management System; Digital Transformation & IoT in Supply Chain & Logistics

Development of Industry 4.0 projects at Pellet Plant-3

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Abstract

The JSW Steel Vijayanagar Pellet Plant-3, one of Asia's largest pellet plants, has implemented digitization initiatives to achieve sustainability goals. With a capacity of 8MTPA, the plant utilizes low-grade iron ore to produce BF-grade pellets. Digital solutions have been implemented to optimize furnace temperature, green pellet bed levels, and energy consumption, resulting in a reduced carbon footprint.

Pellet Plant-3 adopts Industry 4.0 technologies, enabling real-time decision making, boosting productivity, flexibility, and agility, and revolutionizing manufacturing through digital solutions.

- The ML-powered process optimizer plays a vital role in predicting and controlling furnace parameters, ensuring maximum productivity, quality, and energy efficiency. This advanced control technology is specifically designed to forecast and prevent temperature fluctuations, which are critical for maintaining operational stability. By stabilizing furnace conditions at the desired levels, the system not only enhances product quality but also contributes to significant energy savings. The integration of machine learning into this process marks a significant advancement in optimizing furnace performance and overall plant efficiency.
- Pellet size significantly impacts the overall efficiency and performance of a plant, making it a critical factor to optimize. To address this, we have implemented advanced camera analytics to monitor and assess pellet dimensions in real-time. Additionally, we have integrated geo-fencing technology, which, combined with machine learning (ML) algorithms, allows for precise control and adjustment of pellet production processes. These innovations not only enhance pellet quality but also contribute to more efficient plant operations. The application of these technologies is expected to yield substantial improvements in production efficiency and output consistency.

Key words: Machine Learning, Digital Image Correlation, Industry 4.0

DIN_079

Smart Steel Melt Shop LadleE Tracking System

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Abstract

Manual and semi-automatic operations in steel melt shop provide opportunities to optimize operations. Convertor/EAF, secondary steelmaking, casters and other processing stations need to be in complete coordination to tap maximum productivity and process efficiency. Since ladle transfer is enabled by transfer cars and cranes, tracking of their position and movement is key to coordinating operation. Without this, high variation in operational and waiting time reduces productivity and poses challenge for operators at secondary metallurgy to estimate accurate lift temperature for desired superheat. Temperature of molten metal in tundish, or 'superheat', being in the right range is critical towards ensuring optimum casting speed and high cast quality. Deviation of actual superheat towards the lower end of the desired range causes clogging and even early solidification, whereas deviation towards the higher end leads to lower casting speed, risk of process failures like breakouts and higher energy consumption during arcing. Actual superheat depends on thermal loss undergone by the heat during holding/waiting, transport and teeming operation. This loss is a complex function of ladle turnaround time, processing time and other process and design features and hence varies significantly from one heat to another. Plant-specific operations or deviations from regular process flows also add to the complexity.
A comprehensive digital solution has been developed for tracking all cranes, transfer cars and ladles in real time as well as operational duration for heat at processing stations. Based on the melt shop scenario, processing time and events are also forecasted. This enables coordinated operation and movement across the melt shop. The solution's thermal module uses this information to predict lift temperature to enable desired superheat. This thermal module combines a model capturing heat transfer phenomena across various process components with process heuristics to predict the "lift temperature" at ladle furnace and enable desired superheat range at tundish. The model has been tuned and extensively validated against plant measurements for various slab and billet casting grades.

Key words: Superheat, Digital solution, Lift Temperature, Thermal Module, Steel Melting Shop

DIN_049

Smart Online Quality Monitoring a Key Role Player in Advanced Sinter Making Process for Steel Industry

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Abstract

In the world of global competition, customers have increasing demands that companies must meet in order to remain active in the global market. For this reason, it is necessary to use new technologies in the production processes, i.e., to implement Industry 4.0. To do this, it is necessary to implement smart sensors that provide information at all times. In view of this. Tata Steel solved a challenge for online quality monitoring of the sinter which is feeding raw materials to blast furnace.

The FeO content is an important control parameter in the sinter plant. It is important to find an optimum FeO content in order to improve the RDI without altering other sinter properties. It is also an indicator of the thermal state of the sintering process and is employed as a quality control tool at many plants. It was found that the sinter with FeO range of 8•60–9•88% showed higher productivity and higher strength.

At present, FeO is determined at each shift through chemical analysis in lab which is a very lengthy and cumbersome process. In this study, an attempt has been made to develop an online sensor for measuring FeO content in-situ while transporting the feed through conveyor belt. The method consists in measuring the variation of the inductance of the solenoid caused by the introduction of the core of the bulk sinter.

A magnetic coil has been constructed around the conveyor belt carrying the sinter containing the FeO with some magnetic permeability. The coil is rectangular in geometry due to the site condition as because to obtain the permeability of the conveying material. The instrument works on the principle of Faraday s laws of Electromagnetic induction.

This magnetic permeability-based measurement of FeO content through NDT technique is much faster and allows operators to take decisions promptly. This therefore enables a digitization of the traditional quality control approach through designing smart sensors.

Fig. 1: FeO Sensor at Sinter plants TSL

DIN_50

Sensor Based Mill Vibration Monitoring to Control Chatter Marks in ACP Rolling

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Abstract

Aluminium flat rolled products such as Aluminium Composite Panel (ACP) stock require the surface to be free of any marks. Chatter marks generated during high speed cold rolling due to excitation of eigen-frequencies in the 5th Octave frequency range are difficult to predict and leads to rejection of material. Monitoring of critical frequencies which may be excited and their amplitude levels is important to avoid chatter marks in these products.

The cold rolling mill at Hindalco's Hirakud FRP facility is equipped with sensors for measuring mill vibrations during rolling. The data is integrated with the process data in iba DAQ and is available for analysis along with the rolling parameters. iba frequency analysis of the vibration sensor data is presented to identify the various excitations during rolling. The analysis is used for the identification of mill eigen-frequencies such as roll grinding defects, resonant frequencies present in the mill system to design the rolling process for different products. The interaction of different forcing frequencies and their harmonics present in the mill drive system with these eigen-frequencies causing resonance conditions that would lead to chatter marks being generated are highlighted.

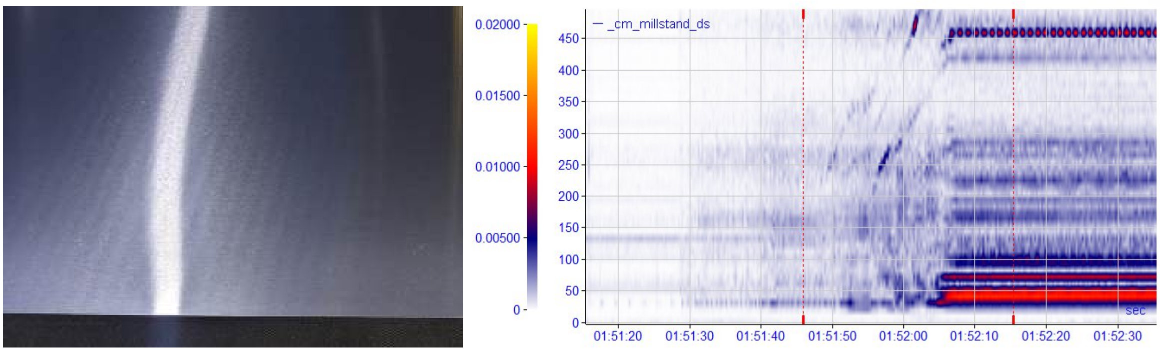

Fig. 1: Chatter marks on surface and vibration analysis to identify eigen-frequency defects

Based on comparative analysis of FFT amplitudes in coils with and without chatter, alarm analytics are being developed in iba and will be implemented through iba-QPanel to identify mill chatter events for timely intervention during rolling. These are then analysed in detail to identify and eliminate the defect through condition based maintenance.

Keywords : Chatter Marks, Mill Vibrations, Sensors, FFT

DIN_068

Enhanced Commodity Price Prediction System

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Abstract

Tata Steel allocates a significant amount of funds to procure coal via yearly agreements and spot purchasing. The coal price is index lined, however, currently Tata Steel does not have any coal price projection system to capture market data and use analytics to create value for the organization. The coal market's extreme volatility, influenced by numerous global market factors, make it difficult to time purchases and predict price movement. It is also challenging to manually track all relevant data and the geopolitical risks affecting delivery and pricing of imported commodities. This paper describes the creation of a predictive model to enhance decision-making in commodity buying through the application of advanced analytics. The model begins by automatically collecting a comprehensive list of potential supply and demand factors related to coal by leveraging contextual knowledge of the coal procurement team. We use Granger causality test, cointegration, non-linear feature importance to analyse and refine these factors. A recurring feature selection process is employed to maintain the model's relevance amidst market shifts. The model incorporates technical indicators derived from market data, such as fast- and slow-moving averages, momentum, Signal, Position, percentage change, seasonality, etc. to discern patterns from the raw data. An ensemble approach, combining tree-based, linear, and deep learning models, is utilized to forecast coal prices up to 12 weeks ahead, with the highest performing algorithm being selected for predictions. Instead of recursive forecasting the model makes direct multistep predictions and is updated weekly. Shapley values are used to extract the top contributing features for the model, which helps procurement managers interpret the results and validate it by relating it to the real-world scenario. The model employs Gen AI to track, sense and summarize coal related news articles and provide sentiment analysis. This provides directional inputs on prices and likely risks. The results demonstrate that compared to time series models and other state of the art models, the proposed architecture has superior performance (directional and value accuracy) for coal price forecasting, providing a robust solution for Tata Steel's procurement challenges.

Key words: Coal price prediction, Direct Multistep Predictions, Gen AI, Shapley

DIN_091

Prediction of Mechanical Properties of Cold Rolled Close Annealed Steel Using Data Science Techniques

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Abstract

Steel manufacturers highly demand the prediction of mechanical properties, as it aids in preventing quality issues and boosting productivity. However, predicting yield strength, tensile strength, and elongation of steel after annealing is challenging due to the highly nonlinear relationship between mechanical properties and process parameters such as cold rolling reduction rate, annealing time, annealing temperature, and alloying elements of the steel. Initially, historical data from the actual rolling process was collected, cleaned, and integrated. Next, the essential characteristics of the variables were determined by calculating the correlations among different features.The Data Science techniques such as Random Forest, Neural Network, Linear regression, K- Nearest Neighbor, Support vector Machine, Decision Tree, and Ensemble methods are used for predicting Mechanical Properties.Moreover, more than 40,000 tensile test data belonging to the production of past 3 years are used during model construction. The model is able to accurately predict the mechanical properties of CRCA steel like YS and TS within an acceptable margin of error of ±20Mpa, El% of ±2% compared to experimental measurements.

Key words : CRCA, Data Science, Cold rolling & Annealing.

DIN_026

A Novel Synthetic Method for Microstructure Segmentation and Phase Quantification

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Abstract

We propose an innovative method for microstructure analysis and phase quantification by creating synthetic micrographs paired with ground truth data. This approach employs a CNN UNET architecture to achieve accurate segmentation of ferrite-pearlite microstructures by superimposing real phase images onto simulated polycrystalline templates. The method is extended to include precise measurement of the angular orientation of pearlite lamellae using annotated synthetic datasets. Additionally, we introduce a reliable technique for calculating pearlite interlamellar spacing. The synthetic generation process is further refined for single-phase micrographs to enhance data quality by removing noise and reconstructing broken grain boundaries. Our methodology is universally applicable to more complex microstructures, such as bainite, ferrite, and pearlite, demonstrating its versatility in multiphase material analysis. These developments are integrated into a user-friendly application, which facilitates dataset creation, model training, phase segmentation, and micrograph reconstruction, making it ideal for both industrial and research applications.

Key words: Phase Quantification, Deep Learning, Microstructures, CNN, UNET

DIN_089

Enhancing Efficiency and Safety in Bulk Material Handling using Industrial Wireless Communication

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Abstract

Industrial wireless technologies have been established as an appealing alternative for distributed control systems and other interconnected automation systems. They offer several advantages over traditional wired communication systems such as enhanced physical mobility, fewer infrastructure requirements, less risk of cable damage, reduced connector trouble and simplicity of upgrading.

RDCIS, SAIL has implemented industrial wireless solution for remote control of Paddle feeders at RMHP, IISCO Steel Plant, Burnpur. The Raw Material Handling Plant of IISCO Steel Plant, Burnpur has four Paddle feeders responsible for extracting material from bunker table and discharging on the conveying system. The paddle feeders have ABB PLC for their control. Process interlocking control signals are connected to the PLC using composite cables through cable reeling drum. These interlocking signals are between the paddle feeders PLC(s) and a control room at remote location. The paddle feeders are located in underground level and as such operation and maintenance at times becomes difficult due to various reasons. This work is an example of the use of wireless communication system for remote access of all the control and interlocking signals of paddle feeders for its operation and trouble shooting. The new wireless control system comprises of Radio Modems, Network switches, digital cameras, LED Screen and an engineering work station. One Ethernet radio modem was installed & connected to the PLC of each paddle feeder. Then two other radio access points were installed in fixed location so as to communicate with the moving paddle feeders. The output of these two access points were connected to another access point located on ground level through FO Cable. This access point at ground level communicates to another radio modem at main control room. The Modem at main control room receives all the signals and communicates to the Rockwell PLC at master side. Once the data of all four PLCs of Paddle feeders are accessible in Rockwell PLC of main control room, the total control and interlocking was possible from this remote location. One engineering work station was installed at control room connected to the radio network to access devices connected to the wireless network. One CCTV camera was installed in each paddle feeder to monitor real time operation. The audio & video signals are also transmitted over same wireless network. The paddle feeders are now accessible from the remote control room. The electrical troubleshooting, programming and even remote operation

DIN_036

is possible from control room. The implementation of remote monitoring and control systems through wireless communication brings several benefits like minimization of physical access, Real-time detection & diagnosis of faults. Man less safe operation of paddle feeders is also now possible remotely from control room.

Keywords: Material Handling, Wireless Communication, Paddle feeders

Use of AI enabled Vision Intelligence to improve workplace safety: Digieye.ai

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Abstract

Advanced AI and Machine Learning (ML) video analytics have been integrated to enhance safety, optimize operations, and improve employee morale in industrial settings. AI-driven insights monitor hazards, unsafe behaviour, and equipment malfunctions, providing real-time alerts for proactive risk mitigation. The technology also identifies inefficiencies and predicts maintenance needs, ensuring consistent quality control and driving continuous improvement.

The Digieye.ai system, deployed at Vijayanagar plant, uses existing IP cameras to monitor critical and hazardous areas. With high-speed servers and GPU-based image analysers, it processes video feeds in real time to detect violations such as PPE non-compliance and unauthorized access, triggering immediate alerts. The system is adaptable, compatible with any IP camera model, and scalable across the plant's infrastructure.

The implementation process included deploying an on-premises server for offline operation, configuring real-time video analytics, and integrating IP-based relay modules to halt machinery during safety violations. Automated alerts—delivered through voice announcements and visual signals—ensure clear communication. By continuously monitoring SOP compliance, Digieye.ai enhances safety, improves operational efficiency, and strengthens overall plant performance.

Key words : AI and Machine Learning, Video Analytics, Real-time Monitoring, Safety Compliance, Predictive Maintenance, Proactive Risk Mitigation, Smart Cameras.

ENVIORNMENT AND SUSTAINABILITY

Oral abstracts

Sustainable recovery of Nickel oxide from spent magnet coatings by Hydrometallurgical route

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Abstract

Nd-Fe-B magnets have become indispensable components in a variety of applications ranging from electric vehicles to wind turbines. However, there are considerable challenges associated with them like the supply constraints, price volatility and geographic concentration of the rare earth (RE) raw materials. Further, the extraction of RE elements also involves radioactive-waste generation and usage of toxic acids. In addition, elements like Nd, Dy, and Tb, needed for magnet making have been identified as critical elements by several nations including India. Consequently, recycling of end-of-life (EoL) magnets has garnered the attention of researchers worldwide for sustainability. In order to provide corrosion resistance to the Nd-based magnets, Nickel is coated over their surface. This study presents the hydrometallurgical recovery of Nickel in the form of Nickel oxide from the surface coatings of the end-of-life Nd-Fe-B magnets. Initially the end of life magnets (500g batch) were dissolved in a basic pH stripping solution at 100ºC to dissolve the nickel coating. The obtained dark green nickel leached solution was filtered and treated with oxalic acid. This treatment led to the precipitation of light green colored Nickel oxalate dehydrate ($NiC_2O_4.2H_2O$) in the solution, which was filtered and dried. Further, the obtained oxalate was calcined to get a dark black colored Nickel oxide powder, which was corroborated by XRD studies. The obtained NiO powder, was observed under SEM which revealed a porous morphology. The purity of the NiO powder was analyzed using XRF and ICP-OES techniques, which suggested ~ 99% purity. This work paves an efficient way for the recovery of valuable Nickel in the form of Nickel oxide and thereby helps in the further recycling of bare Nd-Fe-B magnets.

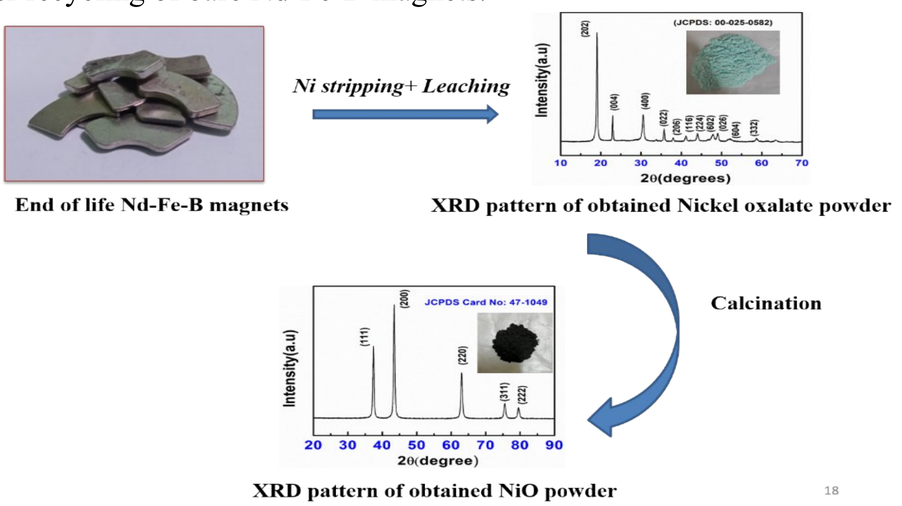

Fig.1: Recovery of NiO from EoL Nd-Fe-B Magnets

Keywords: $Nd_2Fe_{14}B$ permanent Magnets, Recycling, Hydrometallurgy.

MPR_211

Innovation in Solid Wastes Recycling at Pellet Plant

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Abstract

Recycling of solid wastes is essential for achieving sustainability of steel industry. There are several solid wastes in any integrated steel plant that are very fines in size and contain useful elements like Iron, Fluxes (CaO, MgO etc.) and carbon e.g. BF (blast furnace) flue dust, BF GCP (gas cleaning plant) and ESP (electrostatic precipitators) and can be recycled in pellet making. To meet the increasing demand of agglomerates from blast furnaces, attempts were taken to increase the Pellet Plant productivity at Tata Steel Jamshedpur works. However, dryer units of Pellet Plant were identified as bottleneck due to its capacity limitations. It was decided to the increase the throughput of Pellet Plant by addition of ESP Dust from Sinter Plants & Blast Furnaces directly in Ground Ore Concentrate Storage Bins / Ball Mills thus bypassing dryer units. BF Flue dust was added in to pellet plant feed after mixing it with fluxes like limestone and pyroxenite in a certain ratio. BF GCP sludge was introduced after mixing it with inhouse generated pellet fines in the ratio of 1:1.

To study the feasibility of recycling, chemical and size analyses of ESP Dusts from Sinter Plants and Blast Furnaces were carried out. Chemical analyses of all ESP Dusts were found suitable for recycling, but mean size of ESP dusts from Cast House and Stock House of Blast Furnaces were observed on higher side. Based on size analysis, it was decided to recycle ESP Dust from Sinter Plants by directly through Ground Concentrate Storage Bins. However, recycling of ESP Dusts from Blast Furnaces was planned through Ball Mills owing to its higher mean size. Carbon bearing solid wastes like BF flue dust and GCP sludge were found to be chemically suitable for recycling with the main objective to reduce solid fuel rate at Pellet Plant. Only limiting factors was Zn content in BF flue dust and GCP sludge. Therefore, Zn loading at blast furnaces were monitored and accordingly addition of BF flue dust and GCP sludge was controlled. Recycling of solid wastes over the years through pellet plant, Tata Steel, Jamshedpur is shown in figure 1 below. This paper elaborates the journey of innovations in developing techniques for recycling of solid wastes which has not only reduced raw material consumption but also improved production, quality and solid fuel rate at Pellet Plant.

ESU_024

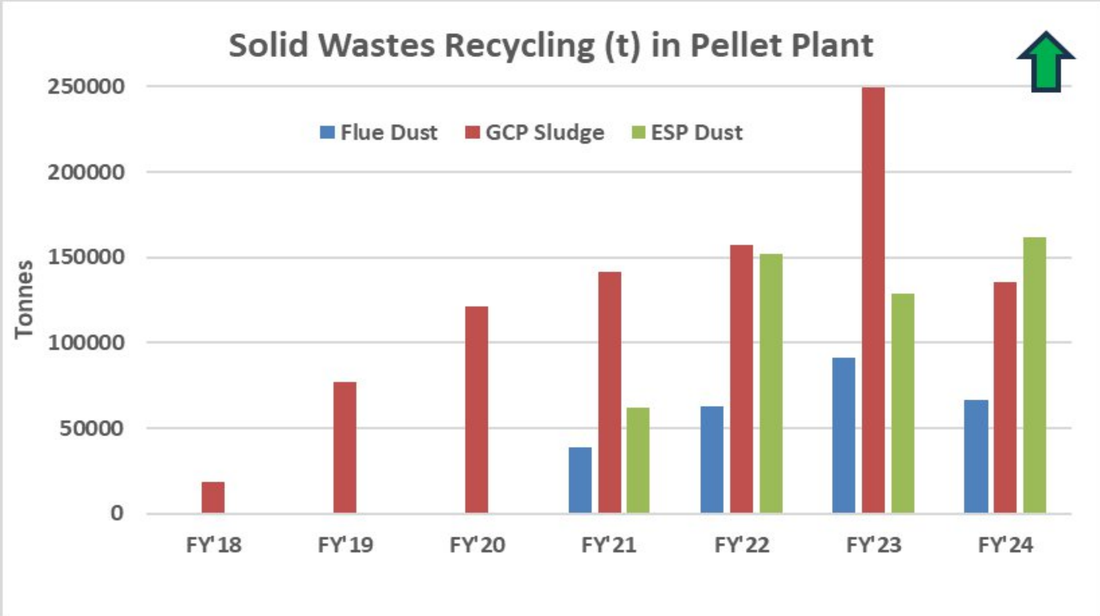

Fig. 1: Recycling of Solid Wastes

Key Words: Recycling, Pelletization, Sustainability

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,

MPR_338

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

RCC_012

Perspectives of Solid-State and Semi-Solid-State Recycling to Produce Pilot Scale Extrusion Billets from AA2024 Milling Chips

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Abstract

Globally, the recycling of aluminium chips via. solid-state (SSR) and semi-solid-state (SSSR) recycling routes are being researched as alternatives for conventional remelting to avoid aluminium melt loss and improve resource efficiency. In this study, pilot-scale extrudable billets was developed from AA2024 machining chips by both SSR and SSSR routes. The pretreatment of chips was carried out similarly for both cases using acetone in an ultrasonicator. In SSR, the cleaned chips were filled in an aluminium canister and closed from both ends. Compaction was carried out at a preheat temperature of 420 ˚C using a 1400-ton hydraulic press to obtain a compacted billet of 150 mm diameter. However, in the case of SSSR, the chips along with extruded butts and profiles were heated to 580 ˚C and poured into a mould to make a billet of 150 mm diameter. Billets from both processes were validated by extrusion using the same hydraulic press with an extrusion ratio of 60 approximately. The overall relative density of the extruded profile is estimated to be 97.5% and 99% respectively for SSR and SSSR as compared to standard AA2024. Cost-benefit analysis was carried out and the percentage saving in expenses for the production of AA2024 SSR and SSSR billets is calculated to be 35% and 47% respectively for SSR and SSSR samples when compared to DC cast AA2024 billet. From this study, it is understood that profiles extruded from SSR and SSSR methods can be a potential choice for various building and construction applications.

Keywords: Solid state recycling; Aluminium chips recycling; Solid waste management; Machined chips; Microstructure.

DM_013

Enrichment of valuable metallic contents from wastes of stainless steel production and its efficient recovery through carbothermic process

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Abstract

Wastes generated during stainless steel production such as bag house dust and pickling sludge hold a significant proportion of valuable metallic and non-metallic oxides. They cannot be emitted or disposed off directly into the environment owing to its hazardous nature and pollution control norms. Recovery of valuables and effective utilization of the residues from such wastes can play a great role in cost reduction and achievement of sustainability goals. The composition of the bag house dust and stainless steel pickling sludge shows that it contains various metallic and non-metallic oxides such as Cr_2O_3, Fe_2O_3, NiO, ZnO, CaO, etc. thus creating the possibility of its usage in the form of agglomerates for SAF metal production. However, the presence of non-metallic oxides add up to cost of the smelting process, making it necessary for its separation from the metallic oxides. The non-metallic oxides in the dust and pickling sludge were removed by wet magnetic separation technique and agglomerated in the form of pellets in a ratio of 80:20. On smelting the heat treated pellets through carbothermic reduction route, about 78% metallic content of iron and chromium was recovered. The results were validated using wet chemical analysis, factsage, XRD and SEM.

Keywords: bag house dust, stainless steel pickling sludge, wet magnetic separation, SAF metal

ESU_033

Extending iron tolerances in recycled aluminium alloys obtained from automotive scrap

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Abstract

Iron (Fe) impurity in automotive aluminium castings is a major challenge in recycling owing to the adverse effects on the structural properties of the recycled alloys. As Al-Si alloys are the primary source of raw material for automobile industries; recycling the scrap is inevitable in tackling carbon emissions. Al-Si recycling has enormous advantages in terms of recyclability, lower energy consumption (and carbon emissions), and being subsequently cost-effective. Nevertheless, Fe contamination in the scrap Al-Si alloys leads to the formation of excessive ternary intermetallics, including Al_5FeSi, Al_9FeSi_2, and Al_3FeSi_2. These intermetallics make the alloy more fragile and brittle, allowing the material to withstand high hardness rather than ductile properties. To resolve this problem, this study proposed a concept called undiluted recycling of aluminum that allows to mitigate the plate-like Al_5FeSi intermetallics influence on mechanical properties. The proposed concept works mainly on the Hume-Rothery substitutional solid solution criteria, where Fe atoms are replaced with elements that pose similar physical properties with them. For instance, elements including manganese, molybdenum, and chromium promote the substitutability of Fe atoms, accompanied by phase modification from the Al_5FeSi into $Al_8(FeX)Si$ (X= Mo, Mn, Cr). This phase modification promotes the mechanical and high temperature properties of the Al-Si alloys significantly compared to scrap Al-Si-Fe alloys. Besides, this study evaluated elements which are partially full-filling the Hume Rothery substitutional criteria; identifying the influence of phase modification, followed by mechanical properties. These elements, including cobalt, nickel, and strontium, were used in the present investigations and detailed analysis of the results discussed in the below sections.

Keywords: Fe intermetallics; Al-Si alloys; Phase modifications; Solidification kinetics; Mechanical properties.

DM_012

Sustainable use of Solid Wastes generated in Mines & Integrated Steel Plants

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Abstract

The steel industry faces the challenge of sustainably utilizing solid wastes generated in mines and integrated steel plants, particularly focusing on the steel-making process and the environmental issues posed by waste products such as steel slag, sludge, and fly ash. To address these challenges, a project was initiated to convert these wastes into valuable products.

Following successful laboratory-scale studies, brick-making using iron ore slime has been carried out at the waste utilization pilot plant. This plant comprises two components: a facility for producing bricks, paver blocks, and hollow blocks, and a raw material preparation plant. The process involves crushing BOF slag to the required size, segregating different size fractions, and separating magnetic and non-magnetic components. The resulting raw materials, combined with binders, are utilized to manufacture diverse products.

Four types of base materials for bricks are manufactured, each weighing approximately 3 kg. After a 28-day curing process, the bricks exhibit a compressive strength of 10-11 N/mm² and a moisture retention of 12-14%. Paver blocks, created with varying compositions, display commendable strength and texture finish. The use of a vibrating table aids in releasing entrapped air during block formation. Following curing, these blocks exhibit a high compressive strength of approximately 40 N/mm² and a low moisture absorption of 3%, aligning with IS standards.

Ongoing experiments involve the formulation of four brick compositions using iron ore slime, indicating a commitment to continuous research and development. Additionally, the project highlights the utilization of steel wastes, including BOF sludge, converter dust, and BF slag, in the production of valuable products.

The successful establishment of a pilot plant and adherence to quality standards demonstrate a holistic approach towards environmental stewardship and resource conservation. It also underscores the importance of sustainable waste utilization in the mining and steel industry.

Keywords: Solid waste, Brick, BOF slag, Iron Ore Slimes, Sustainability

ESU_048

Utilization of waste PET Bottles in the Preparation of fly ash-based Geo-Polymeric Bricks

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Abstract

The escalating environmental concerns and challenges associated with plastic waste have stimulated novel initiatives globally towards waste management and its utilization. As the demand for sustainable construction materials increases, the role of plastic waste has become more significant. This study explores the utilization of waste polyethylene terephthalate (PET) in the preparation of fly ash-based geo-polymeric bricks.

Geopolymers are inorganic polymers, composed of aluminosilicates, covalently bonded in three-dimensional, long-ranged, amorphous networks. Geopolymer bricks have established a strong presence in scientific research, with numerous studies exploring various compositions and methods of incorporating plastics in multiple forms. However, in this study, plastic has been sourced from waste packaged beverage bottles, which constitute approximately 20% of the total plastic waste generated worldwide. During the study, geopolymer bricks were synthesized using industrial wastes such as fly ash (byproduct of coal combustion) as a binder and foundry sand as a filler, along with thin strands of PET bottles (varying concentrations). The plastic surface was deliberately abraded to improve the surface contact before shredding into thin strands. The structural and mechanical properties of the plastic-incorporated bricks were characterized and tested with the help of SEM-EDS and compressive testing machines respectively.

The results revealed a substantial increase in compressive strength, with strength measurements reaching approximately 7 MPa. Furthermore, the durability and strength of bricks increased in correlation with the concentration of plastic incorporated. The findings highlight the prospects of incorporating waste plastics in brick manufacturing as a viable strategy for sustainable construction. This approach not only contributes to reducing the environmental impact but also offers a prospective and economically feasible solution for developing more sustainable building materials.

Keywords Geopolymer · Polyethylene Terephthalate (PET) · Compressive Strength · Sustainable Construction · Industrial waste

ESU_109

Recycling of rare earth of wind turbine magnets by chloridizing roasting – water leaching-precipitation process

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Abstract

Increasing demands of rare earth (RE) metals for advanced technological applications coupled with the scarcity of primary resources have led to the development of processes to treat secondary resources like scraps or end-of-life products that are often rich in such metals. In addition, the installation of wind turbines provides a renewable energy source. However, wind turbine manufacturers generate waste magnets alongside the spent magnets discarded from dismantled units. Spent NdFeB magnet may serve as a potential source of rare earths containing around ~30% of neodymium and other rare earths. Roasting of spent rare earth magnets (NdFeB) has evolved as an attractive method for recycling rare earth elements (REE) to conserve their scarce resources. We studied the chloridizing roasting of spent magnets of wind turbines to convert the REE into water-soluble chlorides selectly. Initial investigations with thermogravimetry (TG-DTA) helped to understand the roasting behavior of magnets. TG-DTA of NdFeB powder showed the commencement of oxidation above 300°C.

Further bench-scale studies of the NdFeB-NH_4Cl mixture corroborated with thermodynamic calculations indicate 300°C as a suitable temperature for the chloridizing roasting process to obtain the $NdCl_3$ and Fe_2O_3. After several trials of different sample sizes and optimizing them, we successfully scaled to 5 kg/batch. Further fine-tuning of the process required the roasting temperature, i.e., 573.15 K, for a shorter period of 4 h in a muffle furnace, which results in the desired formation of water-soluble compounds. Using water for leaching eliminated hazards of chemicals like HCl, H_2SO_4, HNO_3, etc., making this process environmentally friendly and economical. Two products were obtained: mixed rare earth oxides and iron oxide. XRD of mixed rare earth oxide formed after calcination of the rare earth oxalate confirmed the Neodymium oxide with praseodymium oxide and dysprosium oxide. This process has the potential to further upscale industrial collaboration.

Keywords: Recycling; Rae earth; Roasting; Wind turbine

ESU_118

BOF Slag : A sustainable material for cement making

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Abstract

Basic Oxygen Furnace (BOF) is a primary steel making furnace. The slags generated from the BOF converter is termed as BOF Slags. This slag is rich in lime, iron oxide with certain amount of metallic iron. Total lime present in BOF Slag, remain in the form of free lime (CaO)/Portlandite and some other phases like calcium silicate, calcium ferrite etc. Being a hard fused material and some other short comings BOF slag does not have any significant scope of utilization and recycling so far.

Concrete is the second highest consumable material by mankind. Cement being the principal binding material of concrete, is always in high demand. Clinker, besides being the main hydraulic binder of conventional cements is the most carbon intensive material of cement. Furthermore, production of clinker is a very high specific raw material consuming method. Most of the raw materials are from conventional non-renewable resources. Excluding the short comings, BOF slags are having quite resemble mineralogy with the cement clinker. Herein, BOF slag has been treated chemically to produce a supplementary cementitious material for cement making. The develop material has been tested with different formulation of cement making and found promising result. This work has explored a new scope of utilization of an industrial by-product along with the conservation of natural resources.

ESU_118

Hindalco Muri -Zero Waste to Landfill

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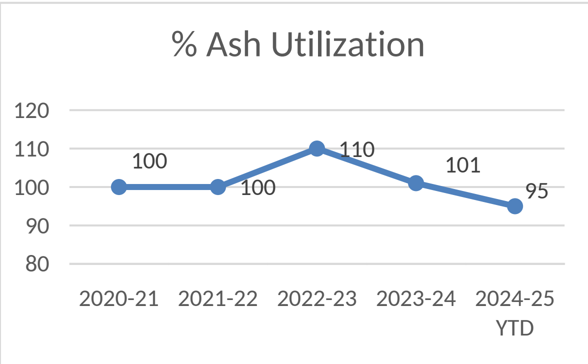
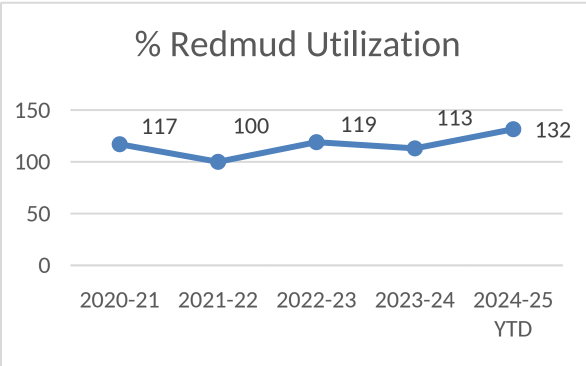
Abstract

The Hindalco Alumina Refinery, Muri works is manufacturing alumina from bauxite ore and having 30 MW Co-gen power plant to supply steam & power for process. Muri unit has embarked on a transformative journey toward achieving "Zero Waste to Landfill" status, with no waste sent to landfills over the past three years. A milestone reached through dedicated efforts in sustainable waste management.

Over the past three years, the facility has achieved 100% utilization of waste by collaborating with specialized recyclers and preprocessors.

Ash and Red Mud Gen vs Utilization detail for 4 years :





Hazardous waste, including vanadium sludge, is directed to Ferro Vanadium recyclers, while used and waste oil are sent to oil recyclers. Empty containers Discarded asbestos sheets are processed by asbestos recyclers.

Biomedical waste generated from OHC has been sent to authorized Biomedical waste recycler for incineration and proper disposal.

E-waste has been sent to authorized recycler. Discarded batteries has been sent to authorized recycler or buyback.

ESU_134

Domestic solid waste management of colony is converted into vermicompost, and plastic waste is sent to authorised recycler for further re-processing and utilisation.

Wasteland to Greenland: 70 acres of Red Mud waste yard converted to Greenland which helped to improve biodiversity.

Exploring an eco-friendly approach for the efficient utilization of coke flue dust: A preliminary assessment for the production of composite pellets

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Abstract

India has emerged as the world's second-largest steel producer, achieving a production volume of 140 million tons in 2023 and aiming for approximately 300 million tons by 2030. While India is rich in iron ore deposits, it faces challenges regarding the availability of metallurgical coal and low-silica limestone reserves. In the fiscal year 2022-23, India imported about 237 million tons of metallurgical coal, significantly increasing the cost of steel production. During coke making, coke flue dust is produced during nitrogen quenching, which is currently not utilized and is simply dumped. This coke flue dust, with a high carbon content (over 70%), has the potential to be used in the production of composite pellets. These pellets are made using coke flue dust and blue dust iron ore fines and are being developed to utilize plant waste, creating a cost-effective metalized feed for crude steel production. When these composite pellets are fired in the air, carbon monoxide gas (CO) is generated, leading to reduction through solid and gas interaction. This paper presents a fundamental study on the firing time and temperature to understand the reduction behavior of composite pellets, followed by a microstructural examination of the fired and reduced pellets. The firing schedule developed from this study was tested to composite pellets containing a total of 76.6% Fe in the pellet, achieving an overall reduction degree of nearly 48% and sufficient strength (120-200 kg), making them suitable for use as feed materials.

Keywords: Composite pellets, Coke flue dust, Blue dust, Reduction behavior, Metallization's.

MPR_191

A novel approach for using DRI bag filter dust at JSW Raigarh pellet plant

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Abstract

An innovative strategy is being tried to utilize DRI bag filter dust as a waste material that is easily available and used as fuel in a pellet plant. The pellet plant's challenges are increasing the use of waste products such as bag filter dust from DRI plants and finding low-cost input materials. Anthracite coal is a typical fuel in pellet making, and its combustion provides the heat needed for pellet making. Other fuels that can partially replace anthracite coal incorporate DRI bag filter dust, which is considered solid waste and is produced in massive quantities at DRI plants. In this study, DRI dust is used as a partial replacement for anthracite coal. Based on the laboratory trial results, DRI dust is combined with anthracite coal in a 1:2 ratio in the pellet plant coal yard and fed into the Bradly Mill along with lime for grinding. There was no significant negative effect of the use of DRI dust, and pellet quality was consistent throughout the usage. However, the use of DRI dust reduces costs for the company. With the addition of DRI bag filter dust, anthracite consumption of coal was reduced by 20% of total fuel, while dust consumption increased to 36 MT/day. The vision of making "clean & green steel with zero waste" can be realized for the survival and growth of the steel business in the future, and the main goal of the companies is now to transform solid waste into wealth for the benefit.

Keywords: DRI bag filter dust, solid waste, anthracite coal, wealth.

ISM_069

Development of Sample Preparation and Analysis Procedures for different types of E-Wastes like Printed Circuit Board (PCB)

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Abstract

The exponential growth of electronic devices has resulted in a parallel increase in electronic waste (e-waste), posing significant environmental challenges. India is the third largest E-waste generator. 62 million metric ton of E-waste was generated in the world in 2022, out of which India generated 4.1 million metric tons as per the UN report. The quantity of e-waste generated in India in FY 2021-22 was 1.6 million metric ton. Out of these, e-waste collected and processed as per CPCB report was only 0.5 MMT.

Printed Circuit Boards (PCBs), a core component of e-waste, contain valuable metals such as Copper, Gold, Silver, Platinum, Palladium Aluminum, Iron, Nickel, Tin, Lead etc. Hence, effective recycling of PCB conserves natural resources and mitigates environmental hazards. This paper focuses on the establishment of a pilot plant aimed at optimizing the systems and procedures for analysis of various types of PCBs derived from E- Waste recycling, thereby contributing to the development of sustainable e-waste management solutions.

The pilot plant is designed to facilitate an in-depth analysis of various metals in PCBs using different methods namely, mechanical pre-processing, pyrometallurgical treatment and chemical methods.

Mechanical pre-processing involves shredding and sorting to separate metal-rich attachments, while pyrometallurgical process focuses on generating a homogeneous portion of representative samples from the lot, extracting and purifying metals from these fractions by using Fire assay methods followed by chemical methods of Gravimetry, and Electrolysis to know the elemental concentrations etc. by experimenting with different parameters and methodologies. The pilot plant seeks to determine the most efficient and environment friendly analysis procedures for waste PCBs.
The pilot project's broader goal is to establish a robust framework of analysis procedures for e-waste (mostly PCBs) that aligns with environmental regulations and helps eliminate the hazardous recovery practices. By enhancing our understanding of PCB recycling, the pilot plant serves as a pivotal step towards taking commercial decisions or in production planning to create a different types of product mix for the furnace, where valuable resources are recycled and recovered, reducing the overall environmental footprint of electronic waste.

The outcomes of this study will guide the development of different analysis and, quick analysis methods, which will give accurate elemental concentration and a scalable and sustainable recycling processes for the product mix at larger scale. This pilot plant will mark a significant step in the field of e-waste management and recycling.

NFM_116

Keywords: E-Waste Management, PCB Recycling, Pilot Plant, Sustainable Practices, Circular Economy

Enhancing sustainability with Niobium: improving alloy carbon footprints and reducing material intensity in their end applications

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Abstract

Is it possible to do business and take care of the environment and sustainability?

This simple question has a not trivial answer, but basically yes, we can do it. Taking care doesn't mean cancelling the environmental impact but reduces it as much as possible. Different applications have different needs, and there are no universal solutions, this is why it is very important that every company contributes as much as possible. Niobium is a metal, extracted from the mine as Nb oxide, and it is processed to obtain different products; the main are FeNb, NiNb, NbO. Nb started being massively used less than 70 years ago, starting from the steel industry, and this is today the most developed area. Historically used to increase the steel strength, it was, and is, used to improve material properties, metallic and not. The FeNb extraction and production is evolving, reducing the environmental impact, year after year; CBMM is one of the first mining company that certified one year ago the CO_2 emissions, with a third party. CBMM production target is to achieve net zero in 2040, and we are already seeing the substitution of primary resources, as the aluminum used in the aluminothermic reaction, to secondary Al. More than that, we already mapped the main actions to achieve our net zero scope; this is a direct contribution from the niobium production, but there are other and more important CO_2 reduction contribution that can come from the Nb use. The second contribution comes from the alloy design optimization, that steel maker does, reducing the amount of alloys used. Using Nb allows to reduce or eliminate the use of other materials, bringing to a direct positive contribution to the CO2 emission, and reducing the cold charging allow to have another positive contribution, saving energy. The third layer of direct contribution comes from the application point of view, Nb increase mechanical properties, allowing the final user to achieve the same performance using less material. In some industry like automotive, there is another possible contribution that come from the substitution of materials with higher environmental impact, like aluminum, to Nb steel. This las contribution can be big, considering the much higher mechanical properties of steel vs aluminum. Nb started contributing also in other application field, like cast iron, nanocrystalline for electric and electronic, aerospace alloys, glasses and battery.

The actual paper wants to bring an overall picture of the different contributions, inviting everybody to consider the environmental impact, because we are all living on the same planet!

Key words: Niobium, Steel, Sustainability, CO2 emissions, Environment, net zero emissions.

"Transition to Plasma Heating and urgent need for the Steelmakers for rapid decarbonisation: the Indian scenario "

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Abstract

Technology landscape for Steel plant decarbonisation looks extremely complex amidst plethora of emerging technologies..some are dormant at laboratory trial and many others are promising but yet to commercialised...posing a constant challenge to Steelmakers :What is the path forward to decarbonise?

In the backdrop of aforesaid Scenerio,this concept paper attempts to unfold the hidden potential of Plasma Technology as a ready retrofit measure to decarbonise the core Processes of the Steelworks.

In the transformation of solid ferruginous ore to molten metal, the role of Reducing agent and the the source of Thermal Energy are of concurrent needs of equal importance .

This paper looks into depth of the Technology Landscape for Decarbonisation and concludes that Hydrogen will be the favorable Reductant and Plasma electrified by green power will be the most viable source for Thermal Energy for the Steelmakers.

The foundation of this concept paper is Author's extensive exposure over four decades to iron and steel making processes at Tata Steel from mining to Rolling .. This paper introduces a novel concept of Plasma Heating for Sintering and Pelletisation, super-heating of blast with plasma fired pulverised coal injection,Plasma Arc furnace for Steel making including secondary refining, Scale free Heating of Slabs with nitrogen as Plasma carrier gas for Hot Strip Mill, decarbonised heating of BAF CRM , Carbon free Calcination of Limestone in LCP plant and oil- less start-up of coal based Captive Power plants in the Steelworks.

As a way forward to Plasma transition particularly for the Ironmakers , a Case Study is presented on "Super Heating of Blast with
Plasma enhancing productivity of Blast Furnace with reduced carbon rate :
H BLAST FURNACE TATA STEEL " .

The paper concludes by saying : Transition to Plasma heating technology as a techno-economically viable means can be adopted by Steelmakers for replacement of
Fossil fuel Energy source with Plasma as an interim measure for Decarbonisation.

The paper is well illustrated with Process flowcharts highlighting the carbon footprints in individual processes of integrated Steel plant and projected carbon footprint print post plasma transition.

Decarbonization & Green Steel Technologies to handle industrial growth and rising decarbonization targets

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Abstract

On one hand, global warming is a concern, on the other hand economies like India must grow with industrialisation. Global warming is to be controlled within the limit of 1.5°C but consumption of steel in India must increase to the world average consumption of 250 kg per capita, a growth indicator for the economy. Developed countries are consuming steel at this average and hence recycling the steel also. But in countries like India the consumption is less than half of world's average hence, scrap generation is not enough, and we need to produce Iron from Ore and then convert it to steel. Means, even if we have sufficient renewable energy for melting, we still need some reducing agent for Iron ore, which is traditionally "Carbon", that we must restrict considering environmental factors. Since Iron Ore is reduced either for making DRI or for making Hot Metal, we need to amend both the processes i.e. DRI and BF to minimise the use of carbon, if not zero. Steps are already taken and amended DRI process with modified melting process are already under implementation. But for India we need to think differently. Since modified processes of making DRI as well as Hot Metal are available, we need to compare both and implement suitably based on social, geographical, and economical factors. Some assessment shows that perhaps Blue Blast Furnace and EasyMelt can be the game changer for India.

Key words : Alternative Iron Making, Decarbonisation, Green Steel, Blue Blast Furnace, EasyMelt

Decarbonization & Green Steel Technologies to handle industrial growth and rising decarbonization targets

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Abstract

On one hand, global warming is a concern, on the other hand economies like India must grow with industrialisation. Global warming is to be controlled within the limit of 1.5^{o}C but consumption of steel in India must increase to the world average consumption of 250 kg per capita, a growth indicator for the economy. Developed countries are consuming steel at this average and hence recycling the steel also. But in countries like India the consumption is less than half of world's average hence, scrap generation is not enough, and we need to produce Iron from Ore and then convert it to steel. Means, even if we have sufficient renewable energy for melting, we still need some reducing agent for Iron ore, which is traditionally "Carbon", that we must restrict considering environmental factors. Since Iron Ore is reduced either for making DRI or for making Hot Metal, we need to amend both the processes i.e. DRI and BF to minimise the use of carbon, if not zero. Steps are already taken and amended DRI process with modified melting process are already under implementation. But for India we need to think differently. Since modified processes of making DRI as well as Hot Metal are available, we need to compare both and implement suitably based on social, geographical, and economical factors. Some assessment shows that perhaps Blue Blast Furnace and EasyMelt can be the game changer for India.

key words : Alternative Iron Making, Decarbonisation, Green Steel, Blue Blast Furnace, EasyMelt

MPR_366

Towards the path of sustainable iron making (Tata Steel India's drive to mitigate CO2 emission)

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Abstract

India's ambitious goal of achieving carbon neutrality by 2070 presents a formidable challenge for the iron and steel industry, a significant contributor to greenhouse gas emissions. Tata Steel Jamshedpur is at the forefront of this challenge, actively pioneering innovative decarbonization strategies.

Recognizing the limitations imposed by resource availability and cost-intensive technologies, Tata Steel Jamshedpur is exploring alternative pathways to achieve its net-zero goal. These efforts include hydrogen and bio-char injection into the Blast Furnace. Though both the trials were successful, the latter was well established and is of regular use due to its ease in handling, storage and implementation. Having said that, injection of hydrogen into blast furnace is one of its kind where a maximum injection rate of 2200 Nm^3/hr was possible in a 4-day trial conducted at E Blast Furnace. Objective of both the trials was to reduce the reliance on fossil fuel rate and hence to reduce CO_2 emissions. Upon injection of 1 kg of hydrogen, 3.2 kg of fuel rate saving was realized per ton of hot metal production, whereas 1 kg of Biochar replaced 1 kg of Pulverized Coal with no adverse effect on furnace process and performance. In addition to these trials, injection of waste plastic into the blast furnace is thought of and works are going to implement it very soon.

Key Words: Sustainability, De-carbonization, Hydrogen and Bio-char injection, Waste Plastic, Fuel rate, CO_2 emission.

ESU_037

Achieving Sustainability through state of Art Technologies in Tundish

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Abstract

Global steel output has expanded dramatically during the past ten years. However, there is a growing demand for clean steel both domestically and internationally. This is the reason that a lot of study is being done in this area right now. However, conventional steel manufacturing techniques have a severe negative impact on the environment and significantly increase greenhouse gas emissions. Right now, the steel industry is undergoing a radical change as it adopts cutting-edge strategies to produce what is known as "green steel." The main objective of this paradigm shift is to rethink the way steel is produced while significantly reducing its environmental effect. It centers on sustainable practices and cutting-edge technology.

In this article, we will dive deep into the innovative technologies developed by Vesuvius1 that may be helpful for the manufacturing of clean and green steel inside the last metallurgical reactor tundish.

Tundish Working lining & back up lining/safety linings are extremely critical refractory component for efficient & safe tundish operations. But both lining products requires long dry out and preheating cycle for the overall preparation and to arrive at the ready to cast condition. This practice poses a huge challenge high CO_2 emission during tundish preparation and increased turnaround time for tundish. Vesuvius has developed QuickStart family of products which minimizes these dry-out and firing cycles and in turn significantly reduces the CO_2 emission and create a faster tundish turnaround cycle. Basivibe Quick start is a feature rich tundish Dry Vibrating working lining which eliminates the requirement of hot curing cycle required for traditional dry vibrating mass. This product also can be used as ready to use for casting by without any preheating at caster which is the conventional practice for any sort of tundish working lining products. Surcast QuickStart is a back-up lining/safety lining product which reduces the overall dry out cycle for any by 50% compared to standard dry out schedule for back-up lining/safety lining products.

Steel continuous casting process rely on the quality and integrity of flow control refractory products to safely control the flow of molten steel. Isostatically pressed tundish nozzles (I.e. SEN, SES &MTSP) are used to transfer molten steel from tundish to mould. Nowadays most SES or MTSPS are preheating in or offline preheating stations to sustain severe thermal stresses at the beginning of casting Sequences. Some cold start flow control refractory components have been used in the past but these solutions show considerable reduction in performance versus conventional preheated products. Vesuvius has developed a Flex start solution of MTSP/SES which can be used without preheating casting sequences as long as regular

preheated solutions. This further eliminates safety risk of handling hot MTSP/SES manually by operators and reduces CO_2 emissions by elimination of SES/MTSP preheating.

Key Words: Continuous Casting, Sustainability, Tundish lining, Tundish Nozzle, Preheating

DM_077

Cost Effective Solution to Achieve Zero Liquid Discharge (ZLD)

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Abstract

India will be severely water stressed by year 2040 and the impending water crisis will impact every section of society. The need of the hour is how we manage water which is a very precious resource.

Industrial growth and the increasing population (and the associated demand for food production / agriculture) has placed a severe stress and demand for available water resources. While demand has been growing at a significant pace, the availability of water has not, being a finite resource.

ZLD: In recent years, growing concern for environmental sustainability has prompted various industries to explore innovative solutions for water management including achieving ZLD.
Advantages of ZLD:

- Reduced water Consumption
- Minimized Environmental impact
- Enhanced product recovery
- Compliance with regulations

Water in Steel Industry: A Steel plant cannot function without water as it is practically used in every shop of a steel plant. Water is used for a variety of purposes like

- Cooling purposes
- Gas Cleaning in Coke Oven, Blast Furnace
- Descaling application
- Steam production
- Dust Suppression

While a large quantity of water is needed at every stage of production more than 90% of the water is generally returned to the system. With spiraling cost of fresh water and demand for same, Steel Industries have moved to more water efficient technologies apart from recycling of waste water. This has resulted in fresh water consumption being reduced to 3 – 4 m3/ton of steel produced.

The industry is also now moving towards ZLD. A ZLD typically comprises of following:

a. Pre-treatment
b. Biological Process
c. Membrane System (to recover fresh water)
d. Evaporation (to achieve ZLD)

The Terminal system of evaporation is generally both CAPEX & OPEX intensive. With recent developments in technology, it is possible to achieve minimal discharge from membrane system which makes achieving ZLD a more economically viable option.
ESU_116

Reducing carbon footprint and waste water in metal industries with dry gas cleaning technology in combination with waste heat recovery system

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Abstract

Iron and Steel industry is considered as one of the major contributor of carbon foot print and industrial waste water. Several development is ongoing for last 40 years to reduce carbon footprint and water requirement during steel making process.
In India, 75% of crude steel is generated from converter steel making process (LD process). Carbon in hot metal is oxidised to CO/ CO2 from 4.2% to approx. 0.2% in reaction with oxygen through blowing lance. In conventional gas cleaning process which is predominant in Indian scenario, gas is cooled through conventional pressurised hot water circulation which is comprising of cooling stack, recirculation pump and fin fan heat exchanger. Cooling stack acts as a heat exchanger takes off heat energy from the gas generated during blowing process. Fin fan heat exchanger dissipates this huge thermal energy to the environment after exchanging heat from the ambient air. The gas is cleaned in a water scrubber system where huge volume of water is used to scrub dust particles from gas by creating venturi effect by 2 stage venturi system. Due to very high loss of pressure to overcome the venturi effect, radian fan is used with a very high suction pressure (approx. 2200 mm) causing higher power consumption.

Primetals technologies introduced dry gas cleaning process for LD converter in early 80s and installed the first dry dedusting system in converter steel melt shop of Voilstalpine stahl, Austria in the year of 1981. Dry gas cleaning system in combination of gas conditioning tower (Evaporation cooler) and Electrostatic precipitator has replaced the water intensive scrubber system completely. Due to very low pressure drop in the gas cleaning process, the power consumption of fan is also substantially reduced. Later on, the conventional hot water circuit is replaced by energy recovery system. This system, comprising of cooling stack (acts as boiler) and a steam circuit use the energy of BOF gas to generate steam. The steam later on used in other metallurgical process like RH/ VD.

Primetals Technologies is the market leader in dry gas cleaning system having references of more than 30 running plants all over the world.

ISM_220

CO2 Sequestration and its Kinetics on Feed and Mechanically-Activated Red Mud

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Abstract

Global warming is a matter of prime concern worldwide, leading to various environmental problems such as rising sea levels, changing weather patterns, and melting polar ice caps. Capturing and storing CO_2 emissions from sources such as power plants, industrial facilities, and transportation can significantly reduce the volume of CO_2 released into the atmosphere, thereby mitigating its warming effect. Another area of concern is industrial waste management. Industrial solid waste such as fly ash, red mud, and steel slag could be used as a feedstock material for mineral carbonation solving both the problems of waste management and decarbonization. The production of Red Mud, a bauxite residue, exceeds 150 million tons annually. This is highly alkaline and a potential source of minerals (calcium and aluminosilicates) that can aid in carbon dioxide sequestration.

Mineral Carbonation, in particular, offers a promising method for the sustainable disposal and immobilization of greenhouse gases. However, its primary drawback is the slow reaction rate. This study aims to increase the reactivity and adsorption capacity of Red Mud through Mechanical Activation using a high-energy planetary ball mill for carbon dioxide sequestration. The activation is carried out using different ball sizes (10,8 and 6mm) while maintaining constant duration and ball-to-sample ratio. CO2 sequestration on both feed and mechanically-activated Red Mud is conducted using a fixed-bed column. The influence of ball size used in planetary ball mill, flow rate, and reaction time has been thoroughly studied followed by the study of its adsorption and desorption kinetics. The feed and mechanically activated red mud are characterized by particle size distribution, specific surface area, XRD, FT-IR, and SEM before and after adsorption.

Keywords: CO_2 sequestration capacity, Planetary Ball Mill, Red Mud, Mechanical Activation, Adsorption and Desorption Kinetics

ESU_036

A new concept for Environment-Friendly Sustainable Green Steelmaking by DRI in the BOF

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Abstract

Green steel refers to the production of steel by reducing carbon emissions. The basic oxygen furnace is the dominating primary steel-making process.it is an auto-thermal process in which hot metal and scrap are used as raw material. Steel scrap is a charge material that will play a key role in the decarburization process. Green steel helps to minimize the carbon footprint of steel production and promotes sustainable development. It aims to replace the purchased scrap. The addition of DRI into the Blast furnace to increase hot metal output and decrease coke rate is well known. However, this option only has economic merit and sustainable development if the steel plant is hot metal limited, and its downstream equipment can process the additional iron units into a cast or rolled products steel. A better option for a large integrated steel maker is to produce DRI using captive iron ore resources and use the DRI across their various steel-making facilities to displace purchased scrap in a basic oxygen furnace charge mix. A case study is presented describing the use of DRI as a purchase scrap replacement and illustrating how a large steelmaker can reduce operating costs and take advantage of a low-cost steel-making process towards sustainable development. Although the scrap price is usually higher than the hot metal, the environmental regulations are forcing the iron makers to decrease hot metal production, as the main source of CO2 emissions. Therefore, steelmakers are looking to use a higher scrap ratio in the charge mix of the BOF. The study also deals with the economic and environmental reasons for the increased scrap usage.

Key words: BOF; scrap rate; CO2 emissions; decarbonisation; design scrap; process optimization.

ESU_088

Novel Superflux Coating to improve Iron Ore Sintering Performance and Reduce CO2 Emission

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Abstract

The iron-ore sintering process contributes up to 13 % of the overall mass of carbon dioxide released from an integrated iron and steelworks. Around 85% of CO_2 emission is contributed by carbon burning in sintering process. The dehydration process of ore and higher alumina content in the ore consumes a lot of heat, which seriously affects the sintering performance and increases the solid fuel consumption of sintering. In the last two decades, lots of efforts have been made all over the world to improve the technology of preparation of raw materials to ahieve higher degree of chemical homogeneity and adequate permeability on the sinter bed for higher productivity, better quality and lower energy consumption.

In this work, we have developed a new technique of coating the green mix with Lime powder which generates a thin low melting slag layer, improving the strength, reducing fines and ultimately low fuel rate and CO_2 Emission in the sintering process. The influence of lime coating on sinter green granules in altering the sintering kinetics and its characteristics was examined. The adoption of lime coating, achieved by spraying the powder lime on surface of preformed green granules has been a focal point in recent research. Experimental trials were conducted using varying dosage of lime powder for coating. The superflux coating not only strengthen the green granules strength but helps in generation of low melting slag on the surface of green granules resulted better slag distribution across sinter phases This phenomenon contributed to enhanced mineralogy formation, resulting in a reduction of sinter return fines by 6-8 points, shortened sintering duration, improve burn through temperature by 25% and decrease coke rate by 4 kgs/tns reduces CO_2 emission by 0.107 t_{CO2}/tcs . Moreover, these techniques resulted in the evolution of the beneficial form of silico-ferrite of calcium and aluminum (SFCA and SFCA-1) which was evident through microstructural studies. This study provides an effective technology for a high-quality sintering process at higher alumina levels.

ESU_073

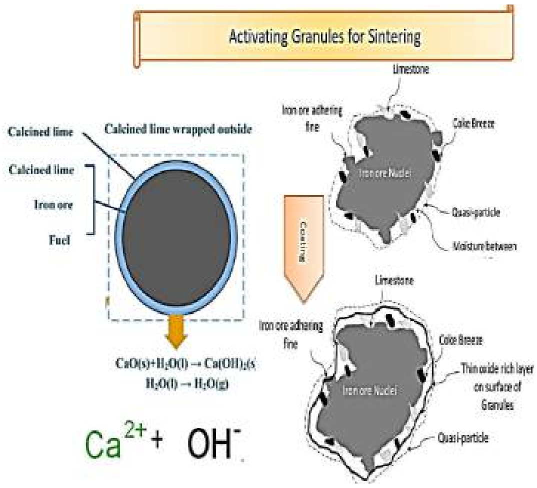

Fig.1a: Mechanism of coating granules

Fig.1b: Plant Scale trial at Sinter plant-2 JSR

Keywords: - Iron ore sintering; high-alumina ore; super flux; Granulation; SFCA; SFCA-1

Transforming Ladle Furnace Slag: Efficient Alumina Recovery with CO2 Utilization for Sustainable Steelmaking

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Abstract

Ladle furnace slag (LFS), a by-product of secondary steelmaking, is produced in quantities exceeding 20 million tons annually. Although typically regarded as industrial waste that contributes to dust and heavy metal pollution, LFS holds potential for various applications, including use in construction materials, soil stabilization, CO_2 capture, and as a partial replacement for lime and synthetic flux in steelmaking. Despite these possibilities, its utilization remains limited, largely due to volume instability from the crystallization of free-CaO and free-MgO during cooling. However, with the growing emphasis on sustainable development and the circular economy, the steel industry is increasingly focused on finding practical uses for slag. This shift has popularized the 3R technique (Reduce, Reuse, and Recycle) for waste handling, opening up potential future applications for LFS in areas such as clinker production, asphalt pavement construction, alkali-activated cement production, brick manufacturing, hydraulic works, agricultural soil acidity correction, water purification.

This study investigates a method for extracting alumina from ladle furnace slag (LFS), which typically contains Al_2O_3 in concentrations ranging from 16-32 wt% depending on the steel grade produced. The process begins with leaching LFS using sodium carbonate to produce a sodium aluminate solution. This solution is then filtered to remove residues, and CO_2 is introduced into the solution to precipitate alumina. The soda solution used in the process is regenerated and re-circulated, enhancing the method's sustainability.

The study achieved over 80% alumina recovery, effectively utilizing CO_2, which can aid in the de-carbonization of the steel industry. Key advantages of this method include generating profit by recovering valuable alumina, reducing storage needs by converting LFS into useful products, and producing no harmful waste. By optimizing the leaching conditions, this approach demonstrates how to recycle materials, reduce carbon emissions, and benefit the environment

Keywords: Alumina, Sodium aluminate, Carbon Dioxide, Waste utilization

ESU_099

Biofuel Utilization in Iron Ore Sintering: A Path to Sustainability..?

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Abstract

The Iron and Steel industry, crucial for global economic growth, consumes significant industrial energy, mainly from fossil fuels. Sinter making, essential in ironmaking, uses about 10% of the Steel industry's energy, with 78% from coke breeze, contributing to greenhouse gases, SOx, and NOx emissions. This study examines replacing fossil fuels with biofuels to achieve carbon-neutral sintering. Conducted in two parts, it uses raw biopellet and biochar at up to 4% in the sinter mix through lab-scale trials. The sinter was evaluated for productivity, yield, sintering time, and tumbler index, while emissions of NOx and SOx were also analyzed.

In the first part of the study, increasing the biopellet proportion from 0% to 4% raised the sintering time from 25.30 to 31 minutes and reduced sinter productivity from 1.78 to 1.09 t/m²/hr. The biopellets, with a calorific value around 66% of coke breeze, lowered the maximum sintering temperature due to volatile matter evaporation. This led to a drop in sinter product yield from 82% to 70%, while sinter strength remained around 65%.

In the second part, using biochar (-3.15 mm size), higher moisture content was needed for optimal granulation. The green mix bulk density decreased by 7.60%, and the balling index dropped by 11.70%. Biochar's higher combustibility and volatile matter content generated maximum temperature quicker, reducing sintering time by 3 to 4 minutes. However, it disrupted the heat and flame front consistency, reducing sinter yield from 82% to 76%. Sinter productivity was maintained between 1.76 to 1.60 t/m²/hr.

In both cases, the use of biofuels significantly affected exhaust gas composition, resulting in reduced overall SO2 and NOx emissions. Despite some trade-offs, such as decreased sinter yield, the use of biofuels offers a promising alternative for sustainable steel production due to their potential to reduce emissions.

Key words : Iron Ore sintering; Biofuel, Biopellet, Biochar; Gas Emission.

ESU_100

Machine Learning Approach for Improving Evaporation Steam Economy and thereby reducing Carbon Footprint

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Abstract

Double digestion refinery is the most energy intensive process where alumina extraction and bauxite residue clarification contribute to system dilution. The evaporation circuit, which is crucial for concentrating spent process liquor and maintaining the refinery's water balance, consumes approximately 25-30% of the total heat input per ton of alumina produced. Given the increasing emphasis on sustainability and the need to comply with stringent decarbonization regulations, digitalization initiatives have gained significant traction to enhance process efficiency and cost competitiveness.

This paper presents a detailed study on the operational enhancements and parameters optimization achieved through advanced process mapping and machine learning (ML) integration. Key improvements include the implementation of side stream installations, increased spent liquor temperature through robust heater management and the integration of real-time data monitoring via the Osi-Pi Vision platform, enabling more precise control over process parameters. The analysis also addresses the failure modes of steam ejectors and the subsequent enhancements made to sustain optimal vacuum conditions.

Furthermore, traditional methods of measuring the quality of final thick liquor rely on laboratory analyses conducted at intervals of three samples per shift, resulting in a 2-3 hour delay for process optimization decisions. To mitigate this delay, ML-based model has been developed to provide real-time predictions of thick liquor concentration and steam economy within the evaporator circuit. The deployment of these prescriptive models has enabled a deeper understanding of the physio-chemical transformations in liquor properties under varying operational capacities, facilitating the identification of optimal operating conditions.

The implementation of a data-driven approach has led to significant improvements in steam efficiency, driven by real-time analysis of process parameter fluctuations and informed decision-making.

Keywords: Alumina Refinery, Bayer Process, Data analytics, Evaporation, Steam Economy

ESU_121

Evaluation of Ceramic Sorbents for CO2 Capture from Iron Making Process under Simulated Industrial Conditions

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Abstract

Mitigating carbon dioxide (CO_2) emissions from steel production is crucial, as the ferrous industry emits nearly two and half tons of CO_2 per ton of steel produced, contributing to about 8-9% of global carbon emissions. An effective approach to managing these emissions involves using sorbents to selectively capture CO_2 at the source, thereby controlling its release into the atmosphere. The development of advanced sorbent materials with faster sorption kinetics, higher capacity, selectivity, and durability is essential for creating efficient CO_2 absorbents.

In line with the CSIR-CCUS mission, CSIR-NIIST has recently established a "Synthesis & Testing Facility for CO_2 Sorbents" (Fig. 1a). This cutting-edge facility features a SCADA PLC-based Sorption Evaluation Reactor, designed to test sorbents on a kilogram scale under various simulated industrial gas mixtures and temperature conditions. It is the first of its kind facility in the country, dedicated to evaluating solid sorbents for industrial CO_2 capture. This facility features a continuous digital weighing system and inlet and outlet gas analysis system for precisely studying sorption kinetics during absorption and desorption of CO_2.

CSIR-NIIST has spearheaded the development of selective CO_2 sorbent materials suitable for temperatures ranging from 200-450°C and is currently evaluating their effectiveness for reducing CO_2 emissions in the iron and steel industries. Blast furnace stove waste gases typically contains 20-25% CO_2 and are emitted at temperatures between 250-350°C. A patented lithium zincate formulation with eutectic mixtures (LZME) has shown a high CO_2 sorption capacity, impressive kinetics, and good recyclability and matches with the industrial conditions stated above. This paper discusses about the kinetics of CO_2 capture from BF top gas and stove waste gas under simulated industrial conditions during sorption and desorption's. Effect of partial pressure of gases on sorption capacity and kinetics will be presented. Further testing under industrial gas conditions and cyclic stability analysis are forthcoming.

ESU_140

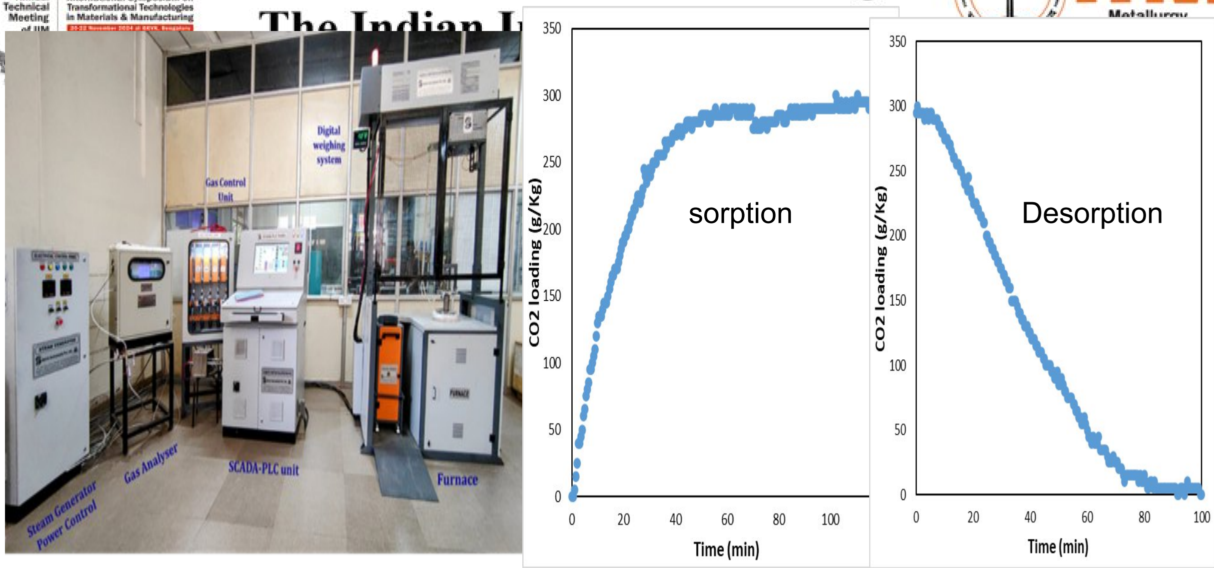

Fig. 1: Photographic layout of Sorption Evaluation Set up, Sorption of CO_2 (100%) on LZME at 325°C and desorption of CO_2 from LZME at 450°C

Keywords : CO_2 Emissions, Steel Industry, Blast Furnace, Ceramic Sorbents, Carbon Capture

Thermoelectric composite demonstrating high power output for clean energy generation

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Abstract

Thermoelectric materials have shown great potential for generating electricity from waste heat. Fabrication of nanocomposites has been proven to be a robust way of enhancing the energy conversion efficiency of thermoelectric materials. We used MXene, a new generation 2D material, to synthesize the nanocomposites. $Ti_3C_2T_x$ MXene has been synthesized by selective etching of Al from Ti_3AlC_2 MAX phase using a low-cost processing technique. Nanosized layered sheets of MXene have been incorporated as inclusions in the matrix of thermoelectric materials by the spark plasma sintering (SPS) method. Thermoelectric properties such as the Seebeck coefficient, and electrical and thermal conductivity of novel nanocomposites have been measured in the range from 323 to 921 K. Introduction of MXene has shown significant improvement in the thermoelectric power factor (PF), and the figure of merit (ZT) of MXene incorporated nanocomposites. Further, the transport properties have been analyzed in correlation with XRD, SEM, XPS, and Raman spectra. MXene-added composite with the highest ZT of 0.9 has shown the maximum power output of 38 meV at a 700˚C temperature difference without leaving any carbon footprint.

Keywords: Thermoelectric materials, MXene, SPS, Composite

ESU_127

Energy reduction solutions through design modifications at Aditya Aluminium

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Abstract

Aditya aluminium smelter is working initially with the specific energy consumption of ~13.5 kWh/kg Al and later the design was retrofitted using copper insert which reduced the specific energy consumption to ~13.3 kWh/kg Al. Further, to reduce energy consumption, the existing design was modified by incorporation of new high insulation material, side wall block shape changes and new version-2 copper inserted collector bar. A 3-D thermoelectric quarter cell model based on ANSYS was used to study the impact of design modifications on pot thermal balance. Based on analytical calculations and thermoelectric analysis, this design provides the scope to reduce the anode cathode distance (ACD) which directly helps to reduce the bath resistance while maintaining the pot thermal balance. The electrolytic bath and metal cavity were changed with the modified design which required the pot energization and start-up law modifications including pot preheating energy & time, resistive coke bed template size, forced cooling network (FCN) modulation. The design was tested in two pots, compared the performance with the similar age of existing design pots, the modified design helps to reduce the total pot voltage gain of ~ 50 mV and increased current efficiency by 0.5 % which resulted reduction in the total energy consumption by ~150 kWh/T Al.

Keywords: Aluminium reduction cell, Specific energy consumption, Copper insert, Current distribution, Cathode lining.

NFM_042

Combinatorial In-situ and Ex-situ TEM: Morphological Evolution and Hydrogen-Driven Redox Interplay in Green Steel Production

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Abstract

In this study, we investigated the reduction of hematite nanopowder under a hydrogen atmosphere. Our primary objective was to gain a deeper understanding of the morphology and shape evolution of these oxides during hydrogen-based reduction. Through our experimental endeavors, we made significant observations. During ex-situ investigation, we observed the intriguing phenomenon of faceting in pure iron nanoparticles after reduction from hematite nanoparticles under a hydrogen atmosphere. This phenomenon highlights the impact of hydrogen on the structural transformation of these nanoparticles. Moreover, our in-situ environmental transmission electron microscopy (TEM) experiments yielded fascinating results, revealing the presence of diverse morphologies such as whiskers, nanorods and pyramids. To validate the transformation of hematite morphology from spherical to a faceting structure containing pure iron nanoparticles, an in-situ heating TEM experiment was conducted on pure iron. This systematic experiment reveals that the initial spherical shape of pure iron remains unchanged even after heating up to 1000 °C. The research provides valuable insights into the reduction behaviour and morphological evolution of hematite nanoparticles under controlled heating conditions. These distinctive morphologies have not been extensively documented in the existing literature, making our findings even more valuable in expanding the current knowledge in this field.

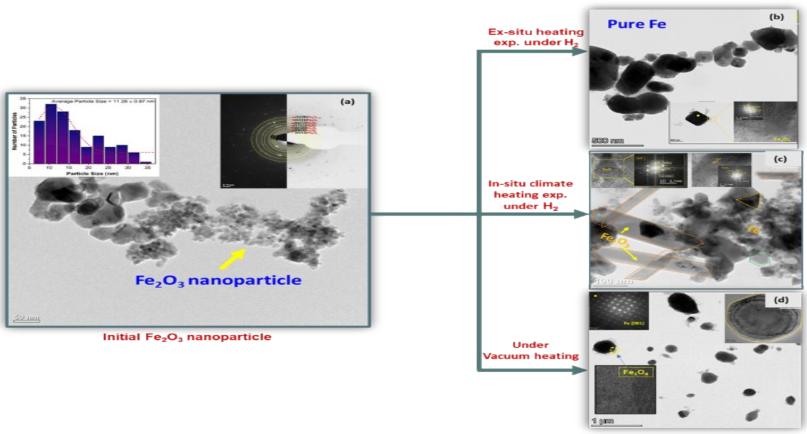

Figure 1: Evolution of Fe_2O_3 nanoparticles during reduction in hydrogen environment using *in-situ* transmission electron microscopy.

Keywords: Hematite Nanoparticles, Hydrogen Based Reduction, In-situ TEM, Morphology

ESU_023

Decarbonization using Dilute Oxygen Combustion Burner in Copper Smelters

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Abstract

The global imperative to mitigate climate change has led industries across sectors to seek innovative solutions for reducing carbon emissions. Copper smelting, a vital industrial process, plays a crucial role in meeting the global demand for copper, a versatile metal essential for various applications in infrastructure, electronics, and renewable energy technologies. However, conventional smelting methods often involve significant carbon emissions, contributing to environmental degradation and climate change. To mitigate these adverse effects, the adoption of innovative technologies such as pure dilute oxygen (O2) Natural gas burners presents a promising avenue for decarbonization within the copper smelting industry, massive decarbonisation unprecedented along with advantage like lesser off gas volume generation with Zero NOx & SO2. Along with environmental impact also fuel consumption reduced with higher output of furnace & improved refractory campaign life achieved post installation of this burner. Decarbonising copper smelting operations through the implementation of pure dilute O2 combustion burners holds immense promise for advancing sustainability in the mining and metallurgy sector.

This write-up explores the concept of decarbonisation in copper smelters through the implementation of pure dilute O2 combustion burners and highlights the associated benefits.

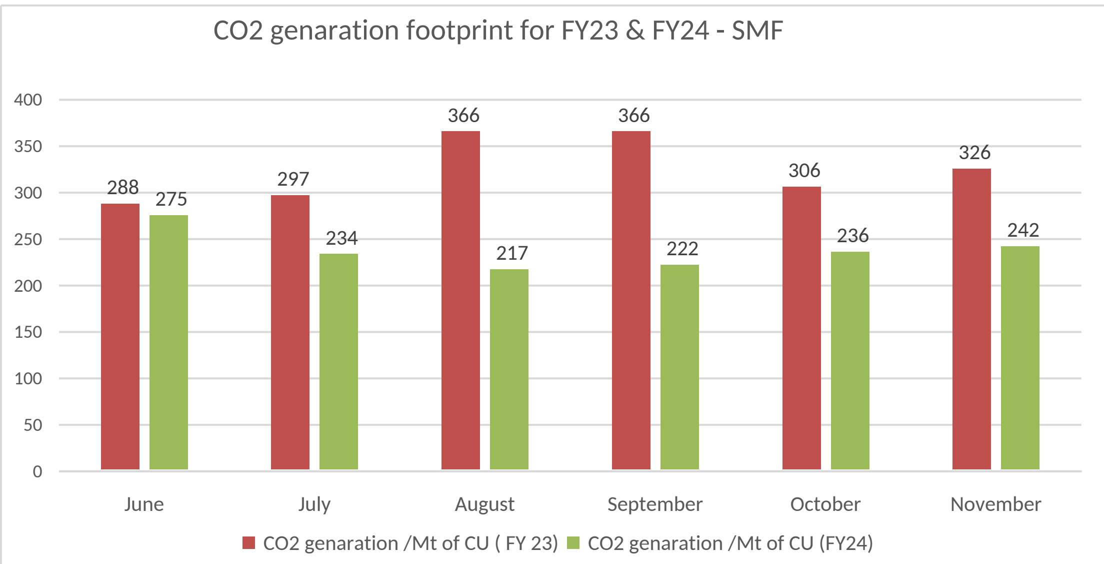

Fig. 1: CO2 generation comparison

Key words: Decarbonization; O2 Combustion Burners; Copper Smelting; refractory campaign.

NFM_023

Millscale to sintered iron-alloy compact by using hydrogen as reductant

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Abstract

This research work focuses on transforming mill scale, a high-iron-content industrial waste generated during hot rolling mill operations, into usable steel powder via a one-step thermo-chemical treatment using pure H_2 gas as the reducing agent. This method, which targets steel production without greenhouse gas emissions, involves reducing mill scale (comprising approximately 72% iron in the forms of Wustite, Hematite, and Magnetite) at 500℃ for 90 minutes in a tubular furnace. The produced iron powder is characterized by using X-ray diffraction, optical microscopy, scanning electron microscopy, and microhardness measurements. Such reduced mill scale powder was sintered using spark plasma sintering. To understand the effects of stable oxide impurities and the porous nature of mill scale on reduction and sintering reactions, a comparative analysis is conducted with oxidized pure iron powder. Additionally, the study investigates the impact of pre-oxidation on the conversion of magnetite to hematite and discusses the reduction kinetics of various iron oxides using thermodynamic and kinetic data. This environmentally friendly approach not only recycles industrial waste but also supports sustainable manufacturing practices, providing valuable insights for future steel production.

Key Words: H_2 reduction; mill scale; spark plasma sintering.

ISM_099

Increasing Scrap Potential in BOF: A key Decarbonization Initiative

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Abstract

The global steel industry indeed relies heavily on coal, primarily for the reduction of iron ore in the blast furnace (BF) process. The BF-BOF (Basic Oxygen Furnace) route, which involves the use of hot metal from BFs, is associated with approximately 2T CO_2 emission per ton of steel produced. Efforts are being made to reduce these emissions through various strategies including increasing scrap rate, adopting alternate technologies and improving energy efficiencies in existing processes. At JSW Steel's SMS#2 in Vijayanagar, the scrap rate was increased from 11.9% in FY23 to 13.8% by FY24-Q2 through partial substitution of hot metal with Direct Reduced Iron (DRI) and Hot Briquetted Iron (HBI) and optimising the blow pattern. The scrap potential is significantly influenced by temperature and silicon content of hot metal. While higher Si content can provide additional heat through exothermic reactions during oxidation in BOF, higher hot metal temperature enhances the melting capacity for scrap materials. At JSW Steel's Vijayanagar facility, the Si content varies between 0.5% and 1.5%. A higher silicon content in hot metal is associated with a lower hot metal temperature. To counter the challenges, avenues were explored to minimize temperature loss during the transportation of hot metal from ironmaking units to the SMS. Through several in-house improvements, it was possible to increase the hot metal temperature by 12°C per heat which directly contributed to an increase in the scrap content by 4 tonnes per heat. As a result, the scrap rate increased to 14.5% by FY24-Q4 and the plant achieved an overall reduction of 0.24 tons of CO_2 emissions per day. By continuing to explore and implement such strategies, JSW Steel is in the path of making significant strides towards more sustainable production practices.

Key words : BOF, Scrap rate, HBI, Decarbonisation, CO_2 emissions

ISM_132

Exhaust to Energy in Alumina Digesters

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Abstract

Waste heat recovery is a crucial aspect of sustainable industrial processes, offering both environmental and economic benefits. This study investigates the potential to recover energy from waste/ low quality heat that is released to exhaust in an alumina refinery. Alumina refining process involves digestion of bauxite ore at high temperatures & pressure. After digestion, pressure is released using series of flash vessels and the evaporative flash steam is optimally used for regenerative heating of caustic liquor. Thus, generated the blow-off slurry still possess temperature of about 104 ℃ i.e., above boiling point. Thereby, produces flash steam which is generally unutilized for its relative low energy content and vent through the relief tanks.

In alumina refineries, steam is the major source of energy used digestion (46%) any efforts to recover waste heat and utilize for other applications will of great scope to reduce steam consumption.

Utkal Alumina International Ltd. (UAIL) Refinery being modern alumina plant operates with 3 low temperature digestion circuits to support overall production requirement. The digestion circuit consumes steam at a rate of 75 tph. Blow off slurry remains at ~104 ℃, approximately 6 tons per train of vapor (waste heat) is being released to relief tank at atmospheric pressure and about 100 ℃ s. Venturi condenser technology was applied to assess its feasibility and effectiveness of waste heat recovery. This abstract provides an overview of the methodology.

With this system, it is demonstrated to recover 1.24 MJ/Day of waste heat that can be able to reduces 15 TPH of LP of steam from wash water heating in mud wash circuit ultimately saves 430 KL/Day of water from vaporization. Waste heat recovery emerges as a viable and sustainable solution for improving energy efficiency and reducing environmental impact in alumina refining processes.

Key words: Waste Heat Recovery, Energy Efficiency, Venturi Condenser

MPR_337

78th Annual Technical Meeting
The Indian Institute of Metals

CO2 Reduction in Steel - SEED Emission Manage

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Abstract

The SEED (Sustainable Energy Environment and Decarbonization) Emissions Manager is an advanced digital dashboard designed to provide a comprehensive view of shop and activity-level CO_2 emissions, enabling the effective planning and execution of carbon reduction initiatives. The platform helps businesses monitor, measure, and manage their carbon footprint, supporting the transition to sustainable energy practices and reducing environmental impact.

The platform consists of four key components: the Web Portal, Qlik Sense Dashboard, MySQL Database, and CBAM Intermediate Template. The Web Portal allows departments to input emissions data, ensuring accuracy and security. The Qlik Sense Dashboard provides powerful visualization tools to analyze emissions trends and identify opportunities for improvement. The MySQL Database serves as a robust data warehouse for emissions data, ensuring scalability and advanced querying capabilities. The CBAM Intermediate Template simplifies regulatory reporting, helping businesses meet compliance requirements with ease. The SEED EM empowers businesses to make data-driven decisions, track progress from a 2022 baseline, and implement targeted carbon reduction strategies. It supports energy efficiency improvements, process optimization, and renewable energy adoption. The platform's ability to monitor key performance indicators (KPIs) at the shop level provides granular insights, enabling more precise emissions reduction efforts. In one notable outcome, the platform tracked a reduction of 111 kg CO_2 per tonne of crude steel, demonstrating its impact on decarbonization. It also provides real-time reporting, identifying abnormalities and triggering corrective actions, ensuring continuous improvement in emissions management. Developed by JSW Steel's digital team, the SEED EM underscores the company's commitment to sustainability and innovation. By offering a comprehensive, user-friendly solution for emissions management, the platform helps businesses reduce their carbon footprint, enhance operational efficiency, and meet evolving environmental regulations while positioning themselves as responsible corporate citizens.

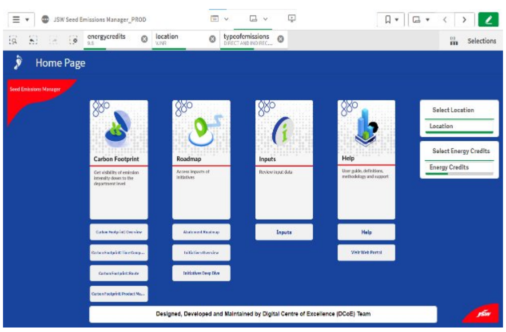

Fig. 1: SEED Emissions Manager Home page

Keywords : SEED EM, emission reduction, digital dashboard, KPI
MPR_400

Synthesis of NMC Active Cathode Material from Secondary Raw Materials Recovered from Discarded Li-Ion Batteries

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Abstract

The increasing demand for lithium-ion batteries (LIBs) in various applications such as electric vehicles and portable electronics has led to a significant rise in the volume of discarded batteries at their end-of-life. Recycling of discarded LIBs for recovery of materials such as lithium (Li), nickel (Ni) and cobalt (Co) has become crucial to mitigate foreign dependency for these critical materials. These critical materials find their potential use as secondary raw materials in battery manufacturing for synthesis of active cathode material composition. $LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$ (NMC 622) is considered as a promising Ni-rich active cathode material of lithium-ion batteries due to low cost and high capacity [1]. The current study focuses on the synthesis of nickel manganese cobalt (NMC) active cathode material from secondary raw materials recovered from discarded LIBs. The cathode material comprising nickel, manganese and cobalt is recovered through a series of hydrometallurgical treatments which include leaching, solvent extraction and precipitation as reported in author's earlier reports [2, 3]. NMC 622 powder composition with the molar ratios of $LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$ was synthesized by using conventional solid state reaction from a stoichiometric precursor mixture of lithium carbonate (Li_2CO_3), nickel oxalate (NiC_2O_4), cobalt oxalate (CoC_2O_4) and manganese dioxide (MnO_2), powders as the starting materials recovered from discarded LIBs. The phase purity of synthesized NMC cathode composition is analysed using X-ray diffraction (XRD) and structural morphology of the synthesized powder is analyzed using Field emission scanning electron microscopy (FESEM).

Keywords: Lithium-ion batteries; NMC active cathode; Sintering.

References

- Wang, Luyang, Bin Huang, Weixiong Xiong, Huacheng Li, Shunhua Xiao, Quanqi Chen, Yanwei Li, and Jianwen Yang. "Improved solid-state synthesis and electrochemical properties of LiNi0.6Mn0.2Co0.2O2 cathode materials for lithium-ion batteries. *Journal of Alloys and Compounds* 844 (2020), 156034.
- Ajay Kaushal, Amit Barnwal, Rajesh S Kumar, Ratheesh Ravendran, Sandip Chatterjee, "A method for recovery of Metal Oxides/Carbonates from assorted waste Li-Ion Batteries" US Patent (2023) US-2023-0391632-A1
- Barnwal A, Balakrishna M, B Priyadarshini, Nair SRK, Ravendran R, Kaushal A (2023) Effective methodology for selective recovery of lithium values from discarded Li-ion batteries. JOM 75:1119–1127 https://doi.org/10.1007/s11837-022-05684-4

ESU_089

Recycling of Lithium-ion Battery Cathode Material by Carbothermic Reduction

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Abstract

Currently, lithium-ion batteries (LIBs) are playing a dominating role in the portable electronics, transportation, and energy storage sector due to their high energy density compared to other rechargeable batteries. The commercial LIBs are composed of transition metal oxides (Co, Ni and/or Mn oxides) and lithium in their cathode material. Due to limited resources and the high cost of Co, Ni, and Li, recycling will alleviate the gap between demand and supply. Furthermore, recycling Li-ion batteries (LiBs) is a sustainable process and a step towards a circular economy. Many research studies have focused on using high temperatures or expensive reductants to convert the used active cathode material to a low valence state, which increases recycling and post-treatment expenses. Hence, in the current study, a low-temperature roasting process followed by a water leaching technique is described to recycle NMC(Ni-Mn-Co) cathode material from used Li-ion batteries. This process can selectively recover lithium from cathodic material. Effects of different parameters, such as reduction temperature, time and amount of reductant, etc., on the reduction of NMC were investigated. High valence oxides were converted to divalent oxides and zero-valent metals during roasting, and Li was successfully recovered during subsequent water leaching.

Key Words: Carbothermic reduction, Circular economy, LiB, NMC, leaching, and Recycling.

ESU_058

Hydrogen reduction of spent Lithium-ion batteries to recover metallic values

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Abstract

The surge in demand for LIBs in electric mobility and portable electronics is expected to contribute to the massive stockpile of discarded batteries. This study investigates the hydrogen reduction of retrieved cathode powder from spent LIBs to recover Ni, Co, and Mn values. Optimization studies were performed on the $LiCoO_2$ (LCO) and $LiNi_xMn_yCo_{(1-x-y)}O_2$ (NMC) cathode powder to efficiently decompose the layered structure to respective metal oxides/metal. It was found that hydrogen can effectively decompose the stable layered structure at a low temperature of ~500-600 ℃ in 60 min. Water leaching of the reduced product, followed by magnetic separation and acid leaching, resulted in 91% Li, >95% Ni, Mn, and 89% Co recovery in NMC, and 80% Li and 99% Co recovery in LCO cathode processing. The dissolved Ni, Co, and Mn were recovered in the form of mixed metal oxalate. The proposed hydrogen reduction of NMC and LCO followed by water and acid leaching was found promising. Processing of 1 kg NMC/LCO powder retrieved from 3.54 kg batteries would result in the recovery of ~180 g Li_2CO_3 and ~1590g of the mixed metal oxalate containing Ni, Co, and Mn oxalate dihydrates or ~1345 kg Cobalt oxalate dihydrate respectively based on the cathode chemistry.

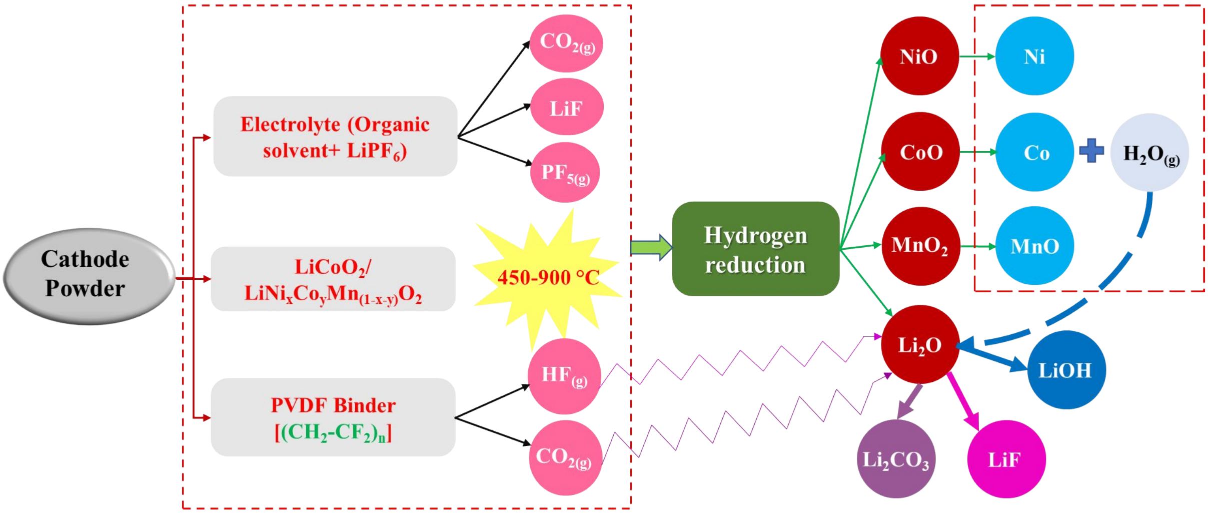

Fig 1. Process mechanism of hydrogen reduction of cathode powder.

Key words : LCO; NMC; Hydrogen; Reduction; Lithium

ESU_083

Synergetic recycling of NdFeB magnet and Li–ion battery cathode material for critical metals recovery

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Abstract

Rare earth (NdFeB) magnets and lithium-ion batteries (LIBs) are critical for a low-carbon economy. NdFeB magnets contain rare earth elements (REEs) such as Nd, Dy, and Pr, while LIBs contain Li, Co, and Ni, all of which are considered critical materials for energy according to the Department of Energy (DOE) 2023. Recycling secondary sources paves the way to mitigate this criticality. NdFeB magnets and LIBs are potential secondary sources as they contain significant amounts of critical elements. In this study, a novel synergetic leaching process is proposed for recycling both NdFeB magnets and LIBs. The process involves using waste ferrous sulfate solution, generated during magnet leaching, as a reducing and leaching reagent for battery recycling. This approach eliminates the need for additional reagents for the oxidation of iron in NdFeB magnets and the reduction of cathode material in LIBs. The magnet is leached in dilute H_2SO_4 at 70°C, followed by double sulfate precipitation for REEs with Na_2SO_4. The REE-depleted but acidic ferrous solution is then used for reductive leaching of LIBs cathode material at 90°C. The overall recovery rates of REEs, Li, Co, Ni, and Mn in this process are greater than 95%. The iron from the magnet material is recovered as a crystalline compound, convertible to goethite and usable as a byproduct. This synergetic approach reduces reagent use and waste, enhancing efficiency, resource conservation, and sustainability

Keywords: Lithium ion batteries; NdFeB magnets; Recycling; Sustainability; Synergetic leaching

ESU_060

Recovery of Cobalt metal from LCO based cathode material of spent Li-ion Batteries

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Abstract

The utilization and advancement in portable electronic devices have inevitably increased the generation of End-of-Life (EoL) lithium ion batteries (LIBs). The cathode material of LIBs contains a significant amount of valuable metals. As a cathode material, Lithium Cobalt Oxide (LCO) is widely used in commercial batteries and resulted in huge scrap of LCO cathode based LIBs. As per the literature, 1 metric ton of spent Li-ion batteries contains approximately US$10,000 worth monetary value of Co. Thus LCO based cathode of EoL batteries must be recycled through eco-friendly and economically viable process. This study reports a unique pyro-metallurgical process to recover Co metal alloy from the discarded Li-ion batteries. Initially, the cathode materials has been separated from discharged LIB and carried-out smelting with the addition of suitable flux. The detailed composition analysis of initial cathode and recovered metal has been carried-out using inductively coupled plasma-optical emission spectroscopy (ICP-OES). These results reveal that the recovered material is Co-rich alloy having around 86.96% of Co. Besides, Lithium from cathode material and Al of current collector has been transferred into the slag. X-ray diffraction (XRD) and Energy-dispersive X-ray spectroscopy (EDS) analysis are also carried out. These recovered Co-rich metal alloys are valuable raw materials to develop the ultra-high strength alloys.

Key words: Recovery, spent Li-ion batteries, LCO cathode, Smelting.

ESU_105

Recovery and Utilization of High Purity Graphite from Spent Port Lining Waste in Lithium-ion Batteries

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Abstract

Industrial spent pot lining or spent pot liner (SPL) is a hazardous byproduct of the electrolytic reduction of alumina (Al_2O_3) to produce pure metal aluminium (Al). It contains about 40-50% of graphite; however, it also contains a significant amount of leachable fluoride and cyanide, which can lead to severe environmental impacts. The presence of cyanide and fluoride in SPL prevents the easy recovery and usage of critical mineral graphite. Most countries worldwide have implemented standard operating procedures (SOP) through their respective environmental or pollution control agencies to manage this waste, considering its toxic nature. Around 22-25kg of SPL is generated per ton of pure metal aluminium, depending upon the technology used. Existing solutions have limitations such as higher processing costs, multiple unit operations, the low economic value of the resultant products, less purity of the products and the generation of toxic effluents, which makes these processes commercially unviable. In this work, we developed a physiochemical process for recovering high-purity graphite (˃99%) as well as other bath materials present in the SPL, such as sodium fluoride (NaF) and cryolite (Na_3AlF_6) with zero toxic effluents. The purity of the recovered graphite, sodium fluoride and cryolite was analysed using Inductively coupled plasma-optical emission spectroscopy (ICP-OES), fixed carbon analysis, Raman spectroscopy and X-ray diffraction pattern. This recovered high-purity graphite from SPL has been demonstrated to be a suitable alternative to the natural or synthetic graphite used in lithium-ion batteries as anode, measured by cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) techniques. The LIB coin cells prepared with the recovered graphite from SPL have a highly reversible capacity and exhibit excellent performance due to efficient lithiation and delithiation in the graphitic lattice. An initial specific capacity of 280 $mAhg^{-1}$, which further stabilised to 230 $mAhg^{-1}$, was observed to be stable for more than 100 cycles with a coulombic efficiency close to 100%. The performance of this recovered graphite from SPL makes it a more promising anode material for Li-ion batteries.

Keywords: Spent pot lining, waste detoxification, graphite recovery, lithium-ion battery and anode making,

ESU062

Investigation of processing routes for recovery of rare earth oxides from spent NdFeB magnets

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Abstract

The increased demand for rare earth elements due to advanced technological applications and supply shortages calls for metal recovery from secondary sources. $Nd_2Fe_{14}B$ (NdFeB) permanent magnet may serve as a potential secondary source due to its high rare earth (~30%) content and vast applications. The present study compares chloridizing roasting and buffer assisted rusting processing routes for the extraction of high purity (96-99%) rare earth oxide values from spent NdFeB magnets as depicted in Fig. 1. Chloridizing roasting followed by leaching, precipitation, and calcination to obtain mixed rare earth oxides. Chloridizing roasting was optimized based on temperature, dosage, and time during rare earth dissolution. Higher dosages favored more NdOCl formation, leading to reduced Nd dissolution. Further trade-off between NdOCl, $NdFeO_3$, and $Nd_2Fe_{14}B$ oxidation decides REEs extraction. The overall extraction of rare earth elements for chloridizing roasting was ~89% with 96% purity. A newly developed process based on buffer-assisted leaching was found successful for the complete structural breakdown of NdFeB and offered ~98-99% pure rare earth oxides with ~94.47% Nd and ~100% Dy extraction.

Keywords: HDDs; NdFeB; Chlorination roasting; Rare earth elements; Buffer Leaching

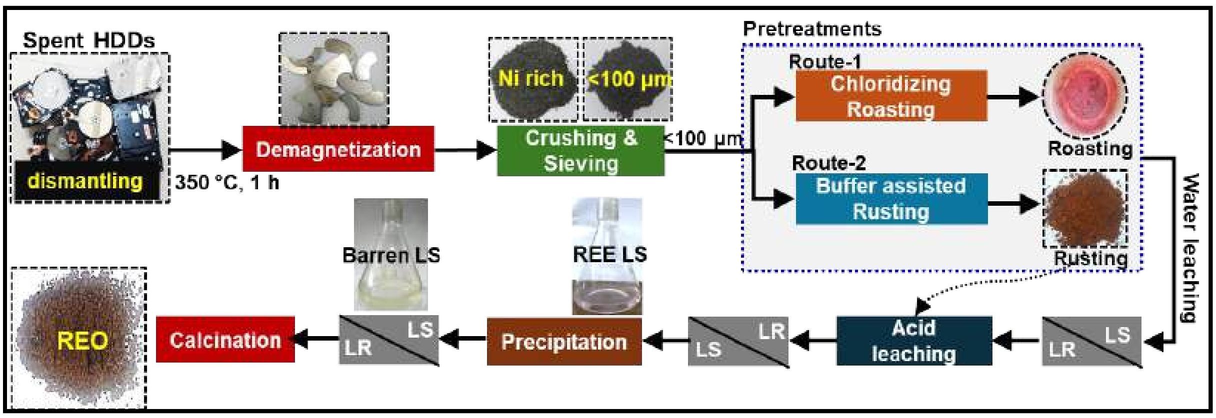

Fig. 1 Processing routes for recovery of rare earth oxides

ESU_082

Environmental Sustainable Process for the Extraction of Precious Metals from Waste Printed Circuit Boards

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Abstract

The recovery of precious metals from waste printed circuit boards (WPCBs) is a critical component of electronic waste (e-waste) recycling, offering both economic benefits and environmental protection [1]. This study explores integrated temperature-based sustainable methods for extracting valuable metals such as copper (Cu), gold (Au), palladium (Pd), and platinum (Pt) from WPCBs. Thermal delamination of WPCBs was conducted in an inert atmosphere within a temperature range of 750 to 850 °C to extract precious metals. The evolution of gas during the processing of WPCBs was also thoroughly studied. The raw PCBs and residuals after heat treatment were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and inductively coupled plasma mass spectrometry (ICP-MS). Using the modified fire assay method for extraction, gold yields were approximately 95% and 99%, with final recovery rates at around 90% and 93%, respectively. By prioritizing sustainability, the recovery of precious metals from PCBs can contribute to resource conservation, pollution reduction, and the development of a circular economy [2].

Keywords: Waste Printed circuit Boards, Integrated, 3R approach, Fire assay method

References:

[1] Manikandan, S.; Inbakandan, D.; Nachiyar, C.V.; Namasivayam, S. K. R. Towards sustainable metal recovery from e-waste: A mini-review. Sustainable Chemistry for the Environment 2023, 2, 100001.

[2] Esyra, K.; Ishak, H.K.; Ismail, S.; Irfan, M.; Razak B.A. Recovery of copper and valuable metals from E-waste via hydrometallurgical method. J. Materials Today 2022, 66, 3077-3081.

ESU_131

Development of a Secured Landfill for Near Surface Disposal of Uranium Tailings: A Pilot Scale Study

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Abstract

Near surface disposal of uranium tailings presents significant environmental challenges, particularly concerning leachate seepage and groundwater contamination. In this paper, we propose a novel approach utilizing a secured landfill system to address these issues, focusing on the Tummalapalle Mill site. Our design incorporates a tailings dry stack layout measuring 990 meters by 310 meters, with a stacking height above ground of 13 meters and an additional 5 meters below ground, capable of handling 63.44 lakh metric tons of tailings. To validate the efficacy of our system, a prototype was constructed within the plant premises, measuring 5 meters by 5 meters by 2 meters, with 1 meter above and below ground.

The key objective of this initiative was to prevent leachate seepage and groundwater contamination while maximizing water recovery lost through evaporation. Approximately 14 metric tons of solid waste deposited at the proposed pilot-scale landfill site. Our secured landfill design incorporates two impermeable liners and a leachate collection system comprising perforated pipes above each liner. The upper system prevents leachate accumulation, while the lower serves as a backup. Collected leachate will be directed to an effluent treatment plant for purification, facilitating reuse for greenbelt purposes.

Secured landfill technology offers several advantages over traditional disposal methods. It provides a safe and monitored environment for waste disposal, ensuring environmental safety and regulatory compliance. Moreover, secured landfills are cost-efficient and relatively safer compared to other waste management techniques. The flexibility of landfills allows for expansion and integration of additional machinery and equipment, increasing landfill capacity. Post-closure, landfills can be repurposed for various activities such as solar power generation and green space development, enhancing their long-term sustainability.

In conclusion, our study presents a comprehensive approach to address the environmental challenges associated with uranium tailings disposal through the implementation of a secured landfill system. The proposed design not only mitigates environmental risks but also offers opportunities for sustainable reuse and development post-closure.

Keywords: Secured Landfill, Uranium Tailings, Near Surface Disposal, Leachate Management, Environmental Sustainability.

ESU_022

Radiant Heat to Power in Iron and Steel Industry: Potential of Thermophotovoltaic Technology

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Abstract

The present study assesses the potential of a thermophotovoltaic (TPV) device as an alternative for recovering radiant waste energy in steel Industry. TPV is a solid-state device for the direct conversion of high-temperature radiant heat of steel slabs/billets into electricity using combination of thermal and photovoltaic effect. The deployment of TPV in iron and steel industry is investigated because of its leading position in terms of energy consumption in industrial sectors. TPV device transforms the photon flux emitted by an incandescent surface into electricity. An idealized analysis of this device is performed to determine its theoretical potential. A preliminary estimation to assess the potential of TPV application in the Tata Steel, Gamharia (TSG) is presented. The maximum potential was found to be 2 MW/h of electricity. The effect of emitter temperature on power density and conversion efficiency is estimated. The power density of the TPV systems with the photovoltaic (PV) cell modules of GaSb was observed to be 1 W/cm^2 at emitter temperature of 1273K. Unlike the power density, the energy conversion efficiencies initially increase to a certain maximum and then decrease with temperature. The TPV technology can promote sustainability of Tata Steel reusing high-temperature waste heat.

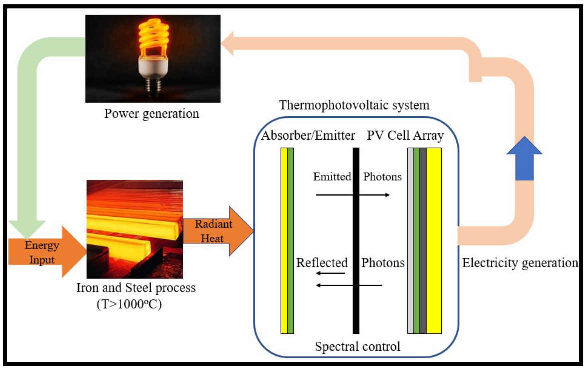

Fig. 1: Schematic of radiant heat recovery in iron and steel industry using TPV technology.

Key words: TPV, Radiant heat, Sustainability, Iron-Steel industry, Energy Efficiency

References:

1. A. Datas, Applied Physics Letters 108, 143503 (2016); doi: 10.1063/1.4945712
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3. H. Daneshvar, R. Prinja, P. N. Kherani, Thermophotovoltaics: Fundamentals, challenges and prospects, Appl. Energy 2015, 159, 560 – 575.

ESU_050

Terraflowing™ Dewatering solutions: alternative tailings management strategies in the iron ore industry

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Abstract

As India aims to achieve its goal of increasing steel production to 300 million tonnes per annum (mtpa) by 2033 from the current 154 mtpa, there will be a significant increase in tailings production. Tailings, the residual ore left after the extraction of valuable materials, are typically regarded as waste. In the Indian iron ore industry, these tailings are usually transported to a Tailings Storage Facility (TSF) with large quantities of water, where they are stored, and a portion of the water is reclaimed and returned to the plant. Given that 10-20% of the ore processed in steel production results in tailings, this translates to the management of 30-60 mtpa of tailings annually.

The handling and storage of wet tailings significantly increases the environmental footprint and risks associated with the industry, due to the extensive use of energy, water, and land. By adopting alternative tailings dewatering methods, such as the Terraflowing™ solutions, higher solids concentrations can be maintained during pumping and it is possible to conserve energy and water, thereby reducing the risks associated with TSFs.

This paper explores the effectiveness of the Terraflowing™ dewatering solutions as an alternative approach to tailings management. It discusses techniques for reclaiming residual value and repurposing tailings for construction uses, and offers recommendations for future practices aimed at mitigating the environmental impact of tailings management.

Keywords: Tailings, Sustainability, Terraflowing™

Reduction of Specific Energy Consumption of Heat Recovery Coke Oven Process

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Abstract

Coke making is a fundamental process in the traditional integrated ironmaking route. It provides support for materials in the blast furnace (BF) and acts as a reducing agent for iron oxides, increasing temperature through its thermal energy.

Coke making is responsible for approximately 10% of the energy consumption in the integrated ironmaking process. Metallurgical Coke acts as a fuel in Blast furnace and is major contributor of cost (Approx. 40%) and Energy (Approx. 70%) in production of Hot metal at Blast furnace and for further processing As Cast, Blooms and Bar rod Iron at JSW Steel Salem works.

To address environmental improvement and reduce Energy consumption, various technologies and Process Optimization techniques have been developed to reduce the Specific Energy Consumption (SEC) due to coke production from 0.355 Gcal/TCS to 0.264 Gcal/TCS.
The Major Contributors are,

1. Improving Coke drying: Optimization of Hard Coke (+25 mm size) moisture from 2.02 to 1.78 % with actions like modification of Quenching cycle and drying process, Energy reduced by 0.0074 Gcal /TCS for FY 24.
2. Waste Heat Recovery: By reduction of Radiation Heat losses from the Oven and with Improved WHRB washing methodology, Capability of Waste Heat recovery steam generation from flue gases were improved by 6 to 7 TPH and there by contributing to the Energy reduction by 0.041 Gcal/TCS in FY 24
3. Fugitive Emissions Capturing: Recovery of approx. 600 kg of Coke dust per day by installing Bag filter Dedusting system contributed to the energy savings of approx.0.0018 Gcal/TCS.
4. Reduction of Specific Power consumption: Optimization of Coke dryer and Dryer de-dusting system power consumption contributed to the savings of 0.0025 Gcal/TCS.

These solutions contribute to meeting Energy reduction objectives while maintaining steel production efficiency. However, due to the unique role of coke in the BF, complete replacement remains challenging. Modern ironmaking still requires approximately 400 kg of coke per ton of molten metal.
These technologies are continually evolving with improving Technology of coke oven plants with lower burning losses, Lower Handling losses and Improved Coal to Coke yield.
Keywords: Coke Drying, Waste Heat Recovery, Fugitive Emissions capturing, Specific Power consumption, Gcal, TCS.
ESU_114

Radiant Heat to Power in Iron and Steel Industry: Potential of Thermophotovoltaic Technology

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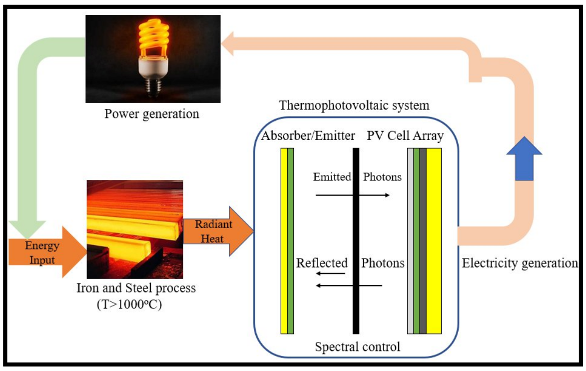
Abstract

The present study assesses the potential of a thermophotovoltaic (TPV) device as an alternative for recovering radiant waste energy in steel Industry. TPV is a solid-state device for the direct conversion of high-temperature radiant heat of steel slabs/billets into electricity using combination of thermal and photovoltaic effect. The deployment of TPV in iron and steel industry is investigated because of its leading position in terms of energy consumption in industrial sectors. TPV device transforms the photon flux emitted by an incandescent surface into electricity. An idealized analysis of this device is performed to determine its theoretical potential. A preliminary estimation to assess the potential of TPV application in the Tata Steel, Gamharia (TSG) is presented. The maximum potential was found to be 2 MW/h of electricity. The effect of emitter temperature on power density and conversion efficiency is estimated. The power density of the TPV systems with the photovoltaic (PV) cell modules of GaSb was observed to be 1 W/cm^2 at emitter temperature of 1273K. Unlike the power density, the energy conversion efficiencies initially increase to a certain maximum and then decrease with temperature. The TPV technology can promote sustainability of Tata Steel reusing high-temperature waste heat.



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ESU_043

Energy conservation in WRM-2 by merging of WRM-2 & BRM-2 compressed air line header

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Abstract

Energy conservation is a critical aspect of sustainable development and environmental stewardship. As part of a sustainable drive initiative, the Specific Power Consumption (SPC) of Long Products was studied, focusing on Wire Rod Mill-2 (WRM-2), which had a high SPC of 250 KWH/ton. Specific Power Consumption refers to the electrical energy consumed to produce one ton of wire rod. To identify areas for energy conservation, a power consumption study of WRM-2 was conducted.

The analysis revealed that the main drive accounted for approximately 64% of the total power consumption, mill auxiliaries for 14%, and utilities for 22%. Both the main drive and auxiliary loads have Variable Frequency Drives (VFDs) installed for better optimization and utilization. Further analysis of the utility area indicated potential for reducing power consumption by optimizing the use of compressed air.

Air requirements in WRM-2 were reduced from 15,200 Nm^3/hr to 11,500 Nm3/hr by optimizing air consumption. Initiatives included installing automatic ON-OFF valves and replacing instruments that can withstand elevated temperatures without needing air for cooling. To meet the 11,500 Nm3/hr air requirement, two compressors with a capacity of 8,500 Nm^3/hr each were operating. The frequency of off-loading the compressors was increased, resulting in 5,500 Nm^3/hr of unutilized compressed air being vented.

These measures demonstrate significant potential for energy conservation in WRM-2 by optimizing compressed air usage and improving overall efficiency.

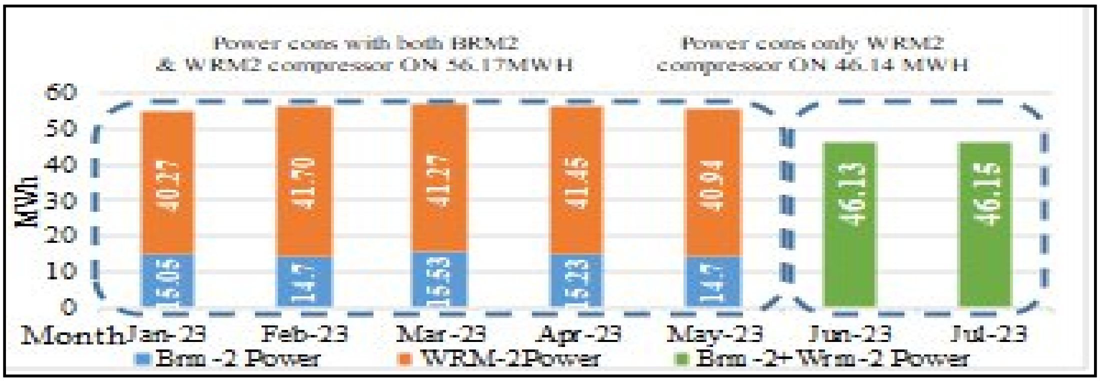

Figure1: power consummation before and after installation.

Key words : TMT bar Mill, Rolling, Compressors.

ESU_101

Aluminium fluoride removal from the waste silica gel

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Abstract

The first production plant for aluminium fluoride from fluosilicic acid came into the stream in 1962 at Linze in Austria. In this process, aluminium hydroxide is treated with fluosilicic acid until an aqueous solution of aluminium fluoride and silica precipitates is obtained. Silica gel contaminated with aluminium and fluorine ions is obtained as waste in the process. The application of silica gel waste is limited because of ~10 wt.% of F ions; this waste is usually landfilled, which may lead to serious environmental issues. However, the high concentration of SiO2 makes this waste a potential source of silica for the synthesis of silicates or construction materials. It was proven that it is possible to reduce the concentration of fluorine ions in the silica gel from 10% to <5% (but not less than 3-4%) by changing the process conditions and by adding alkaline compounds. However, no reports are available to further reduce the F ions' content in the silica gel. In the present work, by performing thermodynamic assessment it is identified ways to remove the F ions from the silica gel. The experiments are conducted based on the thermodynamic evaluation, and the removal of F from silica gel has been observed under different process conditions. The research also delves into the environmental and economic benefits of recycling silica waste, reducing the need for natural raw materials and minimizing landfill usage.

Keywords: Fluosilisic acid, Silica gel, Aluminium Fluoride, Fluorine ions

ESU_054

Reduction of Stack Emission at Sinter Plants, Tata Steel Jamshedpr

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Abstract

Sinter Plant (SP) is a major contributor towards Stack Emissions in an Integrated Steel Plant, with over 35% contribution to overall particulate dust emissions. Over the past decade, TSJ (Tata Steel Jamshedpur) SPs have pioneered innovation starting from Raw Material handling to ESP (Electrostatic Precipitator) maintenance and health monitoring, leading to achieving benchmark level stack reductions. Our innovations elucidate the expedition of TSJ Sinter Plants in reaching stack emission levels below 100 kg/hr in FY24 with best ever production of 9.11 MTPA, by establishing process innovations, control in raw material consumption and quality, enhancing maintenance monitoring of ESPs, Digital Interventions, and the use of HFTR (High Frequency Transformer Rectifier) units in sinter making (First Time Ever).

Starting from extensive study of ESPs by our Engineering and Projects team in FY12 (emissions over 425 kg/hr), Installation of ESPs and Bag filters at all 4 SPs (206 kg/hr, more than 50% reduction), process innovations of higher bed height operation, slow sintering (~170kg/hr), ESP maintenance practices including HFTRs, Online Power Down rapping, HFPS (high frequency pulsating system), Graphene coating technologies and incorporating digital twin (with intensive emission control models) have enabled sinter plants to achieve emission reduction by 300% at Tata Steel Jamshedpur (from FY12-FY24).

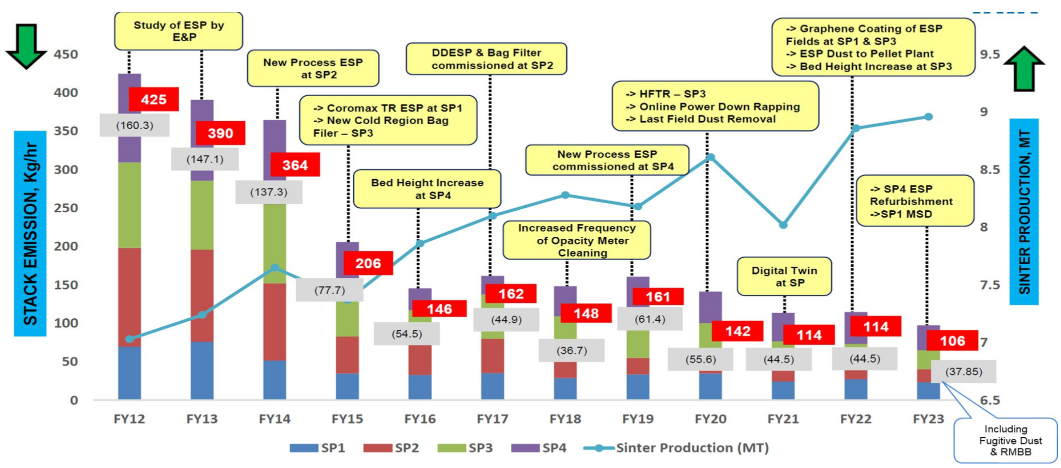

Fig.1: Journey of SP, TSJ through the years with corresponding breakthrough innovations.

Keywords: - Sustainability, Sinter Plant, Stack Emission, ESP, Iron Making and Steel Making

ESU_094

Boosting Photoelectrochemical Water Splitting of 2 dimensional α-$SnWO_4$ photoanode by surface engineering

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Abstract

WO_3 as photoanode has been acknowledged as a potentially low-cost, nontoxic and stable photoactive material for light-driven water splitting. However, such binary oxides suffer from poor visible light absorption due to wide bandgap and severe photocarriers recombination which limit their light harvesting efficiency. With the increasing trend in utilization of all earth abundant ternary metal oxides with suitable bandgap for photo-electrochemical (PEC) water splitting, the exploration of tungstate-based metal oxides is inevitable. In the family of metal tungstate, $SnWO_4$ has the potential to emerge as an efficient photoanode for solar light harvesting. A narrow indirect bandgap semiconductor, *n*-type α-$SnWO_4$ exhibits bandgap energy ~1.9 eV, appropriate for visible light absorption. The reported theoretical photocurrent density of α-$SnWO_4$ under 1.5G solar irradiation is above 17 mA.cm^{-2} which is well above than other ternary photoanodes (10.1039/D3QI01841E). Moreover, α-$SnWO_4$ photoanode has suitable band position for water splitting and has low onset potential for water oxidation. However, the experimental performance of α-$SnWO_4$ photoanode is well below the theoretical value. In a recent report (10.1016/j.cej.2023.144096), the highest ever photocurrent density of α-$SnWO_4$ photoanode was reported as 1.05 mA.cm^{-2} at 1.23 V vs. reversible hydrogen electrode (RHE). Many studies reported that α-$SnWO_4$ has intrinsic defects which lead to surface or interface trap states for photocarriers recombination resulting low photocurrent density. In α-$SnWO_4$ photoanode, during reaction the surface Sn^{2+} is oxidized into Sn^{4+} promoting the formation of SnO_2 overlayer. The newly formed interface between $SnWO_4$ and SnO_2 overlayer introduces traps or defects states in the materials serving as photocarriers recombination centres. Effective control over morphology, crystallographic orientation and surface engineering can significantly influence the PEC performance of α-$SnWO_4$ photoanode. In this work, a controlled hydrothermal synthesis route was followed to fabricate 1D rod shaped nanostructured WO_3 on fluorine doped tin oxide substrate (FTO). Then 1D rod shaped WO_3 was hydrothermally converted into 2D nanoplate shaped α-$SnWO_4$ with a large surface area. Further, the surface of α-$SnWO_4$ photoanode was passivated by simple surface chlorine doping through an additional wet chemical route. GIXRD pattern of 1D rod shaped WO_3 represents polycrystalline monoclinic structure, whereas 2D nanoplate shaped α-$SnWO_4$ shows orthorhombic crystal structure. There was no change in the structure after surface Cl doping on α-$SnWO_4$. However, GIXRD pattern confirms the presence of a thin layer of WO_3 underneath Cl- α-$SnWO_4$. HRTEM images confirm surface Cl-doping does not influence the bulk crystal structure of α-$SnWO_4$. XPS studies of α-$SnWO_4$ confirm the presence of SnO_2 overlayer, whereas no such peak is observed in Cl-doped α-$SnWO_4$. Surface passivation of

defects in $SnWO_4$ by Cl-doping has been evidenced in studies like LSV curves under chopped illumination, *ln(D)* vs. time plots, hole injection efficiency studies, and PL studies. Photocurrent density of 1D WO_3 photoanode is observed as 1 $mA.cm^{-2}$ at 1.23 V_{RHE} and it is enhanced by 1.6 times for α-$SnWO_4$ (1.6 $mA.cm^{-2}$). The highest ever photocurrent density of 1.9 $mA.cm^{-2}$ at 1.23 V_{RHE} was observed for Cl-doped α-$SnWO_4$ due to lowest photocarriers recombination and faster charge separation as well as enhance hole injection. Photocurrent density can further improve by a suitable catalytic layer on the photoanodes.

Keywords: α-$SnWO_4$ nanoplates; Photoanode; PEC water oxidation; Surface Cl-doping

DM_010

Sustainability Lifestyle - For a Greener Tomorrow

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Abstract

Alumina refineries, essential for aluminium production, face significant Environmental, Social, and Governance (ESG) challenges, particularly regarding energy, waste management, and water usage. This paper examines the energy-intensive nature of alumina refining, which typically relies on fossil fuels, resulting in a notable carbon footprint. Improving energy efficiency and transitioning to renewable sources are crucial for reducing environmental impacts. Red mud, a byproduct of the Bayer process, poses environmental risks due to its high alkalinity and potential contamination; effective waste management practices and recycling technologies are vital to mitigate these risks. Additionally, the extensive water usage in alumina refining necessitates sustainable management strategies and pollution controls. Adhering to regulatory standards and engaging with local communities are key to effective governance. Innovation and regulatory compliance are key to enhancing ESG performance and balancing industrial activities with environmental and social responsibilities.

Innovation and circular economy principles are pivotal in advancing sustainability within the alumina refining industry. This paper explores how the adoption of alternative green fuels, can substantially reduce the carbon footprint of alumina refineries by replacing fossil fuels and lowering CO_2 emissions. Innovative technologies and processes that integrate green fuels can enhance energy efficiency and support a transition towards a lower-carbon industrial model. Additionally, the circular economy strengthens red mud management through strategies that transform waste into wealth, utilising it as a byproduct rather than discarding it as a waste and mitigating the adverse impacts of red mud disposal. Circular economy practices also facilitate water neutrality by advancing waste effluent water recycling and achieving zero liquid discharge. By embracing these innovations and circular approaches, alumina refineries can significantly enhance their environmental performance, reducing carbon emissions, managing waste effectively, and optimizing water use.

As a global leader in the metals industry with operations spanning the aluminium and copper value chains in 13 countries, sustainability is central to Hindalco's operations. The company is deeply committed to ESG principles, with a strong focus on enhancing recycled content, implementing circular economy practices for waste management, achieving net carbon neutrality, and promoting water positivity. Hindalco, Belagavi Specialty Alumina Plant is a pioneer in red mud management, employing advanced technologies to reduce its carbon footprint and adopting a focused strategy for water conservation by minimizing freshwater consumption. This approach not only aligns with the company's sustainability commitments

but also supports long-term sustainable refinery operations by adhering to statutory compliance and upholding rigorous sustainability standards, thereby contributing to climate change mitigation.

Key words: ESG, Carbon Footprint, Waste Management, Water Positivity, Circular Economy

ESU_092

Vesuvius's Energy-saver Concept in Induration Furnae

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Abstract

Palletization of iron-ore is the process of compressing or molding sources of iron-ore feed material into the shape of a pellet. Vesuvius offers Pre-cast pre-fired solutions for Burner Ports & Side walls surrounding the burners in the Firing zone of the plant. Vesuvius offers gunning solutions for Preheating zone, cooling zones, DR Mains, downcomers, Wind boxes and ducts. Vesuvius offers Pre-cast pre-fired solutions for baffle walls, lintel blocks & Seal boxes of the pellet plant.

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Vesuvius has introduced the Energy-saver concept at the Pellet plants (PP-1 & PP-2) at AMNS Vizag, through Dry Baffle walls, Dry Lintels and Dry Seal boxes. The solution has proven to be a huge success with performance and stability, successfully running in operation for more than 2 years now.

Replacement of Water circulated Baffle & lintels with Dry Precast shapes – An Energy efficient solution.

Fig. 1: Baffle wall precast

Fig. 2: lintel block

Key words : Pellet, sustainability, advance precast, Baffle wall, lintel block

"Reducing fuel rate by Utilization of Solid Secondary Waste material in Pellet Plant"

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Abstract

Iron ore pellet plants play a vital role in the steelmaking industry, as they transform fine-grained iron ore concentrates into high-quality pellets suitable for steel production. This abstract is about the use of waste material containing iron, fluxes and fuel in the operations of JSW Steel Ltd.'s Dolvi Pellet Plant. JSW Steel Ltd. is a leading steel producer in India, committed to adopting environmentally responsible practices while maintaining operational efficiency and competitiveness. However, the production of steel generates various waste materials, including fines, dust, and sludges, which traditionally pose disposal challenges and environmental concerns.

In recent years, there has been growing interest in exploring sustainable practices in the steel industry, including the efficient utilization of waste materials. Incorporating waste materials containing iron into pellet plant operations presents an opportunity to recycle waste generation, minimize environmental impact, and improve resource efficiency. There are several potential sources of waste materials containing iron, fluxes and fuels such as iron-rich sludges from wastewater treatment plants, mill scale from Steel manufacturing units, and iron-bearing dust from various industrial operations. These materials often contain valuable iron content, fluxes and fuel which can be recycled and utilized as a raw material feedstock in pelletizing plants.

Here, in JSW Steel Ltd. Dolvi complex, the secondary materials used are SMS GCP dust, Blast Furnace Cast House and Stock House dust, SIP Sludge and several Oxide dusts. The dusts are added with iron ore and are then ground in the ball mills in agreeable proportions without compromising the quality. This has led to reduction in solid fuel rate and has proved to very economic along with added benefits of reduced environmental impacts. An average of 32kg/tonn was added to the feed mix in April 2023 in Pellet Plant 1, this has been gradually increased to 45kg/ton in March 2024. This has led to significant reduction of fuel consumption from 13.8kg/tonn to 6.8kg/tonn. Also, in Pellet Plant 2, an average of 41kg/tonn was added to the feed mix, which was increased to 58kg/tonn in March 2024, leading to the reduction of fuel consumption from 9.15kg/tonn to 2.60kg/tonn.

This abstract concludes by highlighting JSW Steel Ltd.'s proactive approach towards energy efficiency and sustainable waste management in its pellet operations. In order to meet its sustainability goals and keep its position as a market leader in the global steel sector, JSW strategically uses its secondary waste materials.

Key words: Secondary Waste, Pellets, Waste Management, Sustainability, Iron-bearing dust.

FAILURE ANALYSIS

Oral Abstracts

Understanding the mechanism of fatigue failure in electroplated compression spring

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Abstract

Compression springs are generally used as a shock absorber in the automotives. Ni-Cr electroplating is one of the most common surface finish techniques for these springs which acts as a corrosion resistant barrier and serves a decorative purpose. This electroplating process is highly hydrogen intensive process, and it introduces hydrogen in the spring. In this study, the effect of hydrogen content on the fatigue property of spring was established. Hydrogen thermal desorption spectroscopy (HTDS) was used extensively to find the suitable de-embrittlement temperature and time. Effect of residual stress and surface micro-cracks on the fatigue property of spring was also investigated. A clear mechanism of fatigue failure in compression springs and its mitigation strategy was proposed.

Key words: Springs, Fatigue, Hydrogen, Fractography, Thermal desorption spectroscopy

FAN_010

Correlating microstructure with fatigue failure in a wire rod

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Abstract

Two wires from different sources (Source A and Source B) were investigated. A complete through thickness micro-textural characterisation including micro hardness, microstructure, residual stress, and inclusion analysis was performed. Both samples were then cathodically charged to see the amount of hydrogen these microstructures can take in. Hydrogen thermal desorption (HTDS) spectroscopy was used to quantify the absorbed hydrogen. Finally, fatigue test was performed on these wires to find out the effect of these microstructures on fatigue property. A preliminary correlation was observed among microstructural properties, hydrogen content and fatigue behavior.

Key words: Wire, Fatigue, Hydrogen, Fractography, Thermal desorption spectroscopy

FAN_013

Effect of high-temperature exposure on the low cycle fatigue behaviour of Haynes 282 alloy

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Abstract

Extensive efforts are underway in countries like Europe, Japan, USA, China, and India to enhance the steam operating parameters in fossil fuel power plants aiming to improve efficiency and minimize greenhouse gas emissions. As a result, developments are in progress to establish power plants with advanced ultra super critical (AUSC) technology. The implementation of advanced ultra-supercritical (AUSC) steam power plants relies significantly on nickel-based super alloys possessing high thermal stability, high resistance to thermal fatigue, high creep strength and oxidation resistance, and good fabricability. Haynes 282 alloy, a nickel-base super alloy, is emerging as a prominent candidate material for AUSC boiler and steam turbine applications among the potential materials considered. During service, the structural components of power plants (ex. turbine blades and discs) experience fluctuating loads due to temperature gradient and result in low cycle fatigue (LCF).

The present work primarily focuses on the study of the microstructure and LCF behaviour of the Haynes 282 alloy. The LCF behaviour of Haynes 282 alloy was studied in two different conditions: (i) standard two-step aging and (ii) two-step aging followed by exposure at 760℃ for 250 h. LCF tests were carried out at 700℃ and 750℃ at different strain amplitudes, viz., ±0.4%, ±0.6%, and ±1.0% and the results were compared in both the conditions. At 700℃, the alloy exhibited initial cyclic hardening followed by softening at all three strain amplitudes in both the conditions. However, at 750℃, the initial cyclic hardening was observed for ±1.0% strain amplitude followed by softening; whereas at low strain amplitudes (±0.4% and ±0.6%) continuous softening was noticed. The measured degree of hardening (DOH) increased with increasing strain amplitude and decreased with increasing temperature for both the conditions. However, the material in 250 h exposed condition exhibited a higher DOH than the two-step aged condition. The cyclic hardening/softening curves, fatigue life curves, and cyclic stress-strain curves were obtained for both the two-step aged and two-step aging followed by 250 h exposure conditions. While the cyclic stress-strain curve of the material in both the conditions marginally overlaps at 700◦C, it shows a shift of approximately 150 MPa higher stress amplitude in the 250 h exposed condition in comparison to the two-step aged condition at 750℃. A higher fatigue life was observed with higher stress amplitude for the 250 h exposed condition at 700℃. Conversely, at 750℃, the two-step aged condition showed higher fatigue life with lower stress levels. Fatigue parameters were evaluated using strain-life plots and

FAN_027

Holloman's equations at both the temperatures for both the conditions. Post-microstructural studies were carried out in both the conditions using field emission scanning electron microscopy (FE-SEM). The size and morphology of γ' precipitates were evaluated for both the conditions at 700℃ and 750℃. Fractography studies revealed a transgranular mode of failure at 700℃ and an intergranular mode of failure at 750℃.

Key words: Haynes 282 alloy, standard two-step aging, high-temperature exposure, electron microscopy, low cycle fatigue.

Fatigue Cracks in MIG Welded Automotive Steel Wheels

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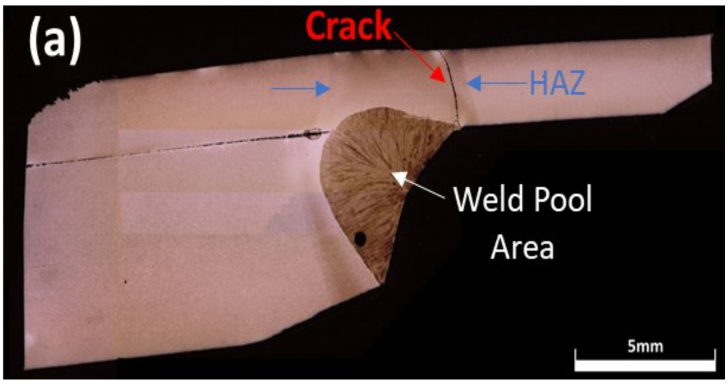
Abstract

The automotive steel wheel is a critical safety component, as it supports the car body and transmits driving and braking forces from the ground. To ensure durability and prevent failure during service, wheel manufacturers perform periodic bending fatigue and radial fatigue tests to simulate common fatigue failure modes under continuous cornering and straight driving conditions, respectively. This study investigated the failure causes in a steel wheel component made from high-strength low-alloy automotive steels. The 6.5 mm thick wheel disc was stamped and pressed into a 2.5 mm thick steel rim formed by flow forming. The disc was welded into rim using robotic MIG seam welder to create the final steel wheel assembly. The fatigue cracking of the component occurred during the application of standardized RFT loading at a factory.

All standard procedures of failure analysis were applied, with a careful assessment of the material characteristics and the cracked surface. The analysis concluded that fatigue cracks initiated in a wheel rim at the toe end of concave weld bead and failures were predominately concentrated at the end of the seam welding procedure. Detailed investigation revealed stress concentration in this region and a significant microstructural change from quasi polygonal ferrite to martensite. The undesirable martensite phase was formed in HAZ of failed wheel rims as a result of higher cooling rates in a low weld heat input condition. The fatigue cracks were not observed when bainite phase was formed in HAZ as a consequence of optimum weld heat input and slow cooling rate associated with convex weld bead at the start of seam welding procedure. A recommendation was given to optimize the MIG welding procedure, ensuring the lifetime specified for the wheel component in the fatigue test.



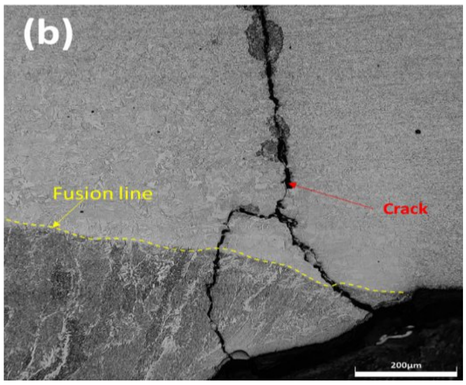


Figure 1 (a) the transverse section of cracked region at the weld joint of rim and disc (b) Optical microscopic image of crack tip

Key Words: Steel Wheels, Failures, Radial Fatigue Test (RFT), MIG Welding, Heat Input

FAN_030

Improvement of Cornering Fatigue Test (CFT) Life cycle by chemistry design modification in HSLA 590 grade Hot rolled coil for Automotive Wheels application

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Abstract

HSLA 590 grade hot rolled steel are widely used in automobile industry for manufacturing of Automotive wheels (Rim & Disc) application. When a vehicle is in motion, its wheels are subjected to various forces, including lateral forces during cornering. These forces can lead to fatigue in the wheel material over time. The cornering fatigue test (CFT) simulates these conditions to evaluate how well the wheel can handle such stresses. CFT is very crucial for automotive wheel manufacturers as it thoroughly estimates the structural integrity of the wheels and hence recommended.

Steel cleanliness has a major impact on the behavior of the steel withstanding such loads. The impact of inclusions on the steel quality varies depending on the shape, size, number and density of the inclusions. Calcium treatment is most commonly used method to modify the morphology of harmful inclusions into spherical morphology which are less harmful, thus contributing to cleanliness of steel. In the current study, the SEM analysis and inclusions present in the CFT Failed component was done in order to understand the nature of inclusions and their role in fatigue life properties. It was observed that amount of Ca based globular inclusions and higher stress concentration inclusions in steel were detrimental to the fatigue life properties. The chemistry design modification was done by removing the Ca treatment and the CFT test performance was validated. The fatigue life of the component without Ca treatment was found to qualify the CFT test with superior performance as compared to the previous design. The microstructure characterization study was done for components before and after chemistry modification revealed the significance of the steel cleanliness on the fatigue life of the wheels.

Key words: Cornering Fatigue Test (CFT), Inclusion, Microstructure, Steel Cleanliness

FAN_033

Investigate the tension-tension mode of high cycle fatigue behavior of continuously cooled carbide-free bainitic steels

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Abstract

The present study investigates the behavior of carbide-free bainitic steels during high-cycle fatigue under tension-tension mode. Specifically, axial fatigue testing was conducted at room temperature with a stress ratio of 0.1. The mechanism and fatigue life analysis reveal that these specimens consist of two stages, namely, the crack initiation and crack growth, observed during the analysis, which is controlled by the local stress cycles and are surface-based. The fatigue fractography analysis of the failed specimens did not reveal any microstructural defects like the presence of impurities; instead, it showed that failure occurred due to crack initiation at the surface. Electron Backscattered Diffraction (EBSD) analysis, used to study the crystallographic orientation of the microstructures in the failed samples, established a link between fatigue resistance and crystallography. The analysis of partitioning between ferrite and austenite, as well as KAM and IQ maps, revealed significant deformation in the retained austenite matrix. The TRIP effect of retained austenite contributed to the experimental steel's excellent fatigue properties by allowing for the relaxation of local stress concentrations, the absorption of strain energy, and a delay in crack initiation and propagation. These findings significantly contribute to the understanding of the fatigue behavior of advanced high-strength steel alternatives and their potential applications in the field of metallurgical and materials engineering.

Keywords: carbide-free bainitic steel, high cycle fatigue, retained austenite, fatigue limit, fatigue strength ratio, S-N curve, TRIP effect

FAN_036

High Cycle Fatigue Behaviour of Ni-base superalloy at 650 ℃

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Abstract

In the present work, the High Cycle Fatigue behaviour of directionally solidified Ni-base superalloy is studied at different stress ratios of -1, 0.7, 0.5 and 0.4 at a test temperature of 650 ℃ and at an applied frequency of 30 Hz. The phases present are γ, γ', γ-γ' eutectics and MC type carbides. The analysis of the fracture surface was done using Scanning Electron Microscopy (SEM), and the deformation mechanism was studied using Transmission Electron Microscopy (TEM). Fractographic analysis showed multiple crack initiation sites, and the fracture surface looked like a faceted fracture.

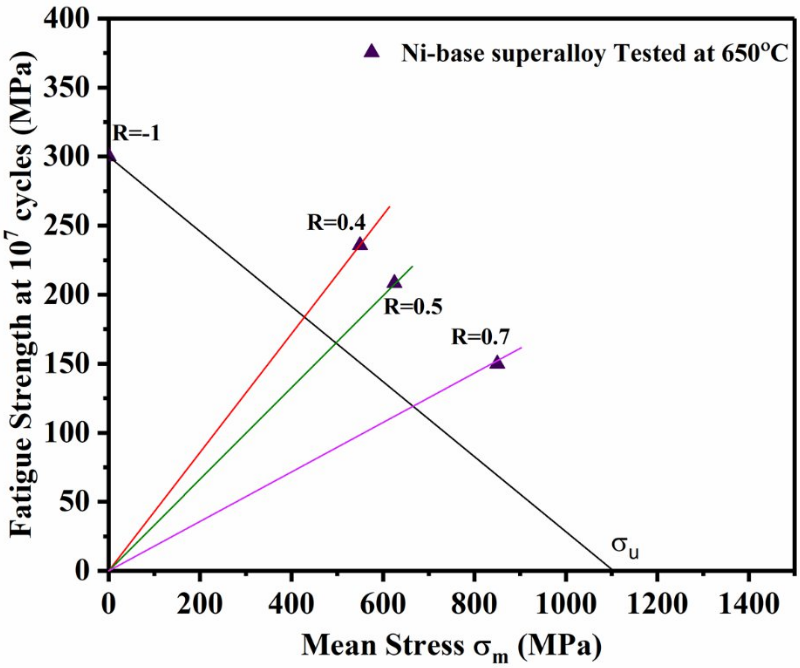

Fig. 1: Constant life diagram for samples tested at different stress ratios at 650 ℃

Key words: High Cycle fatigue, Ni- base superalloy, High temperature, SEM, TEM

FAN_057

Effect of microstructure on the low cycle fatigue deformation behaviour of IN 713 C alloy

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Abstract

The cast IN 713 C alloy is widely used in the aerospace and automotive industries. Despite advancements in casting techniques, microstructural inhomogeneity remains an issue, leading to strain localization during cyclic loading. The impact of these microstructural variations on the low cycle fatigue (LCF) behavior of IN 713 C alloy has not been extensively explored. In this study, LCF tests were conducted on IN 713 C alloy at design significant temperatures, i.e., 650 and 750°C with strain amplitudes of 0.35, 0.45, and 0.6%. The results indicate that deformation heterogeneity, influenced by the distribution of carbides, γ'-precipitates, and γ-γ' eutectics, plays a significant role in the fatigue failure mechanisms. Fatigue cracks predominantly initiated in precipitate-free zones and at oxidized surface carbides. The study also found that regions with higher geometrically necessary dislocations, such as carbide/matrix, eutectic/matrix, γ'/matrix interfaces, and interdendritic areas, were prone to void and crack formation. These areas of increased geometrically necessary dislocations promotes crack initiation and propagation. This study will provide impetus to the designer to identify the strain localization and reveal the damage features turbine blades and wheels.

Keywords: Low cycle fatigue deformation; Superalloys; Microstructure; TEM

FAN_068

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

FAN_003

Mitigation Strategies for Mechanical Seal Failure in Autoclave Agitators Operating at High Temperature and Pressure: A Case Study

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Abstract

Mechanical seal failure in agitators of autoclaves operating under extreme conditions, such as 140 ºC temperature and 7 kg/cm^2 pressure, presents significant operational challenges. This paper investigates the root causes of seal failure and proposes modifications to enhance seal performance and prolong equipment lifespan. The study begins with a comprehensive analysis of the operating environment, including temperature and pressure fluctuations, mechanical stress, and chemical exposure. Through detailed examination of failed seals and performance data, common failure modes were identified, including thermal degradation, seal face wear, and loss of lubrication. Based on the findings, several modification strategies were proposed to address mechanical seal failure. These include the use of advanced seal materials with enhanced thermal and chemical resistance, such as silicon carbide or ceramic composites. Additionally, improvements in seal design, such as optimizing seal face geometry and increasing seal face contact area, are explored to minimize wear and improve sealing performance. Furthermore, lubrication systems were upgraded to ensure consistent and adequate lubrication under high-temperature conditions. This may involve the implementation of auxiliary cooling systems or the use of high-temperature lubricants capable of withstanding the operating environment. In addition to seal and lubrication enhancements, attention is given to agitator design and operation. Modifications such as reducing rotational speeds, optimizing shaft alignment, and implementing vibration monitoring systems are proposed to mitigate mechanical stress and prevent premature seal failure. To validate the effectiveness of the proposed modifications, a pilot-scale implementation is conducted, wherein modified seals are installed in autoclave agitators and subjected to simulated operating conditions. Performance metrics such as seal lifespan, leakage rates, and energy consumption are monitored and compared against baseline data. The results demonstrate a significant improvement in seal performance and reliability following the implementation of modifications. Seal lifespan is extended, leakage rates are reduced, and energy efficiency is improved, leading to enhanced equipment uptime and operational efficiency. In conclusion, this study provides valuable insights into the mitigation of mechanical seal failure in autoclave agitators operating at high temperature and pressure. By addressing root causes and implementing targeted modifications, operators can achieve significant improvements in equipment reliability and performance, ultimately enhancing overall process efficiency and productivity.

Keywords: Mechanical Seal Failure, Autoclave Agitators, High Temperature, High Pressure, Seal Modification Strategies.
FAN_014

Reduction of Inclusion Crack Defects in Thin-Gauge of Low Carbon Steel Grade

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Abstract

Here in this paper we have characterized the inclusion defect in the low carbon steel grade in an effort to reduce cracking. We have considered thinner material since there are more cases of cracking as compared to higher thickness. By EDX analysis we have found the inclusion chemistry and have investigated the source of inclusion. The inclusion rating is calculated for various experimentation in the process parameter and an optimum processing condition is studied.

This research employed automated scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM/EDS), fractography, and optical microscopy techniques to conduct a thorough inclusion analysis on low-carbon steels. A comprehensive examination of the steel-making process is done focusing on the types of inclusions, their formation mechanisms, and the influence of various process parameters. Key parameters such as casting speed, nozzle depth, heat retention in the tundish, and mold level fluctuation (MLF) are analyzed for their impact on inclusion reduction. The effectiveness of different mould powders and the role of Electromagnetic Stirring (EMS) during casting are evaluated in controlling inclusions. The study also investigates the effect of casting slab size on inclusion incidence and the results are compared in this paper. Experimental approaches and technological interventions, including the use of EMS, adjustments in parameters and increasing slab size, are assessed for their effectiveness in minimizing inclusion-related defects are compiled in this paper.

Key words : Inclusion Crack, Electromagnetic Stirring, Low carbon Steel

FAN_018

Significance of width ratio in positioning the weld line of tailor welded blanks to avoid cracks while stamping of automotive door inner panels in IF grade steel

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Abstract

With the growing emphasis on light weighting and material efficiency in the automotive industry, the use of tailored welded blanks (TWBs) in auto parts production has significantly increased. This paper investigates the cracking issues observed during the stamping of door inner panels made from interstitial-free (IF) grade steel, particularly near the weld seam. A comprehensive analysis was conducted to understand crack formation, focusing on the mechanical properties in relation to the width ratio—the ratio of widths used in two blanks of different thicknesses in a TWB—relative to the weld position. Statistical analysis was performed on various components made from the same IF grade steel with different thicknesses. To further explore this issue, TWB components from three major automakers were monitored over a three-month period, examining a range of panel sizes. The study included scanning electron microscopy and microstructural analysis of crack samples, along with mechanical testing of the TWBs. The findings revealed a correlation between the weld seam's position within the panel and performance feedback from the press shop, leading to the identification of an optimal range for the width combination of TWBs. These insights provide valuable guidance for improving the design and manufacturing processes of TWBs, thereby reducing the risk of cracking during stamping.
The results of this study provide valuable insights for automotive manufacturers to optimize the design and selection of TWBs, thereby mitigating the cracking concerns and improving the quality and performance of door inner panels. Components manufactured by welding 1.4mm in combination of 0.70mm and 0.65mm is analysed. Sensitivity of the crack is understood from the width ratio perspective in this paper. while metallurgical & operating parameters are critical for stamping of TWB from a material standpoint, the factors related to the design of the TWBs also play a vital role in the smooth processing of end components.

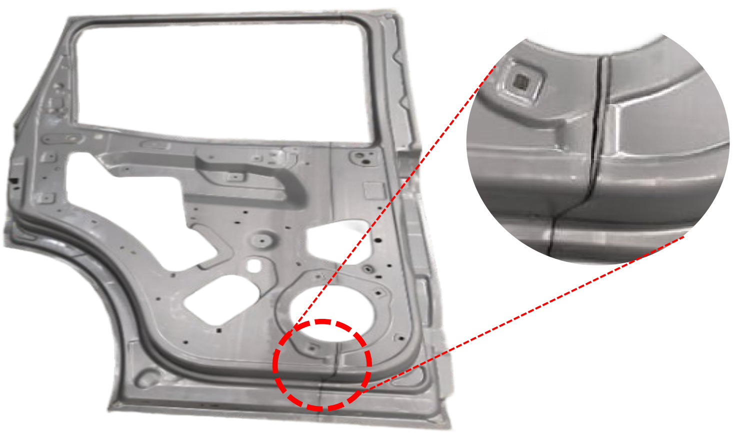

Fig. 1: Crack observed in TWB after stamping

Key words: TWB - Tailor welded blanks, Width Ratio, Cracking, IF- Steel, Door Inner Panels

FAN_058

Role of Material flow in Friction Stir Welding of Al-Cu joint on Fracture behavior

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Abstract

The study on fracture behavior of the friction stir Al-Cu weld highlights the crack initiation and propagation is influenced by the material flow at the interface of the weld. First, a single side weld was carried out using the welding parameters of 800rpm, 50mm/min and offset position of 1.5mm to the advancing side. The microstructure of the weld cross section shows the inter-mixing free weld interface, a Cu intrusion (bulk Cu deformational flow into Al) in the tool-shoulder influenced region and a very fine metallic and intermetallic particles in the stir zone. The interface structure was altered by the second weld which was performed by reverse the single side weld by following the same weld axis and the parameters of the first weld. It resulted in complete overlap of the stir zones with the formation of an additional Cu intrusion to the opposite side to the first one. As the Cu intrusion act as a crack arrester, the crack initiation was spotted at the bottom of the single side weld. The nature of the material flow at the interface in the double side weld localized the crack in the middle of the weld interface and delayed the crack initiation and propagation which supported in two-fold increment in the ductility of the joint.

Keywords: Aluminium; Copper; Material flow; Fracture; Double side weld; FSW.

FAN_061

Failure Resolution of Copper Radiator for Harvester Application

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Abstract

Copper radiator failure analysis studied for Harvester application. Leakage observed at Zero kilometre at customer end and failed radiator taken for failure analysis. Supplier process audit and each stages of process studied to find the route cause for pitting failure. Failed radiator cut section analysis done and observed powdery deposit on bend location of the core tube. Chemical analysis done for the powdery deposits and observed $ZnCl_2$. Observation during process audit - similar deposits with existing process. Process optimization done by implementing Demineralised hot water washing, Top and Bottom plate fixing before core baking. Acid bath contamination also observed with the existing system and modified with optimised concentration with new PP tank. And acid tank dipping changed to horizontal position to vertical position. Additionally, fresh DM water flushing/rinsing/spraying after re-soldering and improved acid washing with optimised time. Four stages of water wash with DM water introduced after acid dipping. Trials carried out with proposed system and compared with failed radiator, existing process radiator and improved process radiator. No deposits, residuals, colour change observed with the proposed process. Outcome of the process audit is, residual flux material containing Zn reacting with HCl which accelerate the pitting corrosion that lead to radiator leak.

Key words: DM Water: De-Mineralized, HCl: Hydrochloric Acid, PP: Poly propylene

FAN_066

Effect of testing parameters on the Fracture appearance behaviour of HSLA steel plates used for underwater applications

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Abstract

High strength low alloy (HSLA) steel is an attractive material for naval and defence applications for its excellent mechanical properties. Steels used for underwater applications must meet certain criteria. The first is a high strength to weight ratio. The deeper it goes, the greater the water pressure. The metal used for the submarine hull and welds also must be of high plasticity. Submarines frequently dive and surface, enduring many load cycles, which can result in fatigue cracking. This means that the steel must meet very strict fatigue and dynamic strength requirements. As with surface vessels, high resistance to corrosion is essential. Low magnetism is also important for military submarines to reduce the risk of detection. Since the submarines are always exposed at sub zero water temperature, fracture behaviour for underwater applications need to be studied.

This paper is all about development of steel plates for underwater applications. After heat making and rolling at New Plate Mill facility at SAIL -RSP, plate is received in as Rolled form by Special Plate Plant. At special plate plant in RSP, heat treatment is done to alter the microstructure and mechanical properties of steel as per the requirements. After heat treatment, samples are sent for tensile testing and charpy impact testing at 6 locations of the plate. On completion of tensile and charpy test, Fracture Appearance samples are taken out of the steel plates. Fracture Appearance testing is performed under atmospheric condition whereas samples are cooled to the desired temperature using industrial freezer (for -10℃) and Air conditioners (for Room temperature testing environment) and conducted under loading rate of <1mm/sec which needs to be maintained. A Comprehensive study has been done for the impact of loading rate, test sample ligament length, notch radius and notch gap on the fracture appearance behaviour of underwater application steel plates. Testing has been performed at different loading rates using manual as well as hydraulic power pack to study the behaviour of Fracture surface and the mechanism of fracture. Similarly the effect of ligament length, radius of notch and spacing of the notch has been studied.

The fracture appearance test study is performed based on three criteria

1) Percentage of ductile and brittle area of fracture.
2) Laminations
3) Separation

MPR_384

Plots have been made against loading rate with % ductile fracture. It is found that at lower loading rate (<20mm/min), % of brittle fracture is lesser compared to higher loading rate 50-60mm/min in most of the samples whereas in some few samples, % of brittle fracture is found to be more. Similarly higher notch radius and notch gap can increase the % of brittle fracture; this study has been done under naked eye. To get the better understanding of fracture appearance surface of samples where ductile to brittle fracture appearance is to be analyzed; SEM observations are done under Scanning Electron Microscope (SEM) Carl Zeiss Make, EVO MA 10 Model at RDCIS, Ranchi. It has been observed that plates having open laminations have high density of inclusions.

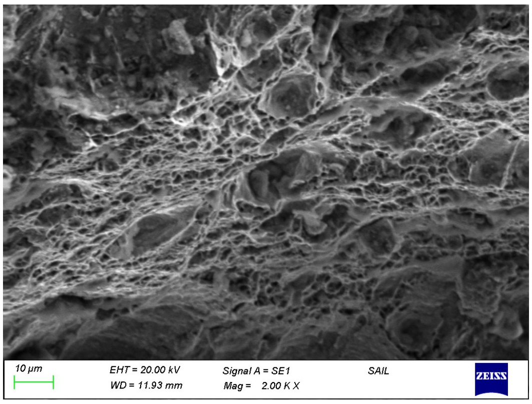

Fig. 1: Study of Fractography under SEM at WD11.93mm and Magnification 2.00KX

Key words: HSLA, Fracture Appearance Test (FAT), Brittle area, Laminations, Separations

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Design Optimisation through Failure Analysis of Aero-Engine

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Abstract

Unlike a ground system, failure in an air system may lead to catastrophe including loss of life, therefore, design of an aero-engine in particular and that of aircraft in general is conservative in nature. Many a time the effect of manoeuver and g-loads could not be simulated during ground level evaluation. However, effort is always on to improve the safety level of the flying machine by modifying the design through addressing failures envisaged or encountered during development & operation respectively.

This paper discusses few case studies of failure analysis of aero-engine components which brings out modification in the design of manufacturing process, inspection methodology and life.

Cracking of Piston in Hydraulic Jack: Modification in Manufacturing Process

Synchronous jet nozzle operation in an aero-engine is being ensured by three piston-cylinder assembly operated by hydraulic oil. Cracking of piston has led to non-synchronous movement of cylinders resulting in malfunction of jet nozzle causing flame out of engine leading to accident of aircraft. Failure analysis of failed piston reveals fatigue mode of failure and further study reveals cracks at the neck radius & cutting of forging flow lines. Further investigation reveals there was a change in neck radius, but the same was implemented during machining in the pre-mod forging. Forging die has been modified to achieve the modified radius in the forging instead by machining which could contain such failure.

Failure of Spiral Bevel Gear: Change in Method of Inspection

Failure of main spiral bevel in a twin-engine aircraft led to single engine landing. During defect investigation, it was found that the failure of main bevel led to loss of drive further resulting in flame out of engine causing single engine landing. Failure analysis of failed gear brings out that failure mode is fatigue having initiation point at a subsurface crack. As this engine has undergone overhaul, it has undergone FPI (Fluorescent Penetrant Inspection) check which can reveal only surface crack. There was a need to introduce MPI (magnetic particle inspection) check during overhaul which could bring out few defective gears thereby preventing such failures in future.

Failure of Detachable labyrinth in Turbine Disk: Design Life for Joints

Detachable labyrinth configuration is finding application in turbine disc for its better

FAN_082

maintainability and further use of disc for an extended period. Failure of one detachable

labyrinth in a turbine disk has led to an aircraft accident in a single engine aircraft. Cracking of rivet was the primary cause of the accident. Accordingly, to obviate cracking of rivets, this riveted joint configuration has been assigned a life apart from engine by life by carrying out investigation on engines having exploited for varied hours of flying.

Failure Investigation & Analyses of Die Plate Used in Twin Screw Extruder for Processing Engineering Plastics

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Abstract

Premature wear of around 300microns on Die plate ID hole within 7 days of service was investigated comprehensively. This strand Die plate was supplied in AISI H13 material in nitrided condition for processing Glass filled (Max40%) PA66 Nylon compounds. Die plate serves critical role in complete Die assembly system in regulating melt pressures and consistent strand profiles. Typically, AISI H13 with surface hardness of around 1100HV after nitriding provides a durability of minimum 6months for the stated application.

Visual examination of the failed die plate indicates severe surface chip off at every strand hole in material entry side. Metallurgical examination on the die plate reveals no anomalies with Chemical composition, Hardness measurement and Microstructure of the base material (AISI H13). Metallography analysis on the die plate cut section indicates severe carbide streaks on the outer surface and no presence of nitriding layer inside the strand die plate ID hole. Phase identification carried out by XRD measurement discovered abnormalities with the Nitriding process, which has resulted in the formation of severe carbide streaks and double layer. Under high operational stresses, Nitriding layer with severe carbide streaks has chipped off immediately resulting in pre-mature ID expansion of 300microns inside the strand ID.

Keywords: Gas nitriding, AISI H13 Die plate, Twin Screw Extruder

FAN_086

Eliminating Cracking Issues during Forming in DP780 grade of Cold Rolled Steel

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Abstract

High-strength dual-phase steel is widely used by automobile manufacturers in crash safety-critical parts. However, these steels are susceptible to thinning and cracking during forming due to various factors like strength parameters and inclusions. For different OEMs, property requirement of this grade varied. This poses another challenging situation for production, as for same grade there were multiple ranges of properties.

Cold rolled steel DP 780 grade having TS ≥780 MPa, YS ≥ 540 MPa and Elongation ≥14% has a Dual-phase structure Ferrite and Martensite. To address the cracking issues, a thorough study was conducted on the grade chemistry, mechanical properties, process parameters of well-performing batches versus poorly-performing batches, the effects of aging and inclusion levels in the not good batches. Statistical analysis shows relation with properties fluctuation with higher carbon levels, Ti/N ratio and SPM elongation. The SEM analysis shows the presence of non-metallic inclusions and MnS segregation. The chemistry was redesigned. Some issues were resolved by limiting free nitrogen through adjustments in titanium levels. The carbon content in the chemistry was reduced to prevent unexpected increases in UTS (Ultimate Tensile Strength) in some coils. This chemistry changes helped in mitigating aging effects and reduce cracking due to high UTS and low elongation. To minimize inclusions, the chemistry was modified using regression modelling of good and bad lots, altering the calcium design to achieve a Ca/S ratio, which controlled sulphide inclusions. Additionally, the existing DP780 grade was divided into two distinct grades by adjusting SPM parameters to meet the different yield strength specifications of various OEMs. These measures significantly reduced cracking instances in the DP780 grade from 8% to 2% at customer end.

In conclusion, tailored adjustments in grade chemistry, process parameters, and inclusion control significantly reduced cracking instances in high-strength, cold-rolled DP780 steel used for complex automotive parts.

Key words : Cracking, DP780, CRCA, YS, UTS, El

FAN_016

Failure Analysis of CBC Coupler Shank at RMHS Plant

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Abstract

The CBC coupler is a crucial component in railway operations, designed to connect two adjacent rakes or locomotives. It is centrally located at both ends of the rakes and allows vehicles to move independently while remaining coupled and transmits both draft (tensile) and buffing (compressive) loads between vehicles, accommodating track curvature and elevation changes while maintaining a secure connection. The CBC coupler's main components include the coupler head, shank, and draft gear, which work together to absorb and dissipate energy during train operations, such as starting, stopping, accelerating, or decelerating. The absorption and dissipation of energy happen through draft gears equipped with springs, reducing the impact between the coupler and railcar which ensures smooth operations during acceleration, braking, or adjustments in tractive effort, essential for maintaining train integrity and performance.

This report details the failure analysis of the Centre Buffer Coupler (CBC) shank from a wagon at the RMHS Plant, Tata Steel Kalinganagar. The failure was observed in the coupler shank, a hollow rectangular bar connecting the coupler head to the draft gear, which fractured approximately 60 mm from the coupler head. Visual inspection and subsequent analysis revealed uneven and rough internal surface with pits and thickness variation in the shank, leading to fatigue failure. The primary mode of failure was identified as corrosion fatigue, exacerbated by environmental conditions involving dust and moisture, coupled with fluctuating draft and buffing loads. The inner surface of the hollow shank was heavily corroded, with the thickness varying significantly across different sides. Ratchet marks on the thinner side indicated fatigue as the primary failure mode. The crack initiated from the inner surface and propagated through the thickness, leading to an overload on the remaining sides, which subsequently failed in a brittle mode. Microstructural analysis showed severe pits due to corrosion, while etched micrographs revealed coarser grains and a decarburization layer of around 320 µm on the inner surface. This layer indicated high-temperature exposure either in service or during manufacturing, which deteriorated the surface mechanical properties and fatigue strength. The chemical analysis confirmed that the material closely matched Plain Low Carbon steel. The decarburized and coarser grain area on the inner surface showed lower hardness compared to the base metal, further confirming the deterioration of material properties due to high-temperature exposure and corrosion.

To mitigate future failures, the analyses suggests improving the surface finish of the inner shank to reduce corrosion rates, avoiding surface decarburization during manufacturing, and

FAN_024

adding copper content (up to 0.6%) to enhance atmospheric corrosion resistance. Regular inspections and maintenance are also recommended to ensure the integrity of CBC couplers in service.

Keywords: Rails and Wagons, coupling, shank, fatigue, decarburization, Grain coarsening, surface mechanical properties, heat treatment, corrosion, surface finishing.

References

[1] Celik, A., Y. Arslan, A. F. Yetim , and I. Efeoglu . "Fatigue behaviour of duplex treated AISI 316L stainless Kovove Materialy 45, no. 1 (2007): 35 40.
[2] https://www.iricen.gov.in/ModelRoom/W1_CBC%20Coupler.html

Study on damage initiation during deformation in metallic alloy

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Abstract

Engineering failures throughout history have provided invaluable lessons about the critical importance of understanding damage evolution, which will help in development of improved materials and processes that ultimately enable safer and more efficient engineered structures. Damage evolution of engineering materials, evaluated through classical or continuum fracture mechanics, typically assumes a pre-existing crack or void. However, they do not provide information about the nucleation of such flaws in an otherwise flawless microstructure. Therefore, a better understanding of grain-scale deformation can provide deeper insights into the damage nucleation at microstructural level. The present study investigates the role of various microstructural features, such as grain orientation and grain boundary characteristics, on the damage initiation in metallic alloys using a combination of Crystal Plasticity Finite Element Method (CPFEM) and Digital Image Correlation (DIC). This combination offers a comprehensive approach to study grain-scale deformation and consequently, enable one-to-one comparisons between experimentally measured data and model predictions. The slip activity across grains has been calculated, indicating that incompatible slip systems in adjacent grains impede slip transfer across the grain boundaries. This results in stress and strain build-up at these grain boundaries making them potential sites for damage nucleation.

Keywords: Damage nucleation, CPFEM, DIC, grain-scale deformation, slip activity

FAN_035

Fracture Mechanics based Studies of Hydrogen Embrittlement : Some Case Studies of Failures

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Abstract

Hyrogen Embrittlement is now accepted as a phenomena rather than just a mechanism. Catastrophic failures due to hydrogen is of prime interest to operators,regulatory bodies and the public in general.Environmentally assisted fracture in general and associated with hydrogen and their mitigation is a big challenge.The embrittlement may be due to internal hydrogen in steel, steel in hydrogen service and blister formation due to reaction with hydrogen. Environmentally associated fracture mechanics based studies on steels and stainless steels indicate that plastically streched zone (PSZ) ahead of the crack tip gets embrittled due to hydrogen . This adversly affects fracture toughness both the crak intiation and its propagation and in turn affects reliability in performance.. The paper elucidates how stretched zone width is reduced or diminished due to hydrogen.The fracture modes and mechanisms change due to hydrogen embrittlement is elucidated with fractography and some case studies from different sectors of industries.

KeyWords: Fracture Mechanics, Fracture toughness, Hydrogen,Embrittlemenr, Fractography ,Failure analysis

FAN_040

Creep crack growth behaviour of 316L austenitic stainless steel at 873 and 923 K

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Abstract

Austenitic stainless steel of grade AISI 316L is widely used as a structural material in power generating and petrochemical industries including nuclear industries due to its superior mechanical properties at high temperature. Components made of this variety of steel are subjected to non-uniform stress and temperature distribution during high-temperature service that produce localized creep damage leading to initiation and propagation of crack up to fracture. The Creep fracture is considered as one of the most dominant failure mechanisms for components operating at high temperatures and hence a priori knowledge of creep crack growth (CCG) behaviour of materials is important for designing of high temperature components in order to avoid unwanted failure due to creep. The objective of the present investigation is to understand the CCG behaviour of 316 L grade austenitic stainless steel and generate reliable CCG data for use in the design purpose of components made of this variety of steel.

The steel used in this investigation has been received in the form of 20 mm thick plate. Orientation imaging microscopy reveals that inverse pole figure (IPF) map of the investigated steel consists of polyhedral grains of austenite with some twins interspersed in some grains. From the IPF map the average grain size has been determined as 29 microns with a grain-to-grain misorientation criterion of 15°. In present study, initially tensile tests have been done at room temperature and also elevated temperatures of 873 and 923 K to study temperature dependent tensile deformation behaviour of the investigated steel. For this purpose, tests have been done at a constant strain rate of $10^{-3}\ sec^{-1}$ until fracture. Dynamic strain aging behaviour has been observed at these elevated temperatures. Constant load creep rupture tests have been carried out at 873 and 923 K over the stress range of 145 to 290 MPa. In total three tests have been done at each of these two temperatures. In this domain of creep rupture tests the maximum duration of the test is 11,747 hrs. at 923 K (applied stress: 145 MPa). The purpose of the creep tests is primarily to determine Norton exponents using power-law relationship between the minimum creep rate and applied stresses for both the temperatures.

CCG behavior of the steel has been investigated using C* parameter. CCG tests have been carried out under various applied load level (constant load condition) of 12 to 18 kN using compact tension (CT) specimens at of 873 and 923 K as per ASTM E1457-19. The creep crack growth rate ($\dot{a}$) vs. C^* [$\dot{a} - C^*$] plots, commonly expressed as $\dot{a} = D(C^*)^{\varphi}$ have been established at 873 and 923 K. Fracture morphologies near the crack tip show the typical intergranular mode of failure.

Keywords: Austenitic stainless steel; Creep; Norton exponent; Creep crack growth behaviour; Intergranular mode.

FAN_047

Failure Analysis Of Inter Shaft Bearing Of Aero Engine

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Abstract

The present abstract reports the failure analysis of inter shaft bearing of an aero-engine. The analyzed chemical composition of the inner race, outer race and the rollers were found to be made of high alloy bearing steel. The cage was found to be made of aluminum bronze. Microstructure and hardness of the outer race, inner race and rollers showed that the components were used in hardened and tempered condition. Microstructure of cage is a cast structure of alpha grains in a matrix of transformed eutectoid beta. Multiple cracks were mainly observed at sharp corners / section variations of the ribs, [1] in similar pattern towards one side. The multiple crack origins in the cage indicate that the cage might have been subjected to high momentary loads, exceeded the permissible loads or inadequate/poor lubrication, which is most likely due to imbalance on a single engine landing. The surface showed smooth fracture on three-fourth of the region while the remaining portion showed fibrous fracture. The sample showed beach marks initiating from one edge. The smooth fracture region revealed thumbnail features and fatigue striations at higher magnification. The final one-fourth area showing fibrous fracture features revealing dimples. The Inter shaft bearing failed due failure of cage. The cage failed due to fatigue, initiated at the sharp corners of the slots cut in the cage, which acts as stress raisers as evidenced by the site of initiation and fatigue features.

References

[1] Introduction to Physical Metallurgy by Sidney H Avner.

FAN_060

Analysis of failure in compressor blades of a helicopter engine

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Abstract

This paper presents the results of failure analysis conducted on a helicopter engine following an incident that occurred during engine computer matching after an engine replacement. The helicopter had twin engines, and during the incident, a loud bang was heard from the No. 1 engine, accompanied by debris ejection from the left side of the helicopter. Detailed examination of the disassembled engine revealed that out of the nine first-stage compressor (CR) blades, eight exhibited signatures of fatigue failure. The fatigue cracks were found to initiate at the blade root platform-to-blade airfoil transition fillet region on the concave side. Analysis of seven stage II CR-blades revealed fatigue crack propagation in five blades, with cracks initiating at the fillet region on both concave and convex surfaces. Examination of the crack origin regions indicated that the cracks initiated from corrosion pits present at the blade root platform-to-blade airfoil transition (fillet) region on the concave side. Multiple deep corrosion pits were observed in the vicinity of the fracture. This region on the concave side experiences maximum bending stress during engine operation and is highly susceptible to fatigue crack initiation. The presence of these stress concentrators due to pitting corrosion was determined to be the primary cause of fatigue failure in the stage I CR-blades. The resulting fatigue fracture in the stage I blades induced high-amplitude vibrations, which led to the failure of the stage II CR-blades by reverse bending fatigue. Therefore, the fatigue crack initiation, propagation, and fracture in the Stage II CR blades occurred subsequent to the Stage I blade failure and during the incident. The fatigue crack initiation and propagation in the stage I blades had developed over time before the incident. The fracture and dislodgement of the stage I and stage II CR-blades caused an imbalance in the rotor shaft, which imposed excessive load on the main roller bearing, leading to damage to all bearing elements and the fracture of the Sealol seal bellows. The generation of debris in the engine was a direct consequence of the fractures in the CR-blades and other dynamic and static components in the system.

Key words: fatigue, corrosion pit, stress concentration, stage I compressor blades

FAN_074

Metallurgical analysis of failure observed on 15-5PH stainless steel fixture during hydro pressure test

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Abstract

15-5PH (Fe-15Cr-5Ni-3.5Cu-0.4Nb) martensitic precipitation hardenable stainless steel was selected for fabrication of fixtures for pressure testing LOX-kerosene turbopump of liquid rocket engine. To meet high pressure test requirements, 15-5PH fixture was used in H900 heat treatment condition to achieve high strength. During hydro pressure test, leak was observed at 200 bar against targeted pressure of 285 bar. On opening of test fixture two through thickness cracks one at about 45° and another at ~35° to the split section were observed, as shown in Fig 1(a). Fractographic and microstructural analysis were performed on samples extracted from the failed fixture. Cleavage mode of failure was observed in fractographic analysis. Optical microscopic sample revealed presence of remnant cast structure which confirms improper thermo-mechanical processing of material used for fixture. Chemical composition, hardness, tensile and impact toughness properties were analysed on samples extracted from failed fixture. Due to presence of cast structure, achieved tensile and impact toughness properties were not meet the intended requirements. Photograph of the failed fixture, fractography of the fracture surface and optical microstructure of sample near failed portion are shown in Figure 1. This work describes efforts made to understand the reason for failure and suggest remedial measures to avoid reoccurrence.

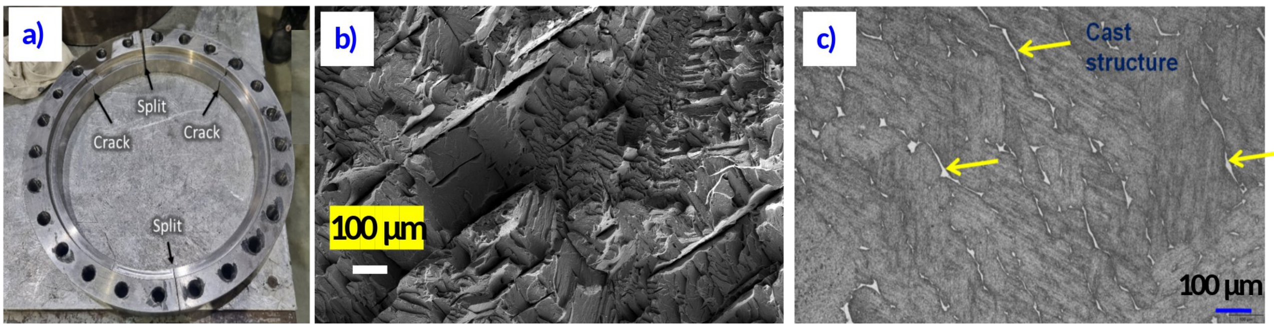

Fig. 1: Pressure tested failed fixture a) photograph, b) fractograph showing brittle failure and c) optical micrograph reveals presence of cast structure

Key words: 15-5PH, heat treatment, thermo-mechanical processing and pressure test

FAN_079

Failure Analysis of Weldment crack in Exhaust Duct Assembly of Jet Fuel Starter Unit

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Abstract

Weld joint cracks were detected on exhaust duct inner shell of Gas Turbine Starter Units, which serves as Jet Fuel Starter (JFS) for main engine of one type of combat aircraft. One such failed starter unit that had completed about 627 starts since new was taken up for defect investigation at the laboratory. Crack was observed along the circumference of the weld joint between the sub-parts *Shell-Inner* and *Ring-Inner* of the exhaust duct assembly (Fig.1). Visual examination and Fluorescent Penetrant Inspection showed that the weldment crack had extended almost ¾ of the circumferential length.

Shell-Inner is a sheet metal part and *Ring-Inner* is a forging. Both parts are made of Nimonic 75 material and are in annealed condition. Laboratory analysis revealed that material of construction (MoC) of the sub-parts *Shell-Inner* and *Ring-Inner* met the specified requirements with respect to chemistry, hardness and microstructure (heat-treatment condition).

Fractographic studies using Scanning Electron Microscope (SEM) of the crack (fracture surface) revealed that the exhaust duct had failed by *reverse bending fatigue*, wherein fatigue failure had originated at multiple locations from O.D. and I.D. surfaces of its inner shell.

Macro/ micro examination revealed that the weld joint between the sub-parts *Shell-Inner* and *Ring-Inner* was free from weld defects like porosities and inclusions. On the *Shell-Inner (Sheet)* side, the weld samples showed satisfactory fusion and penetration. However, on the *Ring-Inner (Forging)*-side, the weld bead showed insufficient fusion and penetration (Fig.2). This lack of fusion and penetration apparently caused notch effect that had acted as sites of stress concentration for fatigue initiation.

Systematic metallurgical investigation carried out to arrive at the cause of failure along the weld joint is described in the present paper. Also, remedial measures regarding the welding process and on the design of Exhaust Duct Inner Shell are discussed.

Keywords: Jet Fuel Starter, Exhaust duct assembly, Weldment crack, Reverse Bending Fatigue, Weld bead fusion and penetration

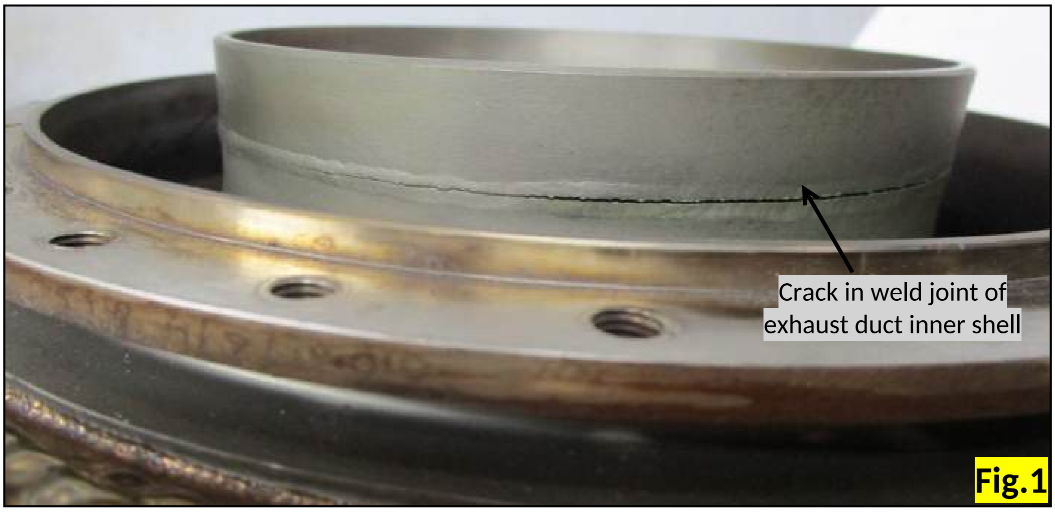

Fig.1

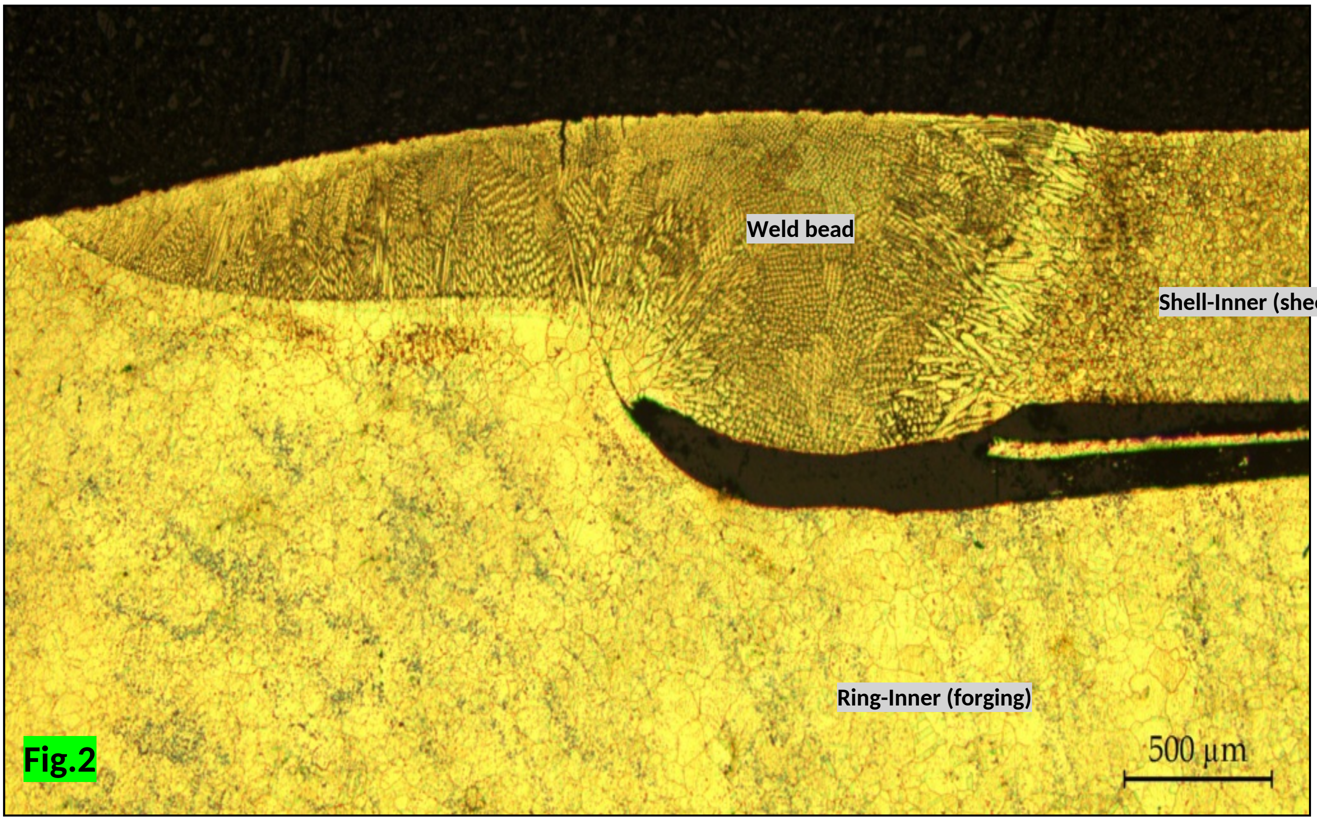

Fig.2

FAN_075

HIGH ENTRROPY

Oral abstracts

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Efficient Screening of Single-Phase Low-Activation High-Entropy Alloys

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Abstract

A large number of compositional degrees of freedom in the search for multi-component high entropy alloys (HEAs) gives rise to an exciting and still largely unexplored materials design space. Exploring the vast compositional space only by experimental means is a formidable task. Computational approaches can efficiently explore the compositional space at a lower time scale. Numerous computational strategies based on empirical models have been proposed which can distinguish the formation of disordered solid solutions (SS) and the combination of SS and intermetallic (IM) phases in multi-principle element alloys.

Motivated to design BCC single-phase quaternary/quinary HEAs in a chemical space constituted by seven low-activation metallic elements, an efficient screening strategy is demonstrated. A high throughput screening of HEAs is performed using thermodynamic modeling with a regular solution model and ab-initio computations. It is demonstrated that the binary regular solution model is enough for calculating the mixing enthalpies of equiatomic/non-equiatomic BCC quaternary/quinary HEAs. Compositionally distinct thirty-six as-cast quaternary/quinary HEAs are considered from the literature to benchmark the accuracies of the existing empirical models for predicting simple solid solutions HEAs. The empirical model φ proposed by Ye et al. provides a good balance in predicting the solid solution and intermetallic alloys with a high degree of accuracy among the models considered in this study. Based on high throughput screening of HEAs, several novel BCC single-phase quaternary/quinary HEAs are discovered and compositional ranges of low-activation elements are suggested where formation for single-phase is most probable. We believe the present study will accelerate the experimental design and development of low-activation HEAs for nuclear fusion/fission applications. We also emphasize that the efficient screening strategy demonstrated in this study is general in nature and can easily be extended to other chemical spaces.

Keywords: high-entropy alloys, high throughput screening, thermodynamic modeling, alloy design

CMS_065

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

PMA_01

Ultrahigh strength and ductile Lightweight High Entropy Alloy for Aerospace Applications

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Abstract

This study explores a novel low density (7.7 g/cm^3) $AlCrFeNiNb_{0.2}$ high-entropy alloy (HEA) designed for aerospace applications, exhibiting exceptional mechanical properties at both ambient and high temperatures. The HEA was fabricated using Vacuum Arc Melting followed by a series of thermomechanical processing. These processes aimed to optimize the microstructure, resulting in a unique combination of strength and ductility. The alloy was subjected to cold rolling (72%), followed by recrystallization at 1100°C for 90 seconds and aging at 800°C for 4 hours. CALPHAD diagram was used for optimizing heat treatment process and understanding the phase stability at various temperatures. The microstructural analysis, conducted using X-ray diffraction (XRD) and scanning electron microscopy (SEM), revealed a dual-phase composition of FCC matrix and L12 intermetallic precipitates. The presence of these coherent precipitates, including Ni_3Nb (Fig.1), contributed significantly to the alloy's mechanical properties. Room temperature tensile test (Fig.1) demonstrated yield strength of (YS) 1400 MPa, ultimate tensile strength (UTS) of 1900 MPa, and ductility 32%. Whereas, at 650°C YS of 900 MPa and UTS of 930 MPa was achieved. These results surpass the performance of many existing conventional and Ni-based alloys. The dual-phase FCC/L12 microstructure, plays a crucial role in achieving these superior mechanical properties. This HEA demonstrates a unique balance of high strength and ductility at both room and high temperatures, making it a promising candidate for high-temperature structural applications in the aerospace industry. The ability to tailor its properties through advanced thermomechanical processing further enhances its potential for meeting the demanding requirements of aerospace materials.

SPC_130

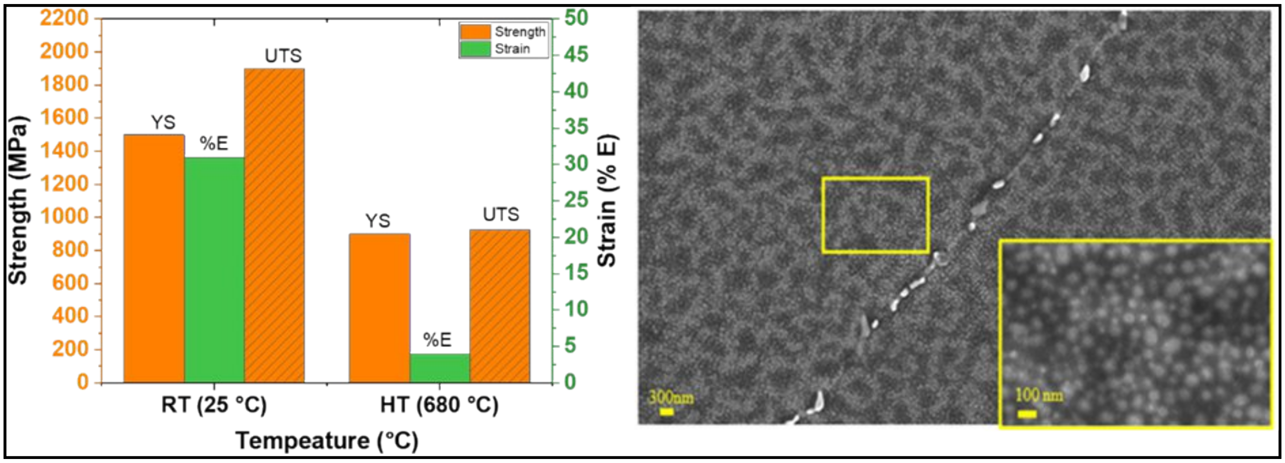

Fig. 1: Novel HEA with excellent tensile properties, high density ordered precipitation

Key words: High entropy alloy, strength and ductility, ordered precipitates, high temperature.

Microstructural engineering for achieving an outstanding strength-ductility balance in a novel high-entropy alloy

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Abstract

High-entropy alloys (HEAs) are an emerging class of materials with significant potential to broaden their applicability across various fields. Unlike traditional alloys, which are based on a single principal element, HEAs consist of multiple principal alloying elements. Among these, face-centered cubic (FCC) HEAs stand out for their exceptional balance of ultimate tensile strength and ductility at both room and cryogenic temperatures. Despite this, the yield strength of FCC HEAs tends to be relatively low, typically ranging below 400 MPa at room temperature. Consequently, achieving a combination of high yield strength (YS), ultimate tensile strength (UTS), and elongation in FCC HEAs remains a notable metallurgical challenge.

In this study**,** a novel non-equiatomic FCC HEA, CoCrMnNi has been developed, which demonstrates an exceptional combination of yield strength (YS), ultimate tensile strength (UTS), and tensile ductility. Remarkably, the YS of this new alloy surpasses 600 MPa, accompanied by effective work hardening to achieve a UTS of ~850 MPa. The alloy also exhibits a total elongation of approximately 100%, which is significantly higher than that of existing FCC HEAs. The alloy and heat treatment schedules were meticulously designed using CALPHAD-based thermodynamic predictions and parametric methods. The heat-treated alloy displays a hierarchical microstructure having an ultrafine FCC phase with multi-scale precipitates dispersed throughout the matrix. The stacking fault energy (SFE) of the alloy was experimentally measured as ~40 mJ/m² indicating a medium SFE class of alloy. Deformation of the alloy was predominantly characterized by dislocation slip, with minor twinning-induced plasticity activation. A detailed structure-property correlation is presented to explain the lucrative mechanical properties of the alloy at room temperature.

Keywords: High-entropy alloy, strength-ductility trade-off, stacking fault energy, precipitates

SPC_079

Effect of novel hybrid-rolling on the microstructure development and mechanical properties of an extremely low-stacking fault energy FCC high-entropy alloy (HEA)

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Abstract

An extremely low-stacking fault energy (SFE) FCC high-entropy alloy (HEA) $Cr_{26}Mn_{20}Fe_{20}Co_{20}Ni_{14}$ (SFE ~ 3.5 mJ/m^2) was synthesized by warm-rolling (WR) and novel hybrid-rolling (HR) (initial cryo-rolling $\frac{\varepsilon_{true}}{2}$, followed by warm-rolling $\frac{\varepsilon_{true}}{2}$), to explore the possibility of tuning nano/ultra-fine-grained microstructure, with exceptional mechanical properties. Severe deformation (90% reduction in thickness, $\frac{\varepsilon_{true}}{2} = 2.4$) has resulted in a finer nanostructure with a higher amount of Cr-rich σ-precipitates ($\tilde{d}$ = 100 nm, $V_\sigma = 27\%$) in HR-processed material as compared to its WR counterpart ($\tilde{d}$ = 130 nm, $V_\sigma = 22\%$), cobborating the finer microstructure and larger stored energy/driving force during the prior cryo-rolling step of HR. Annealing at 700°C resulted in fully recrystallized and equiaxed microstructures with ultra-fine grains and profuse precipitation. HR material exhibited finer grain size and a higher fraction of in-grain precipitates ($\tilde{d} = 1.3 \pm 0.6\ \mu m$, $V_\sigma^{IG} = 14\%$), than the WR-processed material ($\tilde{d}$ = $1.6 \pm 0.5\ \mu m$, $V_\sigma^{IG} = 6\%$). Appreciable strength-ductility (yield strength (Y.S) ~ 1.1 GPa and ductility ~ 20%) balance has been achieved in HR-annealed material due to finer grain size and higher amount of in-grain precipitates, which enables the pathway to design futuristic structural materials with robust properties.

Keywords: high entropy alloys; stacking fault energy; deformation; recrystallization; mechanical properties

SPC_086

Development of high strength and ductile $Fe_{49}Mn_{30}Co_{10}Cr_{10}C_1$ 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) $Fe_{49}Mn_{30}Co_{10}Cr_{10}C_1$ 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 $Fe_{49}Mn_{30}Co_{10}Cr_{10}C_1$ 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.

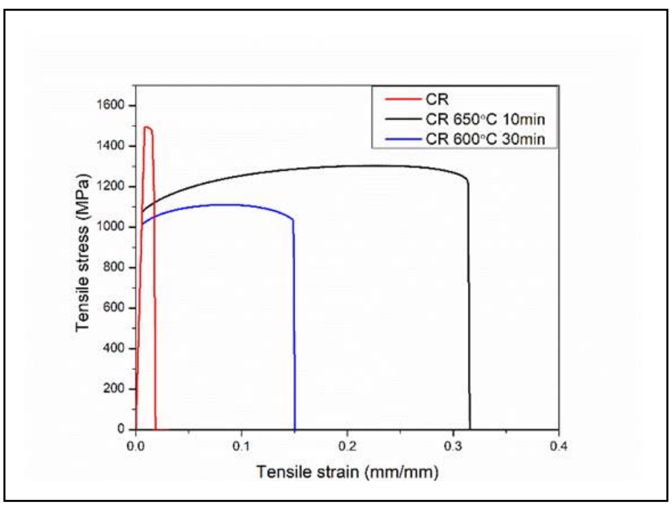

Fig. 1: Tensile stress-strain curves of the $Fe_{49}Mn_{30}Co_{10}Cr_{10}C_1$ MEA in different condition.

Key words: Medium-entropy alloy, Carbon, Interstitial alloying, cryo-rolling, Transformation-induced plasticity.

SPC_085

Short-range order in multicomponent alloys: Cluster Expansion - Cluster Variation Method formulation and application to High Entropy Alloys

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Abstract

In the present work, the cluster expansion (CE) Hamiltonian for multicomponent alloy systems is developed to facilitate the inheritance of cluster expansion coefficients (CECs) of lower-order alloy systems to higher-order ones. This is similar to the extrapolation methods used in CALPHAD. Correlation functions based on cluster variables constitute a complete basis set of functions for the description of the configurational state of the system. They also directly yield estimates of Warren–Cowley short-range order (SRO) parameters. Such basis sets are developed for the fcc, bcc, and cph solid solution phases. The multicomponent CE Hamiltonian is coupled with the configurational entropy obtained from the cluster variation method. The number of CECs, which are the model parameters, is only slightly more than that in the conventional CALPHAD description. The equilibrium state of the system is obtained by using an algorithm proposed by Hillert, which avoids the additional steps of separate minimization of Gibbs energies of individual phases. Further, the SRO parameters, which are the internal configurational variables, get evaluated separately for each phase along with the phase equilibrium calculation making the procedure efficient.

This formulation has been used to investigate the dependence of chemical ordering in HEAs as a function of temperature due to the deviation of configurational entropy from that of an ideal solution. SRO parameters are obtained for a quaternary bcc alloy system. This theoretical formulation is used to investigate the evolution of the twelve distinct SRO parameters in the Nb-Ti-V-Zr system and its ternary subsystems. CECs for the binary and ternary subsystems were obtained by thermodynamic assessments using all the available experimental data. The computed multicomponent SRO parameters facilitate a better understanding of the evolution of SRO in these alloys.

CMS_036

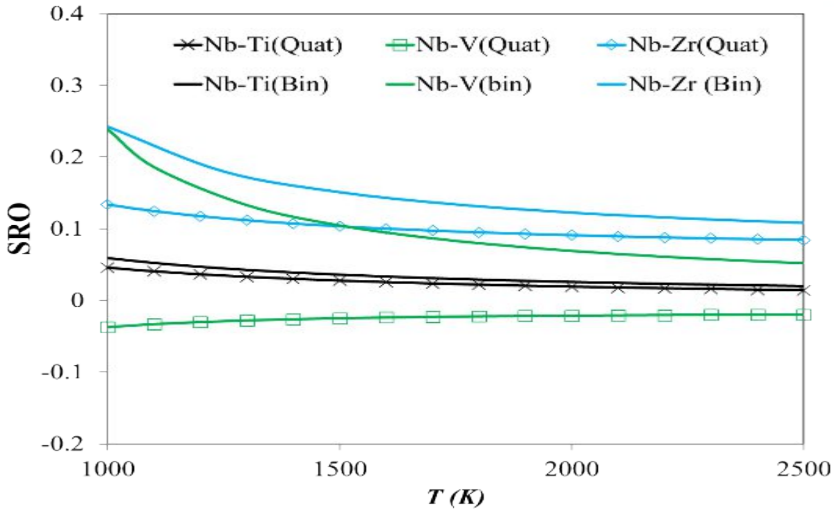

Fig. 1: Comparison of Cowley–Warren first neighbor sro parameter for Nb-V, Nb-Ti, and Nb-Zr pairs in the equimolar HEA Nb-Ti-V-Zr and in the corresponding binary system.

Keywords: CALPHAD, Cluster Expansion, Clauter Variation Method, HEA

Design and Development of Ti-Zr-Nb-based Refractory High Entropy Alloys for Biomaterial Applications

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Abstract

In these studies, four refractory high entropy alloys (RHEAs) TiZrNbFeMn, $Ti_{40}Nb_{20}Zr_{10}Fe_{20}Mn_{10}$, $Ti_{40}Nb_{20}Zr_{15}Fe_{15}Mn_{10}$, $Ti_{40}Nb_{20}Zr_{15}Fe_{10}Mn_{10}Cr_{05}$ were designed and prepared using the vacuum arc melting (VAM) for implant applications. Accordingly, the structural, microstructural, thermal stability, mechanical, biocompatibility and anti-bacterial aspects in these RHEAs were investigated by X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), differential scanning calorimetry (DSC), micro indentation, in-vitro cell culture (MG-63 cell) and anti-bacterial (s-aures and E-coli) techniques. The phase formed in the as-cast RHEAs were mostly consisting of BCC (a = 3.302 Å) and Laves phase (C14). The RHEAs were exhibiting microhardness and elastic modulus in the range of 8-10 GPa, and 127-150 GPa, respectively. These RHEAs showed excellent in-vitro biocompatibility and better antibacterial resistance as compared to Ti-6Al-4V and Ti-13Nb-13Zr alloys. Based upon these properties, the RHEAs, show a promising potential for implant applications, suggesting further study of such implants RHEAs.

Keywords: Refractory High Entropy Alloy; Microhardness and Elastic modulus; In-vitro biocompatibility, Antibacterial Properties.

BSF_020

Development of a Lightweight High Temperature High Entropy Alloy with Unmatched Strength, Ductility, Wear and Oxidation Resistance

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Abstract

Developing a light weight, high-temperature materials with superior strength, ductility, wear, and oxidation resistance is crucial for advanced engineering applications. In this work, we designed a novel light weight (7.67 g/cm^3) ($FeCoNiAl_5Ti_8$) high entropy alloy (HEA) by vacuum arc melting followed by thermomechanical processing. The results show exceptional properties at room temperature and up to 700°C. The HEA demonstrates excellent wear rates of 1.5×10^{-5} mm^3/Nm at room temperature, 1.5×10^{-6} mm^3/Nm at 600°C, and negligible wear at 700°C (Fig. 1), attributed to a protective tribo-oxide layer that prevents metal-to-metal contact. This layer stabilizes at elevated temperatures and high speeds, as confirmed by SEM, EDS, and XPS analyses. Isothermal oxidation studies at 1000°C for 100 hours reveal an extraordinary oxidation rate of 4×10^{-13} g^2 s^{-1} cm^{-4} (Fig.1). Room temperature tensile tests show a yield strength (YS) of 1100 MPa and an ultimate tensile strength (UTS) of 1300 MPa with 23% ductility, while at 650°C, the YS is 800 MPa (Fig. 1). These properties are attributed to the coherent nano-lamellar architecture forming FCC/L12 lamellae, with L21 nanoparticles, as confirmed by STEM. The unique nano lamellar FCC/L12 structure in this HEA surpasses conventional alloys, offering new opportunities for developing light weight ultra-strong oxidation and wear resistant materials for high-temperature applications. In summary, the novel HEA developed in this study exhibits superior properties at both room and elevated temperatures, making it a promising candidate for high-temperature structural and aerospace applications. The ability to tailor its properties through thermo-mechanical processing further enhances its applicability, providing a versatile material for advanced engineering challenges.

MSD_046

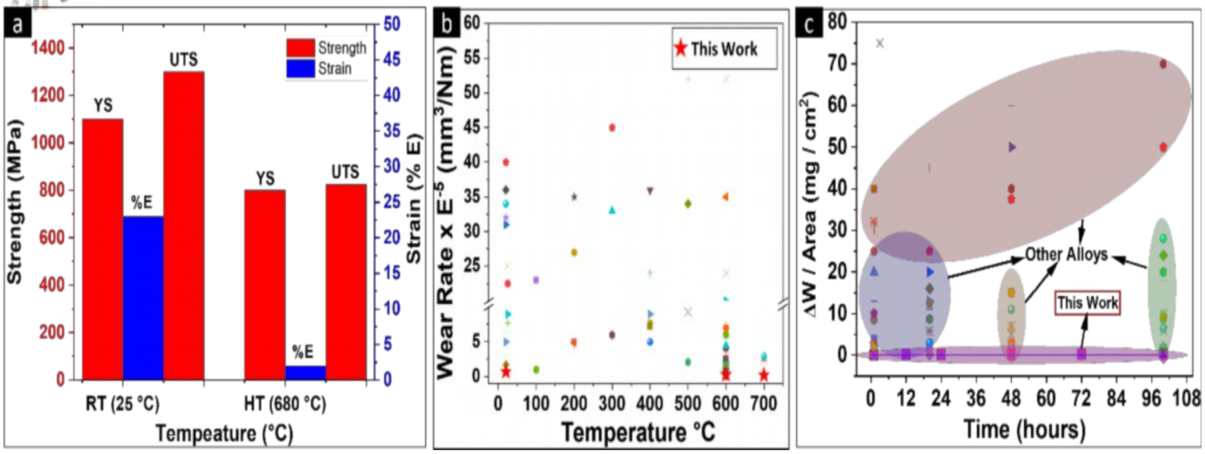

Fig. 1: Trifecta of (a) strength, (b) wear and (c) oxidation resistance in ($FeCoNiAl_5Ti_8$) HEA

Key words: High entropy alloy, wear resistance, oxidation resistance, strength and ductility, high temperature.

Exploring FCC+L1$_2$ based medium entropy alloys for potential high temperature applications

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Abstract

Two Ni-Fe-Cr-Al based compositions were designed using the CALPHAD approach to ensure a γ-γ′ (disordered face centred cubic + ordered L1$_2$ i.e., FCC+L1$_2$)-based microstructure. The designed compositions were melted using commercial grade elements in a vacuum induction melting facility. Post homogenization treatment, both the designed alloys were cold deformed to investigate the static recrystallization kinetics of the alloys at an optimized recrystallization temperature. A heterogeneous microstructure was designed in the deformed specimens based on nil recrystallization, partial recrystallization and complete recrystallization phenomena. All the specimens were aged at 600°C for 5 h. Excellent room temperature mechanical properties were obtained for both the designed alloys with an ultimate tensile strength (UTS) of > 900 MPa and an impressive ductility (TE) of >50 % for >90 % recrystallized and aged specimens. This process condition was also evaluated for high temperature mechanical properties at 450°C, 600°C and 700°C where both the alloys exhibited serrated flow behavior at 450°C with UTS of > 800 MPa and an appreciable ductility of >35 %. Furthermore, the alloys showed a UTS of ~700 MPa and a ductility of >20 % at 600°C. This was followed by softening behavior in both alloys at 700°C. The role of primary carbides formed in the alloys, due to usage of commercial grade elements, was also assessed in the fractured tensile specimens.

Moreover, as the upper temperature limit for possible high temperature applications of the designed alloys is 600°C, the coarsening behavior of the L1$_2$ precipitates was assessed using both experimentally obtained results and thermodynamic and kinetic based simulations. The studies showed a sluggish precipitation kinetics at 600°C in both the alloys. This evaluation also suggested that the designed alloys should be explored further as potential candidate for high temperature applications.

Keywords: Medium entropy alloys, recrystallization kinetics, high temperature properties, coarsening kinetics

SPC_012

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

PMA_009

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.

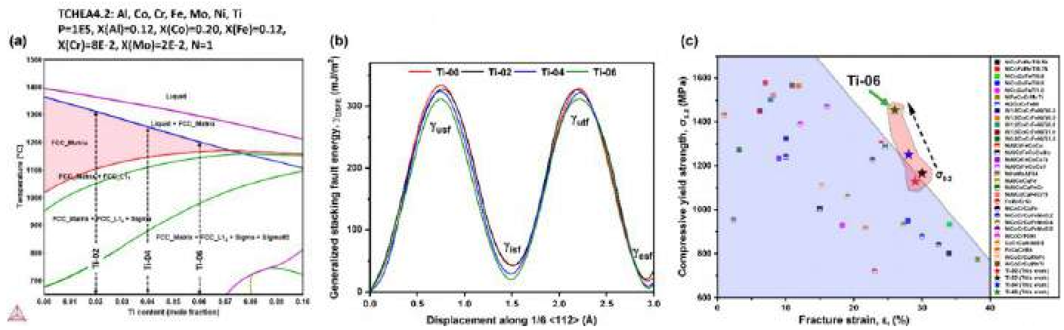

Fig. 1: (a) The pseudo binary phase diagram of the (NiCoAlCrFeMo)-Ti alloy system, (b) generalized-stacking fault energy of FCC {111} <112> slip of $Ni_{46-x}Co_{20-x}Al_{12}Cr_8Fe_{12}Mo_2Ti_{2x}$ (x = 0, 1, 2 and 3) HEAs and (c) comparison of the compressive properties of the present alloys with other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

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

"Designing High entropy Shape Memory Alloys: Leveraging High-Entropy Alloy Principles"

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Abstract

The limited thermal stability and operational temperature remain a challenge to the potential applications of Shape Memory Alloys (SMA) in high-temperature applications. The design of multi-principle element SMAs based on High Entropy alloys (HEA) design criteria could lead to significant improvements in thermal stability and cyclic superelastic or actuation response in extreme environments. Empirical rules are most widely used for designing of HEAs. Some of the key rules are entropy of mixing, atomic size difference, enthalpy of mixing, valence electron concentration, and electronegativity difference.

Establishing similar guidelines for shape memory alloys (SMAs) can significantly accelerate the pace of discovery for new SMAs by narrowing down the search area within the vast compositional design space of multicomponent alloys. In this study, we compiled data on high-entropy shape memory alloys and utilised the compositional features of the alloy calculated from chemical compositions to correlate with transformation temperature. Number of electrons (ev) and valence electron concentration (Cv), average atomic number (Z), entropy of mixture are considered and a more comprehensive map of transformation temperature vs compositional features are constructed. The correlations are further used to formulate empirical rules for categorizing reported High Entropy Shape Memory Alloys (HESMAs) and to guide the design of new alloys.

Keywords: High entropy shape memory alloys, transformation temperatures, compositional features.

BSF_067

Study of electrocatalytic behaviour of FeCoNiAlTi based high entropy alloys for water splitting

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Abstract

The exploration of renewable energy has aroused extensively due to its effectiveness in solving the fossil energy crisis and greenhouse effect. Hydrogen has been investigated as a replacement energy source to increase the renewable energy momentum and reduce emissions. Study of mechanism behind the hydrogen evolution reaction (HER), oxygen evolution reaction (OER), and overall water splitting facilitates the development of augmented electrocatalyst. The investigation of electrocatalytic behavior of high entropy alloys (HEAs) is essential to understand the role of each element in effective water splitting. In this work, the investigation of the electrocatalytic behavior of FeCoNiAlTi HEA with and without Cr addition was carried out. The alloys were fabricated through arc melting and the microstructure was characterized using scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. Electrochemical analysis such as electrochemical impedance spectroscopy (EIS), linear sweep voltammetry (LSV), and potentio-dynamic polarization tests were conducted to evaluate the electrocatalytic behavior and corrosion rate of the alloys. The LSV tests were conducted in acidic medium (0.5M H_2SO_4) with a scan rate of 5mV/sec in a potential range of 0 to -1.5 V for HER, and a potential range of 0 to +1.5 V for OER. The overpotentials obtained at current density 10 mA/cm^2 for the HEA with Cr and without Cr in HER are 475 mV and 523 mV respectively and the overpotentials in OER are -36mV and 115mV respectively. The result indicates the alloy with Cr shows relatively better performance in HER and OER. The HEA with Cr exhibits excellent electrocatalytic behavior for OER. This may be attributed to the formation of Cr_2O_3 which acts as a lewis acid that attracts more hydroxyl ions to the electrode to facilitate the oxygen evolution reaction.

Keywords: Electrocatalyst, High Entropy Alloy, Water splitting, HER and OER reactions

CEB_041

Effect of Thermal Processing on the Flow Characteristics of Equi-Atomic AlCoCrFeNi High-entropy Alloys synthesized through mechanical alloying for Additive Manufacturing

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Abstract

The effectiveness of additive manufacturing (AM) is highly dependent on the flow characteristics of metal powders, namely their sphericity, circularity, and roundness. This research examines the influence of thermal processing on the flow characteristics of equi-atomic AlCoCrFeNi high-entropy alloys (HEAs) powders, produced by mechanical alloying. The study investigates thermal treatments such as annealing in inert environment to improve the flowability in terms of circularity and roundness of powder by altering particle shape and lowering the thickness of surface oxides. In addition, subjecting the material to heat treatment cycles in an inert atmosphere at temperatures ranging from 300°C to 700°C for a duration of 1-hour results in a progressive rise in circularity as the temperature increases up to 700°C. However, the roundness of the material is mostly unaffected by these temperature variations. Upon further increasing the temperatures up to 1200 °C, may cause a decrease in particle size, leading to a gradual decrease in circularity. Increasing the duration of heat treatment at elevated temperatures often reduces the roundness and circularity, with a more noticeable impact at higher temperatures. The study also determines that the temperature range of 650°C to 975°C is necessary for the production of sigma phase, which is a transition from the cubic phase to a tetragonal closed-packed structure. The diffusionless martensitic transition increases the yield strength of the material as well as decreases the depth of deformation during ball milling, which encourages the development of spherical particles.
The objective of optimising these thermal processing settings is to enhance the flow dynamics in terms of high powder sphericity, purity, and a narrow size distribution, of the powder during additive manufacturing (AM). It heavily impacts on the density of coating layers, precision in forming, and uniformity of microstructure, resulting in improved packing density and reduced porosity in the final produced components.

Keywords: Additive manufacturing, high-entropy alloys, mechanical alloying, thermal processing, powder flowability.

IRON AND STEEL MAKING

Oral abstracts

Brucite as an Alternative Flux in Blast Furnace to Improve Productivity, Fuel Rate and CO2 Emission

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Abstract

Currently, the most common fluxing additive as a source of MgO for blast furnace are- Dolomite (CaCO3 · MgCO3) with chemical composition as MgO: 20%, LOI: 40% (Release CO2 on Decomposition) and Pyroxenite (MgO.SiO2) with chemical composition as MgO: 35%, SiO2: 35%. Brucite is a mineral of Magnesium Hydroxide (Mg (OH)2) with MgO content 55-58% and release H_2O on heating. Brucite has the advantage of not containing CO_2 released during calcination, a positive feature for today regarding climate change. Brucite mineral provides excellent opportunity to reduce slag rate of blast furnace and productivity as compared with Dolomite and Pyroxenite as Magnesium Oxide content is 3 times higher in Brucite. By charging Brucite instead of Pyroxenite or Dolomite, Fuel Rate & CO2 Emission can be reduced in blast furnace. G Blast Furnace of Tata Steel- Jamshedpur, conducted trial of Brucite charging for twice as an alternative source of MgO and result were promising. Use of Brucite (@ 8 Kg/THM & 6 Kg/THM (whereas in base period Pyroxenite was running @ 23 Kg/THM & 13 Kg/THM) which leads to decrease of 25 Kg/THM and 12kg/THM in slag rate during both phases of trial. Reduction of normalized Fuel Rate observed 2 Kg/THM & 2 Kg/THM during trial along with healthy & stable movements in Belly and Bosh Zones of blast furnace, all important KPIs (Permeability Resistance, Hot Metal Temperature etc) were within the acceptable range.

	Unit	Base Period-1	Phase-1 Trial	Base Period-2	Phase-2 Trial
Pyroxenite	Kg/THM	23	-	13.6	-
Brucite	Kg/THM	-	9	-	6.3
Sinter & Pellet	%	54 & 42	52 & 46	54 & 42	52 & 46
Slag Rate	Kg/THM	342	317(-25)	325	313(-12)
MgO	%	9.42	9.60	10.07	10.23
Al2O3	%	18.13	19.24	18.80	18.57
Basicity		1.10	1.13	1.14	1.15

Fig.1: Burden and Slag Analysis Parameters

	Unit	Base Period-1	Phase-1 Trial	Base Period-2	Phase-2 Trial
Production	Ton/Day	6292	6191	6359	6465
Coke Rate	Kg/THM	338	327	326	318
Coal Rate	Kg/THM	205	205	203	208
Normalized Fuel Rate	Kg/THM	539	537(-2)	529	527(-2)
CO2 Saving	Kg/THM	0	7	0	7

Fig.2: Impact of Brucite addition in Key Parameters

Key Words : Brucite, Pyroxenite, Dolomite, Slag Rate, Fuel Rate, CO2 Emission

ISM_011

Productivity Improvement at Blast Furnace-02 in JSW Dolvi

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Abstract

This abstract presents a detailed analysis of the factors contributing to achieve high productivity of 3.3 t/m^3/d in Blast Furnace-02 of JSW Steel Dolvi, which has a working volume of 4521m^3(largest in India), a hearth diameter of 13.2 meters equipped with 04 tap holes and 42 tuyeres. Major impeding parameters for achieving highest blast furnace productivity were facilitated by the introduction of centre coke charging, high pellet operation, improved quality of raw material, minimum flux rate, and meticulously maintained slag ratio above 90%. After commissioning, Blast Furnace-02 faced various hurdles such as high heat load, poor permeability, frequent burden slippage poor slag ratio and high fuel rate. Modifications were done such as centre coke charging by Optimizing burden distribution based on burden distribution model, profilometer and top camera to stabilize gas flow inside the furnace enabling control in high heat load variation. Also, by increasing the flow rate of raw material from stock house to furnace to overcome the level loss inside the furnace. Additionally, improvements in physical and metallurgical properties of sinter, pellet, and coke contributed to maintain good permeability inside the shaft. Lastly, adhering to best tapping practices i.e., changing in drill bit diameter and increase of mudgun nozzle diameter, enabled us to achieve quick liquid evacuation. Blast Furnace-02, operate with high pellet operation upto 70% in the burden. The adoption of a minimum flux rate approach was also crucial. Since commissioning, slag rate was 420 kg/thm due to higher gangue input in raw material, limiting our target for higher productivity. By producing super-fluxed sinter, limestone addition reduced by 90% and fuel rate was also reduced by 4.5%.

From all these improvements we finally achieved a productivity of 3.30 t/m^3/d till date.

ISM_057

Blast Furnace Coke Consumption reduction through hot metal Si Reduction from 0.72% to 0.60%

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Abstract

During the production of molten iron, via a reduction process in a blast furnace, along with iron, some impurities also get into the hot metal such as silicon, Phosphorous, and Sulphur. The silicon extracted from iron bearing material goes out in slag as SiO2, but some amount of Si remains there in hot metal, whose major contribution components are PCI and Coke. Silicon content in hot metal varies across the furnaces in TSL in the range of 0.4 to 0.80%. TSM BF2 is maintaining a hot metal content between 0.70% to 0.72%. While higher Silicon levels can be adverse, an optimal silicon amount is crucial for the oxidation process in steel making, as it generates necessary heat. The TSM BF-2 has reduced its Si content in hot metal from 0.72 to 0.60% by stable operation of the furnace process, which was accomplished by optimium RAFT, which resulted in the restraint of SiO gas formation, Higher slag B2, raw material quality reduction in coke ash and coal ash % helps in reduction of Si ingress in hot metal. Apart from that, through digital initiatives like deployment of the silicon prediction model for early indication helps in process optimization. Such a holistic approach has cut down on our carbon footprint in TSM BF2, driving it towards a more sustainable future.

Keywords: Silicon, Coke rate, Carbon footprint, Hot metal quality

ISM_107

Blast Furnace process optimization for sustainable Iron making

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Abstract

The JSW Steel Ltd, Salem plant, a 1.15 MTPA integrated special alloy steel facility, operates two Mini Blast Furnaces (BFs) with useful volumes of 402m³ and 640m³. Maintaining stable and efficient operation of these Blast Furnaces is essential for reducing fuel consumption, which directly impacts greenhouse gas (GHG) emissions. This study investigates various theoretical and practical approaches to lowering the fuel rate in the Blast Furnaces. Through technical research and statistical analysis, several opportunities for fuel rate reduction were identified. Based on these insights, a series of actions were implemented, including optimizing burden distribution by developing a burden distribution model and by using advanced gadgets like acoustic sensor and Furnace top camera, reducing fines input by modifying screens and externally screening of raw materials, improving casting practices, and enhancing maintenance protocols. These improvements resulted in a significant reduction in fuel consumption, which, in turn, led to a decrease in GHG emissions.

Key words : Blast furnace process optimization,

Development of a DeS Simulator for external desulphurisation of blast furnace hot metal by powder injection

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Abstract

Sulphur is an undesirable element in steel owing to its serious impact on mechanical properties and leading to hot shortness during hot rolling. Sulphur originates primarily from the coke used in the blast furnace (BF). Sulphur removal in blast furnace is restricted due to thermodynamic and operational conditions, even though conducive environment does exist in the furnace. Favorable conditions for sulphur removal do not exist in the basic oxygen furnace (BOF)(due to oxidizing environment), so an intermediate operation, external desulphurization of blast furnace hot metal by powder injection is a well-established process practiced worldwide. The process involves chemical reactions between injected fluxes and dissolved S in hot metal. In this regard, co-injection of Mg and CaO, with N_2 as a carrier gas, is widely practiced. In desulphurization (De-S) stations, considerable uncertainties exist about the optimized ratio of these fluxes which should be added for a given set of input and output conditions. Models developed from a mechanistic viewpoint have an edge over the regression-based approach, since they provide insights about reaction mechanisms and can also be used for prognosis of future scenarios different from the conventional operation. In this work, a kinetic model for the external De-S process by powder injection has been developed from a fundamental viewpoint. This model is developed using two approaches– the first is a reaction interface approach developed using MATLAB and the other utilizes a FACTSAGE-based effective equilibrium reaction zone (EERZ) approach. The MATLAB based approach considers contribution only from the transitory reaction zones while the FACTSAGE-based approach considers both the transitory and the permanent contact reaction zones. The developed kinetic model can predict compositional evolution of a wide range of hot metal and top slag chemistries during the external De-S process. Model predictions have been tested with sampled plant trials and laboratory-scale injection data, published in the literature, and reasonable agreement between the two could be obtained. Furthermore, the model has been simulated for some futuristic scenarios and it can serve as a guide for optimizing the flux consumptions in external De-S of newer and challenging hot metal chemistries.

Keywords: Sulphur; Blast furnace; Effective Equilibrium Reaction zone; External Desulphurisation; Process Modelling

ISM_165

High productivity operation of blast furnace – Technology to increase productivity and reduce carbon emissions.

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Abstract

Productivity of the blast furnace is defined as tons/day/m3. Productivity is directly linked with the efficiency of the blast furnace, more the productivity more the efficiency. In this subject use of Direct Reduced Iron (DRI) is a promising solution to increase the productivity and decrease the fuel rate, hence reducing the carbon emissions. Charging DRI in the burden has an impact in the process like lowering of top gas temperature, decrease in bosh and belly wall temperatures, lowering of gas utilization (Eta CO). In Tata steel F blast furnace charging of DRI at 10% is done which is an Indian benchmark. This DRI charging resulted in fuel rate of less than 500 kg/thm and coke rate as low as 285 kg/thm, (lowest among Indian blast furnaces) and an increase in productivity of 0.2 tons/day/m3. In this paper we will be getting into the details of process controls, like burden distribution, heat loss control, maintaining lower wall temperatures with higher percentage of DRI in the burden.

Keywords: Direct Reduced Iron (DRI), Productivity, Fuel rate, Decarbonization.

ISM_153

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

ESU_149

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

Enhancing Efficiency of Hot Metal Desulphurisation through Advanced Kinetic Modelling

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Abstract

Ultra-low Sulphur steel is essential for various critical applications, such as line pipe and electrical uses. The residual Sulphur in hot metal is removed during hot metal pretreatment, which currently has a relatively low efficiency of 15-20%. Hot metal desulphurization (DS) depends on factors like carryover slag weight and composition, hot metal composition and temperature, reagent injection rates, lance depth, gas injection flow rate, and the condition of desulphurization equipment. The overall process of desulphurization is governed by flow conditions as well as chemical reactions. Hence, there is a need to combine the fluid flow and chemical reaction.
In this study, a kinetic model is developed primarily using the concept of effective equilibrium reaction zone approach in which automated equilibrium calculations are performed using macro feature in FactSage^{TM}. The fluid flow related parameters such as mass transfer coefficients are estimated using existing correlations in the literature. In this approach, hot metal desulphurization vessel is divided into three reactors, and based on the reactions in each reactor, the overall composition of hot metal changes. The calculated Sulphur removal from the model is in close agreement with the plant measurements and model calculations reported in literature. Further, the kinetic model is used to study operating conditions that can improve overall efficiency of the hot metal desulphurization. It was observed that the desulphurization rate increases with the presence of elements such as silicon, carbon, and aluminium, and that desulphurization is favored at higher temperatures. Gas flow rate, flux injection rates, and injection time interval also significantly influence the process.
Additionally, slag characteristics impact desulphurization efficiency. Powdered slag samples, obtained from the steel plant were analyzed to understand the post-desulphurization conditions. This analysis provides further insights into the parameters used in the model. This innovative model offers a valuable tool for identifying optimal processing conditions, improving industrial practices, and enhancing the overall efficiency of sulphur removal from hot metal at a lower cost.

Keywords: Kinetic model, Desulphurisation, Factsage, efficiency of DS reagent, hot metal

ISM_055

Co-firing of agro-residue with coal in DRI production to reduce carbon footprints

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Abstract

This work highlights the measures taken in the sustainability direction to replace coal with biomass, resulting in co-firing with 5 to 10% replacement of coal in iron and steel production plants. This work is being carried out between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, and the Indian Institute of Science (RESCONS Solutions Pvt. Ltd), Bangalore, under the Australia-India Green Steel Program. The procedure involves locating the Direct Reduced Iron (DRI) plant in India and exploring the agro-residue and municipal solid waste availability in each of the districts of that state and quantifying them. The approach of the Urban Local Bodies (ULB) in managing solid waste as Micro Composting Centre (MCC) for wet waste and Material Removing Facilities (MRF) for dry waste is studied in order to know the utilization of the waste [1]. The usage of agro-residue as fuel is decided on the basis of the maximum quantity of the crop being grown in the corresponding state, and its properties are also compared with coal. The analysis is also carried out on the distance between the agro-residue source and the DRI plant to arrive at a decision that would be optimal in terms of the transportation cost, energy spent during transportation, and the CO2e emissions during transportation. As a part of the analysis, the proximate and ultimate analysis of the agro-residue is carried out and compared with coal. Biomass, mainly rice husk and rice straw pellets, are prepared and used in the downdraft gasifier to produce syngas of various compositions for the reduction of iron oxides. These results form a benchmark for replacing coal in coal gasification to produce syngas, which can be used either in shaft-based furnaces or rotary kilns to produce DRI. This would mark a remarkable step towards reduction in pollution and improving the environment.

Keywords: DRI, Syngas, Carbon Footprints, Gasification, Sustainability

Reference:

[1] Audit Report of the Comptroller and Auditor General of India Performance Audit on Waste Management in Urban Areas, Government of Odisha, 2022.

ESU_129

Utilizing Bio Char as an alternate & sustainable fuel source in DRI Production for lowering Carbon emission

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Abstract

This project introduces biochar as a sustainable substitute for coal in Direct Reduced Iron (DRI) production, focusing on reducing carbon emissions in the steel industry. With steel production contributing significantly to global CO_2 emissions, our company has committed to achieving Net Zero emissions by 2045. Biochar, derived from biomass via anaerobic pyrolysis, offers a carbon-neutral solution by capturing CO_2 that would otherwise be released during combustion.

The project conducted a comprehensive trial from December '22 to August '23, culminating in a final report by September '23. Key challenges included understanding biochar's chemical kinetics at high temperatures, handling its lower density compared to coal during kiln feeding, and establishing a reliable supply chain.

Results showed promising outcomes: replacing coal with biochar up to 30% reduced CO2 emissions by 37%. Biochar's higher reactivity in the kiln improved carbon utilization and product quality, evidenced by reduced sulfur content in the DRI output.

Future plans involve scaling biochar usage, sourcing from multiple vendors, and enhancing logistical infrastructure. This initiative aims not only to mitigate environmental impact but also to set a precedent for sustainable practices in the steel industry, contributing to global efforts in combating climate change.

Key words: Carbon Emission, Anaerobic Pyrolysis, Reactivity, Carbon Utilization, Biochar, Biomass

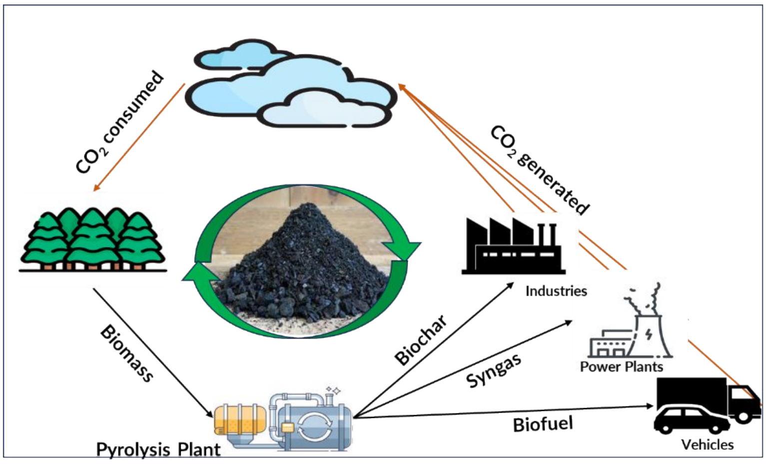

Fig 1: The CO_2 cycle in the generation & consumption of biochar

MPR_325

Maximising and sustaining high PCI rates in blast furnace

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Abstract

Pulverised coal injection is the key enabler to increase the productivity of a blast furnace. Currently all the blast furnaces are equipped with coal grinding and injection facility. Coal injection gives one to one replacement ratio with coke in blast furnace. Increasing coal injection has operational challenges like poor replacement ratio, increase in furnace resistance, increase of tuyere burning instances etc. In TATA Steel we have successfully achieved and sustained injection rates of more than 200 kg/thm through modification in operational philosophy and incorporating design changes. In this paper we will be getting into the details of changes in operational philosophy, process control with high injection rates and design changes in the hardware to sustain high injection rates.

Keywords: PCI, Productivity, High injection rates.

ISM_151

Improving MIDREX Furnace Performance with Low Total Fe Pellets: Real-Time Monitoring and Optimization Strategies

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Abstract

The production of Direct Reduced Iron (DRI) using a MIDREX furnace presents several operational challenges, particularly when utilizing low Total Fe pellets. These challenges include maintaining stable bed movement, optimizing process gas flow, and controlling gas temperatures and composition within stringent parameters. Additionally, the speed of burden feeders and the clustering of materials within the furnace further complicate operations, impacting overall productivity and efficiency. To address these issues and enhance productivity, advanced process control (APC) strategies have been deployed. These strategies involve precise control of critical furnace parameters and reforming parameters, determined through collaboration with technology providers, experienced operators, and regression analysis of significant process variables impacting production.

Real-time monitoring of screening efficiency is a key aspect of these strategies, as it helps minimize the input of fines into the furnace, thereby preserving pellet integrity and ensuring stable operations. Effective lime coating is employed to prevent material clustering inside the furnace, which helps mitigate the risk of material degradation. Optimization of feeder speeds specifically the upper, middle, and lower burden feeders has been carried out to prevent pellet disintegration and enhance overall furnace performance.

Future enhancements focus on implementing screening processes after day bins to further reduce fines input. Additionally, the development of predictive models for channelling and other process parameters is anticipated to improve furnace productivity. These advancements highlight ongoing efforts to refine DRI production processes amidst evolving operational demands and market pressures. By integrating these strategies and continuous improvements, the MIDREX furnace operations can achieve higher efficiency and productivity, ultimately meeting the growing demands of the steel industry.

Keywords: Direct reduced iron (DRI), Productivity, Advanced Process Control (APC).

ISM_084

Optimizing Direct Reduced Iron Metallization Using Predictive Modeling: A Case Study of JSW Steel Dolvi Ltd

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Abstract

JSW Steel Dolvi Ltd operates a single direct reduced iron (DRI) unit using Midrex technology. In the fiercely competitive global steel market, raw material prices are volatile. With India facing a scarcity of high-quality iron ore, steel industries are compelled to refine their operations despite lower Fe(T) content in the ore. Globally, JSW Steel operates two Midrex furnaces processing iron ore with Fe(T) content below 63%, both situated in India, with Dolvi representing the second unit.

The quality of iron ore and pellets significantly influences the metallization process of Direct Reduced Iron (DRI), which in turn plays a pivotal role in steel production. A decrease in DRI metallization directly impacts the operations of the Steel Melting Shop (SMS), affecting yield, power consumption, electrode usage, flux requirements, and overall productivity. These operational inefficiencies escalate the operational costs of the SMS unit, thereby impacting the Earnings Before Interest, Taxes, and Amortization (EBITA) of the steel product.

Optimizing DRI metallization, particularly with lower Fe(T) raw materials, presents a substantial challenge across industries. This study addresses this challenge by developing a predictive model that integrates key input parameters related to raw material quality (Pellets) and process parameters within the Sponge Iron Plant (SIP). A comprehensive analysis involving 272 parameters examines their impact on various variables influencing DRI metallization.

Through regression modeling, six controllable parameters were identified, focusing on those with significant relative impacts. Among these, four actionable parameters were pinpointed for targeted optimization efforts. This predictive model not only enhances the understanding of DRI metallization dynamics but also provides a structured approach for improving operational efficiency and cost-effectiveness in steel manufacturing processes, crucial for sustaining competitiveness in the global steel market.

Keywords: Direct Reduced Iron (DRI), Metallization, Predictive Modeling, Operational Efficiency.

ISM_077

Enhancing Blast Furnace trough campaign life

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Abstract

Trough life is an important factor to continuously sustain high production rates in blast furnace. Tata Steel F blast furnace is a medium size blast furnace having two troughs with average daily production of 4100 TPD. Double trough operation is a necessity with this production rate. Earlier the trough life was around 115000 tons after which the trough goes down for repair. Data analysis was done and important factors like specific erosion of slag/air interface, specific erosion of slag /metal interface and metal trajectory from taphole which affects the campaign life of trough has been identified and studied, after which based on this certain design change was done and cast house practices and daily management of cast house has been strengthened. After implementation of the new design and strengthened cast house daily management practise trough campaign life increased by 54% to from 115000 tons to 178000 tons. In this paper we will be getting into the details of the design change and modification in cast house daily management practices.

Keywords: Trough campaign life, Productivity, Design.

ISM_156

H-DRI Vertical Shaft Reactor – the thermodynamic and kinetic analyss

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Abstract

The limited availability of coke and evolving technological shifts have led to the increase in demand for the production of iron using alternative routes. One such method of iron making that is being proposed is vertical shaft reduction process using hydrogen, known as H-DRI. For any process to be analyzed, first one needs to use the principles of thermodynamics to look at the feasible operating window. Further, kinetic aspects in terms of heat transfer, chemical kinetics, etc. need to be looked at. In this work, first a thermodynamic analysis is done to arrive at feasible window. Subsequently, a one-dimensional packed bed reactor model with heat transfer and reaction kinetics is developed to simulate the axial temperature and composition profiles.

Key words: H-DRI, Hydrogen reduction, shaft reactors

ISM_212

Development of cold bonded briquettes from chromite overburden and its smelt profile assessment for submerged arc furnace and mini blast furnace applications

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Abstract

Chromite overburden is basically the top-layer byproduct from chromite mining that contains around 0.4 to 0.9% Ni, 0.02–0.05% Co, 40-45% Fe (T), and 20-25% SiO_2, respectively. These mineral values are less in quantity but possess significant values therefore this material can be considered as a potential raw material for Ni input. As per IBM statistics, overburden is getting accumulated at the mine site for decades and reached a level of 230 MT (2019). During mineralogy studies, this overburden is found to have a complex mineral association. Minerals present are iron bearing (goethite, hematite), chromite (ferro-chromates), gangue (silica as quartz, kaolinite, silicates). This mineralogy creates difficulty for an efficient beneficiation. One of the major concerns is mud generation or stickiness during water treatment. However, various preconcentration methods have been attempted for upgrading the metal values to some extent. Hydrometallurgical route was also being carried out by several peers that acquired good results in leaching out the desired mineral. Again, these processes faced certain concerns based on the economic viability as well as the environmental acceptability. In line with the previous approaches, the present study is proposed to utilize the lean grade lateritic overburden as an agglomerated raw material through cold bonded briquetting. Three briquetting methods (roller press, extrusion, vacuum press) are carried out to identify the best one. Cement is used as binder and bentonite is used as plasticizer. Different binder composition is tried which resulted in a desirable agglomerate product. Also, the briquettes are assessed for their strength and high temperature smelt characteristics to sustain the submerged arc furnace and blast furnace operating conditions.

Keywords: Chrome overburden, Chrome economy, Agglomeration, Smelt profile, Sustainability

MPR_261

Hydrogen in Pelletizing –Testing in world most modern Pellet-Pot grate facility

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Abstract

In the global green steel transformation hydrogen will become the key factor in terms of CO_2 reduction. The quality demands of the feed material for hydrogen-based DR plants require a specific analysis from the run-of mine-unprocessed iron ore to the ready-made high-quality pellets. Primetals Technologies passion for pelletizing and the consideration of THE ENTIRE METALLURGICAL PROCESS CHAIN from start to finish are fundamental for our pelletizing plant solutions.

Innovative technologies such as hydrogen-based DR systems are placing increasing demands on the quality of raw materials. Due to the exceptional variability in the qualities of naturally occurring iron ores, such as magnetite, hematite and goethite, refining the ore to a high quality, requires precise analysis and careful plant design. This process relies on achieving the best possible results from ore beneficiation and agglomeration.

The use of hydrogen burners in the pelletizing sector may be just the next step towards a CO_2-neutral steel production. Primetals Technologies now will be able to investigate the use of hydrogen as a fuel in the pelletizing process by its upgraded pellet pot grate testing facility. This paper introduces the capabilities from Primetals Technologies operating the world's most modern in-house pellet pot grate testing facility. By this achievement, Primetals is ready to lead the way for future challenges in "Green Steel" Pelletizing.

Key words: Pelletizing, Hydrogen, Pellet testing, Iron Ore, Green Steel, Transformation

MPR_187

Double Deck Roller Feeder System: A Sustainable Solution to Iron Ore Pelletization

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Abstract

The iron ore pelletisation process is a vital step in producing high-quality pellets for use in blast furnaces and direct reduction systems. Recent improvements in material handling technology have offered the Double Deck Roller Feeder System (DDRFS) as a possibility for increasing efficiency and sustainability in pelletisation facilities. AM/NS India Odisha asset is the first one in India to implement DDRFS. This study is about the effects of DDRFS installation on key operational parameters and energy usage in an iron ore pelletisation process. DDRFS installation resulted in significant enhancements in the heat and pressure dynamics of the pelletising process. Specifically, the DDRFS increased the temperature at the bottom of bed by 6.3%. This temperature increase is critical because it allows for more efficient pellet heating, potentially enhancing overall product quality. Furthermore, pressure was significantly reduced by 17.2% by implementing Double Deck (DD) and a 20.3% decrease in Cooler Zones 1 and 2 (CZ1 & CZ2). These pressure decreases indicate improved material flow and less resistance, which can increase overall processing efficiency. Energy usage minimization is a considerable advantage to DDRFS installation. The method resulted in a 47.18 MW reduction in power consumption per day for pellet production. This significant reduction in power usage demonstrates the DDRFS's commitment to more sustainable operations by reducing the energy required for pellet production, hence minimising the plant's carbon footprint. Furthermore, this system's adoption improves the quality of pellets, cold compressive strength increases 223 to 241.

Finally, incorporating DDRFS into iron ore pelletisation processes has numerous benefits, including improved thermal management, lower operational pressures, lower power usage, and decrease carbon footprint. These advantages lead to more efficient and sustainable pellet production, making DDRFS an important addition to modern pelletisation technology.

Keywords: DDRFS, Pelletisation , CCS and carbon footprint.

ESU_133

Assessment of Alternative Reductants on Composite Pelletization for Direct Reduced Iron Production

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Abstract

The steel industry is under increasing pressure to adopt more sustainable practices, particularly in reducing carbon emissions. Direct Reduced Iron (DRI) production, which traditionally relies on natural gas and coal as reductants, presents a significant opportunity for improvement. This study investigates the use of alternative reductants in composite pelletization processes for DRI production, focusing on blast furnace flue dust (BFD)—an iron-rich, carbonaceous byproduct from blast furnaces. Utilization of reactive carbon and/or carbon composite agglomerates will shift the iron oxide reduction process toward lower carbon consumption[1]. The reduction of self-reducing Fe-bearing process waste and carbon composite pellets in a rotary hearth furnace in the temperature range of 1000°C to 1300°C has been reported[2]. The current study examines the effectiveness of BFD in reducing iron oxides within composite pellets, using high-grade iron ore blended with BFD at C/Fe weight ratios ranging from 0.12 to 0.21[3]. Experimental results reveal the influence of these alternative reductants on key process parameters, including reduction efficiency, metallization rates, and overall energy consumption. The reduction conditions were optimized by a suitable thermal profile. The findings indicate that the alternative reductants can impart significant strength, reduction, and metallization in DRI. A Reduction degree of around 95% and a metallization degree of around 80% have been achieved with a slightly higher stoichiometric C/Fe ratio and with the optimized heating conditions. The findings suggest that utilizing BFD in DRI production is less energy-intensive compared to traditional pelletization-induration-reduction systems, offering a viable pathway for more sustainable DRI production. This study provides valuable insights that could guide the steel industry in its transition towards greener technologies.

Keywords: Composite Pellet, Direct Reduction

References:

[1] H. Ahmed, "New trends in the application of carbon-bearing materials in blast furnace iron-making," Dec. 01, 2018, MDPI AG. doi: 10.3390/min8120561.

[2] S. H. Chung, K. H. Kim, and I. Sohn, "DRI from recycled iron bearing wastes for Lower carbon in the blast furnace," ISIJ International, vol. 55, no. 6, pp. 1157–1164, 2015, doi: 10.2355/isijinternational.55.1157.

[3] S. Mishra and G. G. Roy, "Effect of Amount of Carbon on the Reduction Efficiency of Iron Ore-Coal Composite Pellets in Multi-layer Bed Rotary Hearth Furnace (RHF)," Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science, vol. 47, no. 4, pp. 2347–2356, 2016, doi: 10.1007/s11663-016-0666-1.

ISM_191

Effect of Caustic Compound (NaOH) on Green and Fired Pellet Properties

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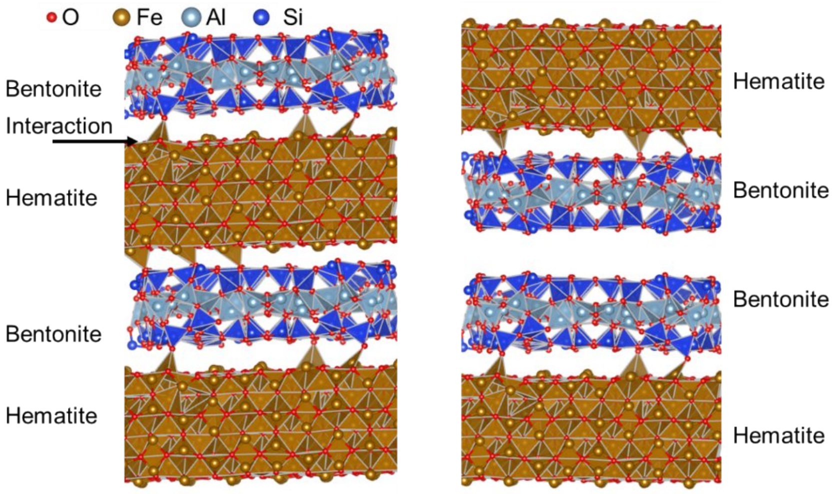
Abstract

Globally, bentonite is being used as a binder in iron ore pelletizing due to its high swelling index, thermal resilience, and water absorption capacity. However, the conventional use of bentonite contributes to increased gangue content (Al_2O_3 and SiO2) in pellets, subsequently affecting blast furnace operations in terms of high solid fuel consumption, low productivity, and high slag rates. In this work, sodium hydroxide has been used with bentonite to reduce its consumption without affecting the pellet properties. Pellets are prepared by varying the NaOH addition from 0% to 0.1% at an interval of 0.02%. Green and fired pellets were tested for green compressive strength (GCS), dry compressive strength (DCS), drop number, cold compressive strength (CCS), Hoogoven simulations (HOSIM), softening-melting, and swelling index (SI). The interaction between hematite and bentonite was studied using molecular modeling simulations (ReaxFF MD). Microstructural studies (optical and SEM-EDS) of pellets were carried out for phase quantification and to assess the chemical composition of slag phases. Besides, FactSage simulations were performed to validate the slag phase formation. It is inferred that a 50% reduction in bentonite consumption is possible at 0.04% NaOH with a 12% improvement in CCS. Laboratory results were validated for a seven-million-tonne pellet plant with 0.02% and 0.04% NaOH dosage. Plant trial shows that there is an 18% and 39% reduction in bentonite consumption with the addition of 0.02% and 0.04% NaOH dosages, respectively.

Keywords: Pellet, Bentonite, Sodium Hydroxide, Cold Compressive Strength, HOSIM, Swelling Index

Graphical Abstract



MPR_114

Characterization of physical strength and metallurgical properties of Iron Ore pellet based on pore distribution in it

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Abstract

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

MPR_138

Microstructure and Slag Phase Evolution during Firing of High Alumina Iron Ore Pellets

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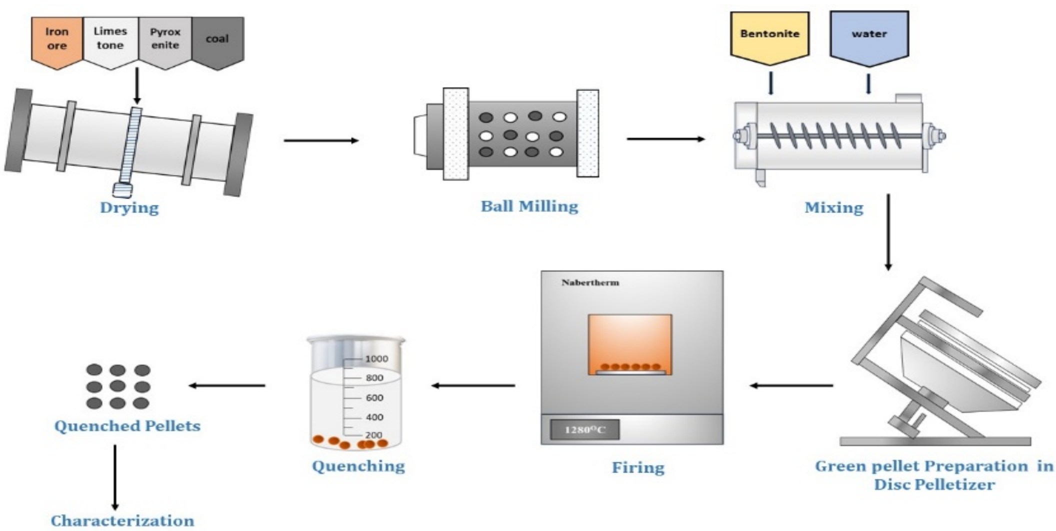
Abstract

The quality of iron ore pellets depends on type and amount of raw materials (Iron ore Fines, Fluxes, Slid Fuels and Binder) used, firing temperature and time. High alumina in iron ore fines has a detrimental effect on quality of pellets in terms of cold compressive strength (CCS), Reduction degradation index (RDI), Tumbler index (TI) and Abrasion index (AI). In work three iron ore fines with varying alumina levels 2.3%, 3.1% and 3.9% was used for phase evolution studies during pellet making. Iron ore fines subjected to chemical analysis, XRD, TGA/DSC and dilatometry studies. Iron ore pellets were prepared with different alumina levels and quenched in liquid nitrogen at 1100,1200 and 1300 °C to understand the formation and distribution of slag phases with respect to alumina content. Quenched pellets were subjected to XRD for phase identification. Phase quantification of quenched pellets carried through image analysis to measure the quantify of phases. Microscopic studies of pellets were carried out through stereo microscope, optical microscope and scanning electron microscope. EDS analysis of pellets was carried to map the elemental composition of oxide as well as slag phases at different temperatures. Factsage studies were performed to validate the slag phase evolution at different alumina levels with experimental data. The major phases present in iron ore fines are hematite, goethite and gibbsite. The major phases present in pellets quenched at 1300 °C are hematite (Fe_2O_3), magnesioferrite ($MgO.Fe_2O_3$), Dicalcium silicate ($2CaO.SiO_2$) and Dicalcium dialuminate ($2CaO.Al_2O_3$)

Key words: Iron ore Alumina, Pellet, Slag Phase, Factsage, XRD

Graphical Abstract



ISM_060

"Reducing fuel rate by Utilization of Solid Secondary Waste material in Pellet Plant"

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Abstract

Iron ore pellet plants play a vital role in the steelmaking industry, as they transform fine-grained iron ore concentrates into high-quality pellets suitable for steel production. This abstract is about the use of waste material containing iron, fluxes and fuel in the operations of JSW Steel Ltd.'s Dolvi Pellet Plant. JSW Steel Ltd. is a leading steel producer in India, committed to adopting environmentally responsible practices while maintaining operational efficiency and competitiveness. However, the production of steel generates various waste materials, including fines, dust, and sludges, which traditionally pose disposal challenges and environmental concerns.

In recent years, there has been growing interest in exploring sustainable practices in the steel industry, including the efficient utilization of waste materials. Incorporating waste materials containing iron into pellet plant operations presents an opportunity to recycle waste generation, minimize environmental impact, and improve resource efficiency. There are several potential sources of waste materials containing iron, fluxes and fuels such as iron-rich sludges from wastewater treatment plants, mill scale from Steel manufacturing units, and iron-bearing dust from various industrial operations. These materials often contain valuable iron content, fluxes and fuel which can be recycled and utilized as a raw material feedstock in pelletizing plants.

Here, in JSW Steel Ltd. Dolvi complex, the secondary materials used are SMS GCP dust, Blast Furnace Cast House and Stock House dust, SIP Sludge and several Oxide dusts. The dusts are added with iron ore and are then ground in the ball mills in agreeable proportions without compromising the quality. This has led to reduction in solid fuel rate and has proved to very economic along with added benefits of reduced environmental impacts. An average of 32kg/tonn was added to the feed mix in April 2023 in Pellet Plant 1, this has been gradually increased to 45kg/ton in March 2024. This has led to significant reduction of fuel consumption from 13.8kg/tonn to 6.8kg/tonn. Also, in Pellet Plant 2, an average of 41kg/tonn was added to the feed mix, which was increased to 58kg/tonn in March 2024, leading to the reduction of fuel consumption from 9.15kg/tonn to 2.60kg/tonn.

This abstract concludes by highlighting JSW Steel Ltd.'s proactive approach towards energy efficiency and sustainable waste management in its pellet operations. In order to meet its sustainability goals and keep its position as a market leader in the global steel sector, JSW strategically uses its secondary waste materials.

Key words: Secondary Waste, Pellets, Waste Management, Sustainability, Iron-bearing dust.

ESU_055

Pellet Reducibility Index and it's relation with Carbon Deportation

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Abstract

This study explores the influence of increasing the Fe revert portion and coke breeze on the reducibility index (RI) of iron ore pellets, noting an improvement in RI from 74% to 78% with higher levels of these components. Phase quantification reveals a magnetite content of 16% in fired pellets, which is significantly above the optimal threshold of less than 4%. The elevated magnetite levels, coupled with high alumina content and low porosity, result in a reduced RI due to the formation of low-melting compounds such as fayalite and hercynite, which impede the diffusion of reducing gases. Additionally, high carbon content and increased firing temperatures further contribute to higher magnetite content and reduced porosity. The study also finds that high alumina iron ores necessitate greater heat input in the furnace, and that a new solid fuel blend shows a 10% increase in carbon deposition in the -45 micron fraction compared to the previous blend. These results highlight the critical need for optimizing pellet composition and processing conditions to enhance reducibility and efficiency in ironmaking operations.

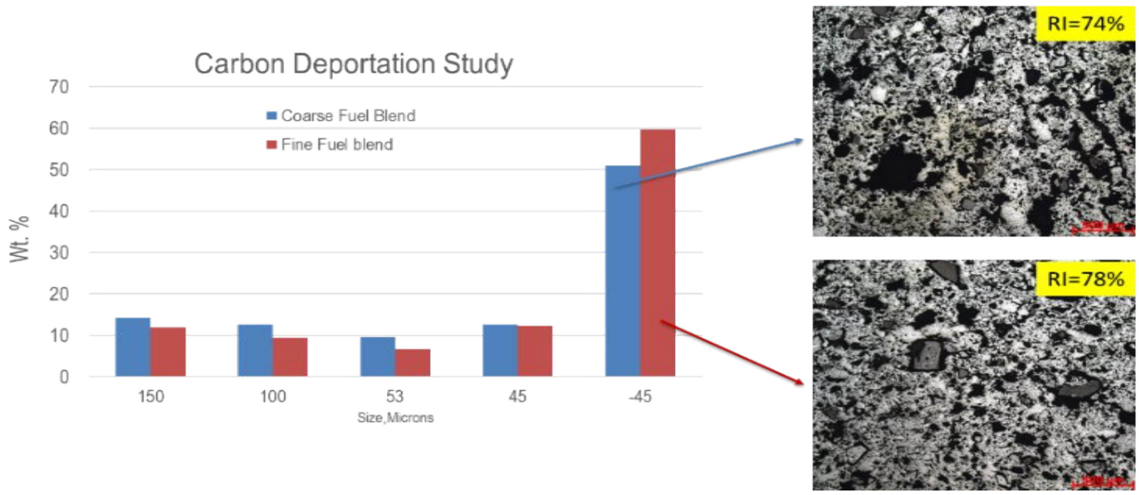

Fig. 1: Carbon deportation and porosity distribution in low and high RI.

Keywords: .
Reducibility Index, Pellet, Magnetite, Fayalite, Hercynite, Porosity, Fe revert.

ISM_224

CO2-Free Flux for Sustainable Iron Ore Pelletizing

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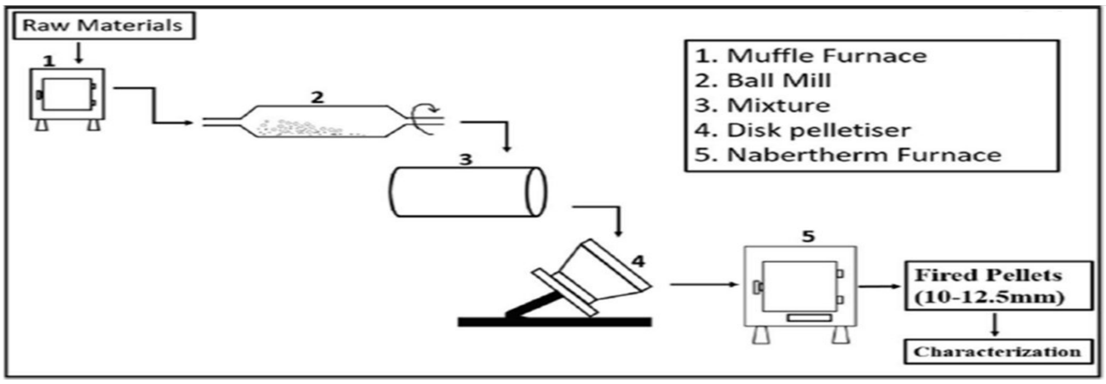
Abstract

The iron and steel manufacturing sector directly accounts for 7–9% of global CO2 emissions. Raw material preparation, such as iron ore sintering, pelletizing, and coke making, is the major CO2 emitter. As climate change becomes a major concern, steel manufacturers need to lower CO2 emissions without hindering efficiency or increasing costs. In recent years, the percentage of iron ore pellets in blast furnaces has increased due to its uniform size, good reducibility, and high tumbler index. Pelletizing is energy-intensive and emits considerable CO2. Around 20% of CO2 emissions during pellet making come from fluxes. In the present work, the authors established a novel CO2- free flux called wollastonite (CaO.SiO2) for sustainable palletization. Pellets with varying percentages of wollastonite (0–6%) are prepared and tested for chemical, physical, and metallurgical properties. Image analysis through an optical microscope is carried out to quantify the phases of fired pellets. SEM–EDS is performed to evaluate the chemical composition of the melt and slag phases. The results showed that the reducibility index (RI) and swelling index (SI) of pellets decreased with an increase in wollastonite dosage. Pellet strength increases with an increase in wollastonite addition up to 1.2% CaO (2.27% wollastonite), and a decrease in strength is observed thereafter. The increase in strength is attributed to the increase in slag bonds. The decrease in strength beyond 1.2% CaO is mainly because of an increase in low melting eutectics and more magnetite content. Pellets with 2.27% wollastonite to get 1.2% CaO showed good physical and metallurgical properties. After lab scale studies, taken plant trials in 7 million tonne/annum pellet plant and observed 20 points improvement in CCS, 25MJ/tonne energy reduction, 15% reduction solid fuel and increase in production by 18 tph.

Keywords: Pellet ·Wollastonite,Cold compressive strength Reducibility index ,Swelling index

Graphical Abstract



ESU_212

Development of a hybrid lime prediction model for Basic Oxygen Furnace (BOF) to optimize the lime addition in BOF steel making process.

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Abstract

Basic Oxygen Furnace (BOF) steel making is a batch process. In this process, a basic refractory lined converter is employed to convert the hot metal produced from blast furnace into liquid steel. Oxygen is blown into the converter at supersonic speed to convert impurities such as carbon, silicon and phosphorous etc. to their respective oxides. These oxides are acidic in nature and hence would damage the basic refractory lining of the converter. To prevent these adverse effects, flux is added to the hot metal during the process. The constituent of the flux, (CaO and MgO) would reacts with these acidic oxides to form the slag. Hence, optimum amount of lime addition is the most significant aspect of the steel making process because it influences both cost and quality. The inherent complexity and stochasticity of the process along with batch-to-batch variation of the operational and process parameters such as vessel lining erosion, retained slag quantity, scrap variation and hot metal input chemistry variation etc are the most significant challenges posed to any process model in achieving consistent performance. This work outlines the hybrid model for predicting the optimum lime quantity. The hybrid model has both the generalizability and robustness of the first principle model and the versatility of the machine learning models. The first-principle based model is based on the principles of mass and energy balance, thermodynamics and reaction kinetics. The weakness of this model is that it doesn't consider variation of process nuances along with the vessel life and varying lining conditions. However, these factors have adversarial impact on the model's performance. To compensate the shortcomings of the first-principle based model, a machine learning model has been developed. The success of the machine learning model depends on the selection of features and feature engineering. Inspired by the governing physics, the synthetics features have been derived to achieve good performance. Finally, the hybrid model takes weighted average of the predictions of both the models as the final output lime. The results show that desired chemistry (actual Phos<aim Phos) was achieved in around 80% of the heats where hybrid model was followed.

Key Words: BOF, first-principle based model, Machine learning, Hybrid based modelling.

ISM_110

Study and development of Ultra-low Nitrogen Interstitial Free Steel through RH Degassing Process

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Abstract

Interstitial Free steel has its applications in automotive sector requires the stringent chemistry. The study for development of ultra-low nitrogen steel focused on nitrogen control practices implemented in the production of interstitial-free (IF) steel at the Ruhrstahl-Heraeus (RH) degasser. Nitrogen is an undesirable element in IF steel due to its detrimental effect on steel properties, specifically increasing brittleness. It forms nitrides with aluminum and titanium, damaging the steel surface and compromising its performance. Therefore, stringent control of nitrogen content is crucial for IF steel applications, particularly in automotive skin panels. Multiple trials including Hot metal purity and avoiding scrap addition minimizes nitrogen introduction at the primary steelmaking stage. Focus on higher Turn-down temperature for reduction of vacuum treatment time at the RH degasser and Buffer station elimination and specific flux addition with Calcined dolomite addition helps prevent nitrogen pickup during reblows etc. Sulfur reduction in steel along with vacuum degassing at RH degasser also being tried. The case study demonstrates that achieving ultra-low nitrogen levels is possible at the RH degasser. Sulfur acts as a surface-active element, facilitating nitrogen escape from the steel. The presented case study effectively demonstrates the successful implementation of best practices for nitrogen control in IF steel production, resulting in nitrogen levels below 15 ppm.

Keywords: Interstitial Free Steel, Ultra-low Nitrogen, Sulphur Control, Vacuum degassing, RH Degasser

ISM_108

Deoxidation of Steel by Using Calcium Carbide as Alternative in Secondary Metallurgy

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Abstract

The crude steel production of unalloyed and low alloyed steel grades from Hot metal or Iron sponge needs always an oxidation of the raw material in BOF or EAF. This is required to remove the accompanying elements of the raw iron melt, mostly carbon but also to minimize other non-desirable trace elements.

The carbon content plays the important role, because it´s the main element in the raw material iron. Depending on the steel grade produced the carbon content needs to be reduced to the specific level - in the BOF usually down to 0.03 %. During this process all other elements in the melt are also subject to deoxidation process – specifically if they have a higher affinity to oxygen compared to iron.

Independently from the process route via BOF or EAF oxygen is dissolved in the iron during this process. Typical oxygen levels before tapping are in the range of 700 to 1200 ppm (Celox).

One of the tasks of the secondary metallurgy is to bring the oxygen content of the steel with deoxidation to less than 40 ppm in the final product, depending on the steel grade. In order to achieve this low oxygen content and to finalize the transformation from Iron to steel there are different deoxidizers in use. The oxides formed during deoxidation are usually present in the melt as alumina, agglomerates or different kinds of Spinel. Although most of them rise from the metal bath and will be absorbed in the slag the remaining oxides influence the quality of the final steel as well as the process.

The art of secondary metallurgy is to produce steel with a minimum level of oxides in the final steel product. Oxide`s or **non-metallic inclusions** play an important role in the subsequent processing (e. g.: castability during continuous casting, surface defects during rolling), but they do also influence the mechanical and chemical properties of the final steel product. In the submitted paper an alternative method of deoxidation of steel in the secondary metallurgy by calcium carbide is introduced and explained. Aim of this method is to minimize the content of non-metallic inclusions. Additionally, to a better cleanliness of steel, you also notice by the subsequent improvements in processing (casting –nozzle clogging). Furthermore, economic cost savings can be achieved in your production depending on the price of usual deoxidizing elements compared to Calcium carbide in the country of application.

The presentation comprises methods, techniques of deoxidation of steel in secondary metallurgy and safety instructions by using calcium carbide.

Keywords: Secondary Metallurgy: Deoxidation; Calcium Carbide

DM_015

The role of MGO briquettes on argon oxygen decarburization (AOD) converter life

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ABSTRACT

Salem steel plant, SAIL we are one of the different stainless steel makers in India. The life of the AOD vessel is greatly affected by process time, input metal weight, chemistry, process temperature, Fluxes and basicity of the slag. AOD life was 90 just before MgO briquettes but after addition AOD life is 105(15 lives is getting more). The MgO briquette of 300-500kg per heat was added during processing of metal in AOD. Our study finds the MGO briquettes plays important role in improving the vessel life into 105 heats. MgO at different quantities on life was studied.

The MgO briquettes not only help for slag saturation by MgO and also the chemical erosion of the dolomite brick is greatly controlled. Thus AOD life has improved into marginally. It has helped us to reduce the cost of production.

ISM_140

Affival Sustainable Steel Strategy by combination of Ca HDX LS™ cored wire and Affival Edge technology

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Abstract

Affival, as a steelmaking supplier and the pioneer in the development of cored wire injection technology [1] - the simplest way for trimming additions in ladle furnace as well as other secondary metallurgy vessels - with more than 40 years of experience in the manufacturing of cored wire and its associated injection equipment, is continuously developing sustainable solutions promoting circular economy. Concretely, this paper presents an innovation package which enables to reduce consumables while keeping a high level of performances. First innovation is dealing with calcium based cored wire for calcium treatment of steel.

Affival recently developed the last generation of calcium-based cored wire, and its application to secondary metallurgy process, called Ca HDx LS™ -Low Splashing-, patented cored wire based on the hybrid technology which associates on one hand, the benefit of HDx™ technology for a better thermal protection of extruded metallic calcium and on the other hand, anti-splashing technology based on a technical powder sourced from a side-product of high purity premelted synthetic slag, which surrounds the extruded metallic calcium. Ca HDx LS™ wire use ensures that the release of calcium, which takes place deep within the melt, contributes to enhancing the performance of the calcium treatment: higher Ca-yield and tighter deviation of the calcium content. Additionally, the use of Ca HDx LS™ wire enables to enhance the cleanliness level of steel since the high purity premelted synthetic slag powder contained in the cored wire is acting as a accelerator of the inclusions removal from steel to slag.

Ca HDx LS™ wire associated to Affival Edge technology, based on the automatization of the data collection of key parameters impacting the calcium treatment such as chemical composition of steel, temperature and cored wire injections conditions and their live analysis, leads to the optimization of the calcium treatment operations. On the top of that, Affival Edge technology is also dedicated to monitor any events on the cored wire feeder which could interfere with a smooth injection of cored wire into liquid steel. At the end of the day, some extra material savings -Ca HDx LS™ cored wire- are reachable.
Those two combined solutions enable in fine to finetune injection conditions for a suitable calcium-based calcium cored wire (Ca HDx LS™) so that calcium treatment performances are enhanced leading to a better castability while keeping economic advantage of cost of calcium treatment per ton of steel and promoting sustainable steel strategy thanks to optimisation of

calcium treatment. Last but not least, this combined solution, thanks to its beneficial effect on cleanliness of steel is helping to increase the level of quality for special steel grades.

Key words : Calcium treatment, cored wire, digitalization

ISM_063

Usage of advanced Tundish furniture to improve surface quality in Low C & IF steel grades at SMS2 Slab Caster

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Abstract

Continuous Casting (CC) 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 related to Quality persist the CC process predominately due to Mold Level Fluctuation (MLF) and Clogging of Submerged Entry Nozzle (SEN). Mold level fluctuation refers to the variation in the height of the molten steel meniscus within the casting mold during solidification, which can adversely affect the product quality and casting stability. On the other hand, SEN clogging occurs when non-metallic inclusions (NMIs) deposit on inner walls of SEN and mono-block stopper thereby obstructing the flow of molten steel through the SEN leading to interruptions in casting and final product defects. Industrial observations indicate that steel grades featuring low carbon & IF content allow permissible MLF up to 10 mm, and approximately 10 % of IF & low carbon slabs produced has MLF greater than 11 mm, this leads to slab rejection and yield loss due to re-work. MLF needs to be decreased for these grades due to their critical application. To minimize the NMIs of steel reaching the mold, new tundish furniture named Atom & Ripple stopper has been introduced in the tundish fixed in the well block area 80 mm above the working lining. After series of trials found that this furniture minimises inclusion deposition by locally altering the flow and changing the feeding angle. Atom shall generate turbulence along the inner surfaces above the outlet, delaying the vortex formation during tundish draining. Maximises surface for collection of non-metallic inclusions instead of flow channel below. After using the Atom & Ripple stopper, the total defect counts per coil is reduced from 0.87 to 0.36.

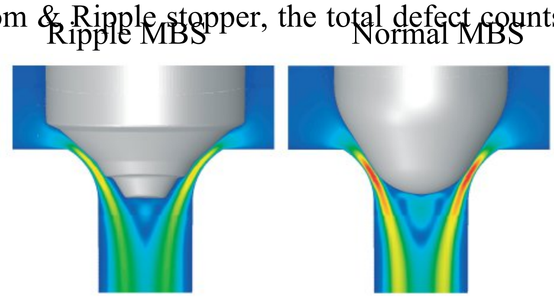

Fig. 1: ATOM
Fig. 2: Ripple Stopper

Key words: Steelmaking, Continuous Casting, Atom, Ripple Stopper.

ISM_136

Use of Sludge bricks as replacement of scrap in steel making

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Abstract

Generation of high iron containing wastes such as mill scale, dust and sludge are inevitable in steel making process hence it is important to develop and implement processes to recycle and re-use these wastes as raw material. Also, insufficient supply of in-house scrap and high cost of external scrap, utilisation of alternative coolants i.e, bricks/ briquettes made of Sludge as partial replacement of prime steel scrap can be introduced to meet the demand and also to take care of huge quantity of unutilised sludge.

Feasibility study of making bricks using different combinations and proportions of Sludge, Mill Scale and Lime dust was tried and tested to get the desired composition/specification of bricks.

On performing different trials i.e. trial no 1 to trial no 3 and of various types i.e. type A to type F. Sludge bricks of trial 3 and type E with Bentonite, cement as binder gives the best CCS of 90kg/cm^2 after two weeks of natural curing.

Type A to F (Sludge bricks of trials)

Key words: Mill Scale, Sludge bricks.

ISM_176

Improved Deoxidizer and Slag Former

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Abstract

Aluminium (Al) deoxidation is indeed a critical step in the steel refining process, primarily because it plays a significant role in improving the cleanliness and overall quality of the final steel product by removing oxygen from molten steel. Prime Al in the form of bar, wire, shots are widely used as deoxidizer during tapping and secondary steelmaking process. The deoxidation using Al Bar typically occurs in the teeming ladle, where molten steel is transferred after basic oxygen furnace (BOF) or electric arc furnace (EAF) treatment. In the present study, a novel low cost Al-deoxidation compound containing 30-35% Al, 32-42% Al_2O_3, 16-26% CaO and 0-10% SiO_2 was used as the killing material has been used as an effort to reduce the production cost of these grades. The primary objective of this compound was to efficiently reduce the consumption of Al bars used during tapping of steel from BOF. While the Al in the compound acts as a deoxidiser, Al_2O_3 present in it helps in early formation of slag by reacting with lime (CaO) and forming low melting Calcium-Aluminate phases. As a result, Al bar consumption got reduced by 40 kg/heat with every 100 kg addition of the compound. It also reduced lime+Synthetic slag consumption by approx. 100 kg/heat. Early slag formation helped in reducing the arcing time by 25% and thereby lowering down the power usage by 23%. This compound's ability to lower prime Al usage, reduce flux and power consumption, and maintain product quality makes it a promising development for improving the sustainability and cost-effectiveness of steelmaking processes.

Keywords: Al-deoxidation compound, Prime Al, Cost reduction, Primary steel making, Killing agent,

ISM_166

Impact of Silicon in base metal on the galvannealed coating in high hole expansion grade steel having a minimum tensile strength of 590MPa

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Abstract

Here in this paper we have studied the impact of substrate chemistry on the surface appearance of the galvannealed coating of high strength grade steel having the minimum strength of 590MPa. Silicon is added in the base metal so as to achieve strength but it also prone to silicon oxide formation which is difficult to remove during the descaling process. The surface of silicon added steel has scaly surface over the whole surface. In this paper the scale surface is studied in the SEM to observe the surface microscopically and EDX analysis is done to find out the composition of the scale. The galvanneal coating by annealing after zinc coating on the substrate. During the annealing process, the iron form the metal diffuses into the zinc coating which leads to morphological changes in the coating. The diffusion of Fe into Zinc coating is sensitive to surface activity. During the presence of scale, the surface activity varies and the diffusion of Fe at the scales location are hindered. Due to this the diffusion of Fe across the surface are non-uniform and it leads to the non-uniform surface appearance. The experiment is conducted on the continuous galvanizing line at different galvannealing temperature for the silicon added and non-silicon based chemistry. The base grade is having a tensile strength of 590MPa and a hole expansion ratio of 60. A comparative study of the surface achieved in Silicon and non-Silicon based chemistry is explained in this paper. Additionally the impact of Silicon in the base metal on the mechanical property are also summarized.

Key words : 590R, scale, Silicon

ISM_031

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Production of Low Nitrogen Steel Using Coal-Based DRI in CONARC Process.

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Abstract

Nitrogen present in solid solution in ferrite is free nitrogen which will provide some strengthening however it had a detrimental effect on causing strain aging in steel along with carbon. This will result in decrease of formability, fracture toughness & contributing luders band formation. Removal of nitrogen from steel is difficult because of its lower diffusion coefficient. Only 10-30% of nitrogen can be removed in a degasser. So primary focus is to avoid nitrogen pick up in steel by strengthening the control measures to avoid exposure of steel to the atmosphere.

CONARC is a combination of two process i.e., converter & arcing. In this process oxygen blowing is carried out in first phase and arcing is carried out in the second phase. Tata Steel Meramandali faces elevated nitrogen levels in its final product due to the use of coal based DRI in the CONARC process. This is attributed to the lower carbon content in coal-based DRI compared to gas-based DRI, causing reduced slag foaminess & insufficient control of air ingress due to lower CO generation.

Additionally, 30% fines getting generated during DRI production are briquetted and reused as CBI in CONARC. Presence of nitrogen in binder contributes to higher nitrogen content in CBI. Process experiences increased nitrogen input as DRI and CBI constitutes 40% of the charge mix. At TSM low end applications steel having high allowable nitrogen is routed through CONARC, as steel from this route has higher nitrogen levels relatively to BOF route. But, as the demand for high-end grades requiring lower nitrogen increases, the CONARC route poses a bottleneck. The primary goal is to extract value from CONARC by minimizing the final nitrogen content in steel.

For achieving a good foaming effect high reactivity, high carbon content, and low ash content in the carbon source is required. The carbon oxidizes and reduces the iron oxides in the slag phase, generating numerous bubbles. This results in slag foaminess and partial recovery of the iron. This foaminess not only improves the nitrogen pick up but also serves as a key factor in effectively concealing the electric arc. This enhancement plays a vital role in improving the efficiency of energy transfer to the bath, thereby leading to a reduction in power consumption and electrode consumption during the arcing phase of the process. This paper focuses on generating sufficient slag foaminess & creating a controlled environment that prevents air ingress & minimizes N2 pick-up, contributing to the process's efficiency and desired outcomes.

Keywords : Cold Briquette Iron (CBI), Direct Reduced Iron (DRI), CONARC

ISM_024

Effect of Strain Rate on TRIP effect in SS 301LN Stainless Steel for safe body structure of Transport Application.

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Abstract

The incorporation of 301LN grade stainless steel, specifically the 301LN variant, into metro coach construction is revolutionizing safety and performance standards. This material exhibits a unique transformation behaviour under high strain rates, where the metastable austenitic structure undergoes strain-induced martensite formation. This transformation enhances the material's mechanical properties, significantly improving its strength, hardness and Elongation during deformation events. The strain-induced martensite not only fortifies the steel against dynamic impacts but also optimizes its crashworthiness by augmenting energy absorption capabilities.

These properties are critical for the demanding environment of metro coaches, where both durability and safety are paramount. The TRIP (Transformation-Induced Plasticity) effect of 301LN stainless steel contributes to its ability to resist catastrophic failures during collisions, providing a higher level of safety for passengers. By leveraging the inherent strength and toughness gained from the martensitic transformation, metro coaches constructed with 301LN grade stainless steel set new benchmarks for impact resistance and structural integrity.

The project presents a comparative analysis of strain rate on AISI 301LN with 304, 304L, and 304Cu grades, demonstrating that AISI 301LN exhibits the highest TRIP effect, leading to superior strain hardening and strength under mechanical stress. The key to 301LN advantage lies in its lower Stacking Fault Energy (SFE), which promotes a more pronounced Transformation-Induced Plasticity (TRIP) effect. This lower SFE facilitates greater strain-induced martensite formation under mechanical stress, leading to higher strain hardening and enhanced mechanical properties compared to its counterparts. Quantification of transformed martensite using Metallography, Ferritescope and EBSD Techniques.

References:

- Sunil, S., Kapoor, R. Effect of Strain Rate on the Formation of Strain-Induced Martensite in AISI 304L Stainless Steel. Metal Mater Trans A 51, 5667–5676 (2020). https://doi.org/10.1007/s11661-020-05968-x.
- Debasish Chatterjee. Metallurgical Perspective of AISI 301LN (EN 1.4318) Grade Austenitic Stainless Steel for Future Transport Applications. International Research Journal of Materials Sciences and Applications, 2020 3:9.

ISM_185

A Case Study on Desulphurisation of teel in AD

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Abstract

With the increase in demand for stringent quality of steel, the requirement for steel with low sulphur has increased significantly. Sulphur is considered detrimental for steel in terms of surface and internal quality, as it contributes to hot shortness. While, in most of the integrated steel plants, the sulphur is removed at the hot metal stage in pretreatment stations, the secondary steel manufactures, who use either Electric Arc furnace or Induction Furnaces routes doesn't have this opportunity. As they mainly rely on solid charge materials like scrap, pig iron and Direct reduced Iron, thus the liquid steel produced contains high sulphur.

Some of these secondary manufactures also use AOD furnace for producing high-end qualities, where this high sulphur level becomes a bottleneck. As AOD employs oxygen-based refining, removal of sulphur is metallurgically challenging. The authors took up the challenge to develop an efficient steel desulphurisation process to cater this steel desulphurisation requirement of secondary steel manufacturers.

A customised desulphurisation process, including a new reagent has been developed to treat the liquid steel in AOD vessel. During the application of this reagent at one of the secondary steel manufacturers, with an addition of around 2 kg per ton of liquid steel just after the oxygen blow in the AOD, sulphur was dropped from a level of 0.080% to 0.015%. This has opened a new opportunity to all these secondary manufactures to produce high-end low sulphur steels without any significant investments in plants and equipment or the need for high quality raw materials.

Key words: Steel Desulphurisation, Sulphur, AOD, EAF, DRI

ISM_048

Mitigating Surface Defects in 304 Stainless Steel: A Study on Annealing Temperature Effects and Scale Formation

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Abstract

304 stainless steel is a versatile and widely used austenitic alloy, renowned for its excellent corrosion resistance, formability, and weldability. Comprising 18-20% chromium and 8-10.5% nickel, it is ideal for applications across various industries, including automotive, aerospace, and food processing, where durability and minimal maintenance are crucial.

During the processing of 304-grade stainless steel, surface defects such as rough white oxide lines and black streaks have been observed in the 2B finish at the Cold Rolled Annealed and Pickling (CRAP) line, particularly in the rolling direction. These defects are not detectable during the Hot Rolled Annealing and Pickling (HRAP) stage due to high surface roughness but become visible only after cold rolling and subsequent CRAP processing. This visibility of defects significantly impacts dispatch targets and affects export dispatches, presenting a major challenge for production and delivery goals.

The occurrence of these defects has been linked to the annealing profile used during the HRAP stage, which influences the scale formation on the strip surface. The scale typically comprises multi-layered oxides, including chromium oxide (Cr_2O_3), which forms the outermost protective layer, and iron oxides such as Fe_2O_3 and $FeCr_2O_4$, which form beneath it. By increasing the annealing temperatures, the scale becomes thicker and more uniform. This improved scale facilitates easier removal during water quenching, shot blasting, and pickling at the HRAP stage. Consequently, this adjustment helps reduce the surface defects, such as rough white oxide lines and black streaks in the rolling direction that manifest after cold rolling and CRAP processing. These observations align with existing literature on scale development and its impact on surface quality.

By implementing targeted adjustments to the annealing profile, particularly optimizing the annealing temperatures during the HRAP stage, we achieved a significant reduction in surface defects—from 15% to less than 2%. This enhancement in scale uniformity and adherence results in better surface quality and performance in subsequent processing stages, leading to improved production efficiency and more reliable dispatch targets.

Keywords: 304 Stainless Steel, Solution Annealing, Pickling, Scale Formation & 2B Finish

ISM_17

Minimization of Surface Roughness generated in the Titanium stabilized austenitic steel - 321/EN 1.4541 grade in the 2B Finish

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Abstract

Grade 321/EN 1.4541 is a Ti-stabilized austenitic stainless steel (SS) that renders a set of unique advantages, such as superior high-temperature strength, adequate creep resistance, and excellent oxidation and corrosion resistance, compared to the conventional austenitic stainless steels. One of our prime customers used this grade to produce bellows in Thickness 0.15-0.2 mm “Bright Annealed” surface. Bellows are generally used in car vehicles to absorb the vibrations and noise produced from the engine during combustion. The hydroforming technique is being used for the production of bellows. However, one of the biggest challenges, which we faced during the stabilization of this alloy is the exhibition of surface roughness observed at CAPL (cold rolled annealing line) stage in Thk 0.5mm. The surface appearance of the coils produced is of significant importance as the end application of it may be for the aesthetic look. Thus, the work presented here investigates the probable reasons for the exhibition of this defect.

The defect of "surface roughness" has been a persistent issue in cold rolled annealed and pickled (CAPL) coils of 321/EN 1.4541 grade. This defect typically manifests as a "flowery pattern and line type" on the strip surface, particularly after processing to an intermediate thickness of 0.5 mm with a "2B" finish. Although significant reduction of the defect has been achieved through strip grinding using silicon carbide belts, followed by rolling to a thickness of 0.15-0.2 mm and bright annealing the surface, this process incurs additional costs and productivity losses. Given that the end application is surface-critical, avoiding intermediate strip grinding would result in an unsuitable surface for the customer.

From our observations, when processing the coils at the CAPL stage to a thickness of 0.5 mm with a "2B" finish, the defect intensity is higher on the top surface of the strip compared to the bottom surface. This is attributed to greater temperature exposure on the top surface, which leads to more scale formation during the CAPL stage. In response, the annealing profile at the CAPL stage for 321/EN 1.4541 grade was adjusted from 1080°C to 1040°C, along with modifications to the pickling parameters. This adjustment resulted in a completely defect-free surface, eliminating the need for intermediate strip grinding.

This approach led us in producing the Ti stabilized 321/EN 1.4541 grade in “Auto exhaust” market segment making us the only supplier across India and contributing our part in making India “Atmanirbhar Bharat”

ISM_200

Innovative Measures to Minimize Silicon Content in High Carbon Ferrochrome Production

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Abstract

Low Silicon High Carbon Ferrochrome (Low Si HC FeCr) is a specialized grade of Ferrochrome that commands a higher market price due to its low silicon impurity content. There is an extra premium associated with lower content of %Si in the prime metal. Tata Steel FAMD (Ferro Alloys Mineral Division) aims to penetrate this value-added product market, focusing initially on achieving silicon content below 2%. However, controlling silicon levels in high carbon Ferrochrome produced in Submerged Arc Furnaces (SAF) is challenging due to extreme reducing environment with elevated process temperature favouring Silicon reduction from silica into the metal. Typically, slag tapping occurs at temperatures above 1700°C, within-furnace temperatures averaging around 1800°C, favouring the reduction of SiO2 and resulting in silicon overdose in the alloy.

The silicon content in the metal depends on various parameters such as input chemical properties, slag chemistry, carbon input, electrode control, and overall process control. To address this, a trial was conducted at the Tata steel, FAMD to achieve silicon content below 2% by adjusting basicity, carbon rate, and metal Cr%. The trial successfully demonstrated that increasing slag basicity (B3) by a ratio of 0.2, increasing MgO/Al2O3 by 0.15, and maintaining a higher Cr/Fe ratio in the alloy led to reduced silicon content. This paper presents the methodology, parameter adjustments, and results of the trial, providing valuable insights into the production of Low Si HC FeCr.

Key Words: Carbon rate, Basicity, Low Si HC FeCr, Cr/Fe ratio

ISM_149

Effect of Copper content in the austenitic stainless steel 304 grade on the Deep Drawability

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Abstract

Austenitic stainless steel 304 is well-regarded for its excellent corrosion resistance and formability. This study investigates the significant impact of copper content on the deep drawability and cold rollability of 304 stainless steel, highlighting copper's superior role as an austenitic stabilizer compared to nickel. We examined three material variants: 304(Cu 0.5%, Ni 8.1%), 304(Cu 0.03%, Ni 8.1%), and 304(Cu 0.03%, Ni 8.5%), while keeping other elements constant (C 0.05%, N 0.05%, Cr 18.1%).

Our results demonstrate that increasing copper content improves both deep drawability and cold rollability. Analysis using Nohara's Md30 parameter, which estimates the temperature at which 50% strain-induced martensite forms during deformation, shows that the 304(Cu 0.03%, Ni 8.1%) variant has a higher Md30 temperature, indicating a greater tendency for strain-induced martensite formation and increased ferrite content, as measured by Ferritoscope, which reduces formability. In contrast, the 304(Cu 0.5%, Ni 8.1%) variant, with a lower Md30 temperature, exhibits superior drawability and requires lower roll forces during cold rolling, making it more suitable for complex deep drawing applications, such as producing sinks with straight draws and zero-radius corners.

The study also highlights copper's effectiveness as an austenitic stabilizer compared to nickel. While nickel is a common stabilizer, it is significantly more expensive at 1600 Rs/kg compared to copper at 800 Rs/kg. Copper's role in stabilizing the austenitic phase provides a cost-effective alternative to nickel, offering significant economic and performance advantages.

Further research should explore additional aspects of copper's impact, such as its effect on corrosion resistance in various environments and its impact toughness at sub-zero temperatures. These insights are essential for industries requiring high formability and cost-effective material solutions, including automotive and appliance manufacturing, as well as the production of complex components like sinks. This study establishes a foundation for developing copper-enriched 304 stainless steel variants, emphasizing their technical and economic benefits.

Keywords: Ductility, Formability, Strain induced α′-martensite, Nohara's Md30 Parameter

ISM_180

Minimization of Edge Slivers in 410DB Grade Stainless Steel

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Abstract

Slivers, elongated surface defects, can significantly degrade product quality, increasing scrap rates and production costs. This project aims to minimize Edge Sliver defects in grade 410DB(11% Cr)which is martensitic stainless steel grade primarily used for the Disc Brakes application.
In this project, a Lean Six Sigma methodology – the DMAIC Framework was employed to systematically identify and mitigate the root causes of Sliver-C edge defects. Tools like, Random Forest – Data Analysis using software like Alteryx was employed and Scanning Electron Microscopy (SEM) analysis on the defect samples were used to identify potential elements for the defect. The results from the analysis indicated that ferrite potential (FP), sulphur content (%S), and SEN port type and immersion depth were the primary contributors to sliver defects. Modification were made to the ferrite potential and sulphur content, and modifications were introduced to the SEN port angle and immersion depth. These changes optimized the balance between these critical factors, significantly reducing sliver formation. Process changes were standardized and integrated into the production workflow to maintain quality improvements. The incidence of defect was markedly reduced, evidenced by lower error rates over successive production runs, thus effectively reducing Sliver-C Edge defects in grade 410DB stainless steel production, improving product quality and production efficiency while reducing costs.
Keywords: Sliver-C Edge, martensitic stainless steel, Lean Six Sigma, Random Forest, SEM, Ferrite Potential

ISM_183

Coke Drying System- An Engineering Solution for Reduction of Coke Moisture at G Blast Furnace

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Abstract

Raw materials which are used in blast furnace for producing pig iron are coke, iron bearing materials (Sinter, Pellet etc) and fluxes. In general, around 70% of total cost belongs to the coke cost. Profitability of pig iron production mainly depends on how judiciously use of coke is managed. Till October'2021 majority of the coke at G blast furnace was supplied from Battery 5,6 &7 Coke Plant which was Dry Quenched Coke (CDQ). CDQ coke supply stopped from December'2021 after Battery 5 & 6 upgradation job start and HMC coke from Haldia along with wet quenched coke supply from battery#7 started. HMC Coke already contains high moisture and moisture increasing intensity increased more in monsoon during loading, unloading & transport due to its susceptibility to absorb rainwater. Therefore, G blast furnace likely to suffer utmost during monsoon compared to earlier monsoon period with CDQ Coke. Increase of Coke Moisture in Blast Furnace adversely impact Fuel Rate & Productivity because of condensation of moisture in upper part of furnace, improper preheating of burden inside furnace, decreasing of furnace isothermal zone, disturbance in charging system followed by process disturbance etc. In this scenario reduction of fuel rate in G Blast Furnace supposed to be a major challenge. Team of G Blast Furnace tried to explore various available options for reduction of coke moisture. After several discussion and brainstorming session between cross functional team, G Blast Furnace installed Coke Drying System (CDS) in its Stock House. For drying coke, a tapping point from existing cold blast line was drawn and this wind with temperature (~210 Deg C) is mixed with ambient air of an Induced Draught Fan (ID Fan) to control wind temperature. Next this mixed air with temperature (~100 Deg C) is supplied to all Coke Bins for drying Coke. After installation of CDS System at G Blast Furnace Stock House reduction of 1% coke moisture became possible with decrease of 3 Kg/THM Carbon Rate.

Parameters	Unit	Period Without CDS (Dec'21-Sep'22)	Period With CDS (Oct'22-Oct'23)	Change	Impact	Gap
Production	tpd	6455	6503	48	Increase in Production Rate	
Coke Rate	kg/thm	321	318	3	Reduction in Coke Rate	
Coal Rate	kg/thm	204	203	1		
Corr. Fuel rate	kg/thm	524.0	521.0	3.0	Reduction in Fuel Rate	
Corr. Carbon Rate	kg/thm	442	440	2	Reduction in Carbon Rate	
Total_Oxygen_Flow	Nm3/hr	62662	64126	-1464		-148
Sp_O2_Rate	Nm3/thm	233	237	-3.68		
Total Agglomerate	%	93	93	0	-1.5	0.00
HM Si	%	0.63	0.62	0.01	2.5	0.25
Coke Moisture before CDS	%	6.36	6.86	0.50		
Coke Moisture after CDS	%	4.95	4.44			
Coke Moisture Dcecrease	%	1.41	2.42	1.01	3	3.03
Flux Rate	kg/thm	5	8	-3.00	0.3	-0.90
Coke Ash	%	14.27	14.2	0.07	5	0.35
Humidty	gm/Nm3	20	20	0.08	0.45	0.04
Slag Rate	kg/thm	326	325	1.00	0.15	0.15
HBT	DegC	1194	1193	1.00	-0.12	-0.12
Overall Benefit in Fuel Rate(Kg/Thm)						2.80

Fig.1: Reduction of Coke Moisture after CDS installation compared to Non CDS Period

Key Words: Coke Moisture, Isothermal Zone, Coke Drying System, Fuel Rate, Productivity

ISM_012

Control of Coke moisture in wet quenching process

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Abstract

Recovery coke ovens play a vital role in integrated steel plants by ensuring a continuous supply of coke and gas essential for steel production. At JSW Vijayanagar Works, 10 recovery coke oven batteries are in operation: eight with 4.3m tall ovens and two with 6.25m tall ovens, with two additional batteries scheduled for commissioning. This paper discusses the experiences in maintaining coke moisture at less than 5% through the wet quenching process at the blast furnace end from Coke Oven#5 Battery-A & B.

Coke quenching involves cooling hot coke from 1050°C to below 150°C, necessary for handling on conveyor belts. This process can be achieved in two ways: by circulating inert gas, such as nitrogen, known as the Coke Dry Quenching (CDQ) process, or by spraying water on the hot coke, known as the Wet Quenching (WQ) process. This paper focuses on controlling coke moisture through the Wet Quenching route. Coke moisture from Coke Oven#5 was initially high, with a mean of 6.0% and variation between 4 to 10% at BF-3 and BF-4, where the wet quenching process was used.

The study identified several root causes affecting coke moisture during this process. The water discharge pattern above the hot coke in the loco wagon was analysed, revealing differences in the dispersion angle of some spray nozzles. The water flow, driven by gravity from tanks at a certain height, reduced as tank levels dropped during the quenching cycle. Significant factors included the retention time of quenched coke in the wharf and the waiting time of the quenching car before discharging quenched coke to the wharf. Moisture levels also varied with the level of coke in storage bunkers, increasing with longer retention times. Additionally, coke moisture was affected by coke fines sticking to the chutes and coating the dry coke, as well as by water condensation in the pipe conveyor used to transport hot coke. Open ends of the pipe conveyor at the head and tail-end allowed rainwater entry, with the water remaining undrainable due to level differences, removable only by passing coke through the conveyor. Proper centring during quenching and water spray on hot spots in the wharf were also critical factors to be looked into.

Changes were incorporated in nozzle distribution depending on the density of coke in the bucket, leading to an optimized quenching cycle. SOPs were strengthened for water drain time, coke discharge to the wharf, and hopper retention time by incorporating signal interlocks. Further, other shortcomings such as rainwater entry and spot quenching were also addressed. For better safety, an emergency water spray was also installed along the length of the wharf conveyor. Incorporating these solutions significantly reduced coke moisture levels, reducing variation to a range of 3-5%. The findings from this study are significant and can be applied to other coke ovens with wet quenching facilities.

Key words : Coke Warf, wet quenching, condensation, steam, fines, retention, water spray, pipe conveyor, condensation

MPR_266

Analyzing microstructure to predict Coke's hot strength Characteristics

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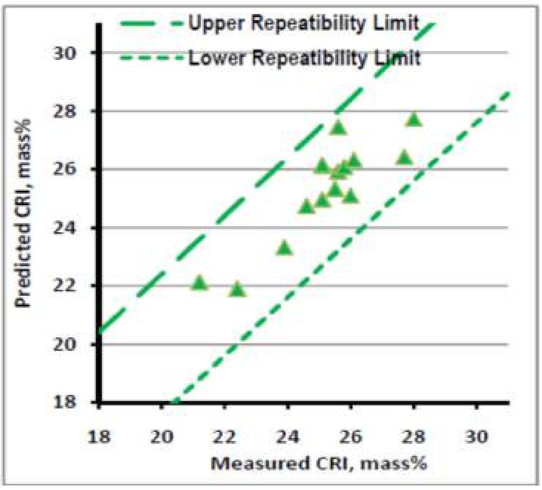
Abstract

Coke is the most important raw material fed into the blast furnace in terms of its effect on the blast furnace operation and hot metal quality. Over the last few decades, due to iron making trends towards increased size and higher throughput of blast furnace together with high levels of pulverized coal injection, the hot strength of coke has gained further significance.

Coke structure evaluation is an important factor in deciding the coke quality. Microstructural analysis of coke in terms of different carbon forms were studied under reflected type microscope. Different microscopic carbon forms are indicative of the constituent macerals of the individual coal and its rank. A correlation was developed for prediction of CRI & CSR from coke microstructure parameters. Figs. 1 & 2 show the deviation of predicted (using the correlation) CRI & CSR, respectively, from the measured values. From the figures, it can be seen that except for one predicted CSR value, all the remaining twenty nine predicted values (CRI & CSR together) fall within the 'Repeatability Limits' prescribed in ASTM D5341/D5341M. In essence, microscopic analysis of coke structure serves as a fundamental tool for quality control, process optimization, performance prediction and innovation in the coke-making industry.



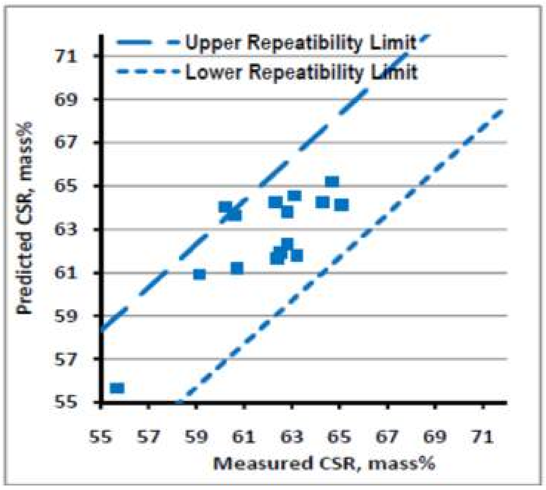


Fig. 1: [

Fig. 2: [

eviation of predicated CRI from measured CRI

eviation of predicated CSR from measured CSR

Key words: Coal, coke structure, CRI,CSR, coke petrograph

ISM_042

Enhancing Coke Quality through Streamlined Coal Preparation Techniques

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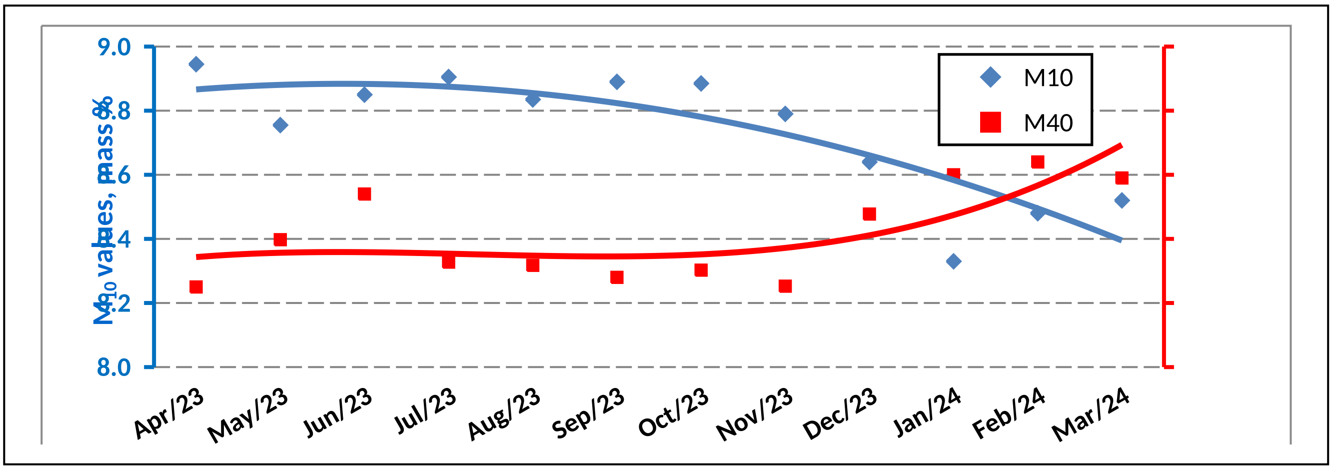
Abstract

The quality of coke, particularly its cold and hot strength, is crucial for ensuring the smooth operation of a Blast Furnace. Coke serves as the primary raw material that significantly influences both the operational efficiency and the quality of hot metal produced in the blast furnace. In the period of 2021-22, the M_{10} index, a key indicator of coke quality at BSL, stood at approximately 9.2 wt. % despite using a blend of imported coal comprising 75 to 80 wt. %.To enhance coke quality, plant trials were conducted using a rationalized coal preparation scheme, which established a comprehensive database for coal blends and coke quality. Carbonization studies on the charged coal were carried out using 20 kg batches, focusing on optimizing granulometry. These studies demonstrated that refining the coal charge granulometry by reducing both coarser and micro-fine fractions led to improvements in coke quality.

The 20 kg trials revealed significant enhancements across various coke quality parameters: the M_{10} index improved by 0.9 points, the M_{40} index by 1.0 points, the Coke Reactivity Index (CRI) by 3.9 points, and the Coke Strength after Reaction (CSR) by 3.1 points. Specifically, there was a notable improvement in the M_{10} index, which decreased by 0.5 points from 9.2 wt. % to 8.7 wt. %.In conclusion, optimizing the coal charge granulometry resulted in enhanced hot and cold strength properties of coke, underscoring its pivotal role in bolstering blast furnace



efficiency and hot metal quality.

Key words:Coke, M_{10}, Optimization, Granulomet

ISM_044

Dosing of inferior grade coke waste material in Metallurgical Coke Making

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Abstract

In the iron and steel industry, the rising price of the raw material is leading to an increase in the production cost of hot metal. Coke, which is the primary raw material for iron making accounts for the significant cost of hot metal. Hence, to minimize the cost of coke making, usage of inferior grades of coal is thought of at Tata Steel Jamshedpur. In addition to the Pulverized Coal (PC) *(which is already in practice)*, usage of waste such as Coke Dry Quenched (CDQ) dust and Swamp Breeze is thought of as an alternate input in Coke making. Though the objective is to replace the existing hard coking coals up to certain extent, focus was to do it, without compromising the coke quality and also favoring the economics. CDQ dust & Swamp Breeze act as inerts in the coal blending. Inerts helps to improve the coke mean size during the carbonization process, by suppressing the thermal stresses, leading to lesser fissures generation and formation of bigger size coke. Having said that, it is important to maintain the overall reactive to inert ratio in the blend. Various Design of Experiments (DOE) and plant trials were carried out to optimize the dosing of CDQ dust and Swamp Breeze in the coal blend.
In the pilot oven study, with the addition of Swamp Breeze by 1% & 2% respectively, marginal drop in the Coke CSR was observed. CDQ dust addition was carried out by varying the amounts of addition between 1% and 3 %. From the plant trials, it was observed that 1% dosing of CDQ dust in the blend divulged as optimum percentage for attaining higher coke mean size with an improvement in the BF coke yield by 0.5%.

Keywords: Coke dry quenching dust, swamp breeze, coke mean size, coke yield.

Coke Moisture Reduction: A case study on Techniques and its effect

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Abstract

Coke quality plays an important role for the production of hot metal in Blast Furnace. Extraneous materials, like moisture, reduce the actual amount of carbon available for reduction in Blast Furnace. High moisture content in coke not only reduces its calorific value but also adversely affecting the overall energy efficiency of blast furnaces. Further, in case of high moisture content of coke, additional heat will be required to drive away this extra moisture leading to higher coke rates. The reduction of moisture in coke is a critical aspect of improving the efficiency and effectiveness of metallurgical processes, particularly in the iron and steel industry.

This paper explores various methods and technologies employed to reduce coke moisture content, such asmoisture absorption and drying techniques.Moisture absorbents was sprayed on wet coke at a dosing rate of 500-1000 gpt for its effect on reduction in coke moisture. Additionally, an innovative approach for reduction in coke moisture was also evaluatedby blowing heated air at 300-350 °Con conveyor belt. A series of trials were conducted to compare the effectiveness of these methods in reducing coke moisture levels. The study found that drying technique, significantly lowered moisture content by 1 wt. % compared to the absorption technique, which reduced moisture by 0.5 wt. %, while maintaining the structural integrity and chemical properties of the coke.The result indicates that the adoption of drying techniquecan lead to substantial cost savings and a reduction in CO_2 emissions, making the process not only economically viable but also environmentally sustainable.

key words: Coke, Coke Moisture, Absorbent, Heated Air

ISM_083

Enhancing Coke Reactivity through Innovative Polymer Coating: HG-200

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Abstract

Improving the efficiency of blast furnaces is crucial for enhancing productivity and reducing operational costs in metallurgical processes. This research focuses on HG-200, a novel polymer coating designed to enhance the reactivity of nut coke, thereby optimizing blast furnace performance. The innovative approach involves the application of HG-200, which is blended with a bio nano carbon base that releases hydrogen and other reactants at elevated temperatures (500-600°C). This release enhances the reactivity of the coke, leading to increased production of carbon monoxide (CO) and syngas, both essential for efficient blast furnace operations.

The study's methodology includes the application of HG-200 coating on coke surfaces, followed by measuring hydrogen release and reactivity enhancement using Thermogravimetric-Mass Spectrometry (TG-MS). The impact on coke properties, including Coke Strength after Reaction (CSR) and Coke Reactivity Index (CRI), is evaluated. Additionally, reactivity simulation tests in an environment similar to the blast furnace environment are conducted to simulate blast furnace conditions and observe the coated coke's performance. Pilot testing in a blast furnace setting is performed to validate efficiency improvements. A comparative analysis of the environmental impact before and after HG-200 integration is also included.

Results from the tests indicate a significant increase in CO gas levels at temperatures between 830-870°C, reaching up to 6%. The initiation of weight loss at approximately 600°C, with a maximum weight loss of 78mg, demonstrates the reactivity of the coated coke. These findings suggest that HG-200 significantly enhances coke reactivity, contributing to improved blast furnace efficiency and reduced environmental impact.

Further studies on the impact of similar additives on different grades of coal like anthracite, thermal coal used in DRI and Power plants is being studied. The initial results are highly encouraging and the innovation has the potential to reduce the carbon footprint of the existing processes.

Key words : Blast Furnace Efficiency, Coke Reactivity, HG-200, Polymer Coating, Metallurgical Process

ISM_105

Improvement in Coke Mean Size with data driven diagnostics and predictive modelling

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Abstract

Coke mean size plays a vital role in both coke making and iron making processes, significantly influencing the efficiency and quality of production. In coke making, the size of the coal charge, carbonization conditions, screening and quenching processes determine the mean size and quality of the resultant coke. Larger coke particles tend to provide better mechanical strength and reactivity, which are essential for maintaining permeability in the blast furnace. Conversely, an inappropriate coke size distribution can lead to operational inefficiencies, such as reduced furnace stability and increased fuel demand. Therefore, achieving an optimal coke mean size is essential for maximising the overall productivity and cost effectiveness of coke and iron making operations.

To address these challenges, this paper proposes a two-stage modelling approach: the development of a diagnostic model followed by a prediction and optimization model. The diagnostic model aims to identify and analyse the key factors influencing coke mean size, utilizing historical data and process parameters. By employing advanced statistical techniques and machine learning algorithms, the diagnostic model provides insights into the critical variables causing deviation in coke mean size from its optimal value. This foundational model serves as a basis for understanding the current performance and identifying potential areas for improvement.

Once the diagnostic model is established, a prediction and optimization model is developed. This model leverages the insights gained from the diagnostic phase to forecast coke mean size under various operational scenarios. By integrating predictive analytics with optimization techniques, the model can suggest optimal operating conditions to achieve desired value of coke mean size. This holistic approach not only enhances the predictive accuracy but also enables proactive adjustments to the process parameters, ensuring consistent and optimal coke quality.

Key words : Productivity, Diagnostic, Predictive, Optimization

DIN_078

Prospect for Cokemaking for Sustainable Iron and Steel Productio

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Abstract

The iron and steel industry faces a critical juncture, balancing global demand with environmental concerns. Worldwide efforts to address these issues have led to advancements in energy efficiency, waste reduction, and emissions mitigation. Sustainable practices such as reducing energy consumption, achieving zero discharge, and utilizing industrial waste present compelling alternatives to conventional methods. The urgency to transition towards eco-conscious practices is to be emphasized by the sustainability challenges of traditional production. The investment in innovative cokemaking technologies has shown promising results, indicating the feasibility of eco-friendly production methods. This paper explores pathways towards a greener future by reframing these technologies as catalysts for sustainable iron and steel production. Also providing valuable insights, it illuminates the potential for a more sustainable approach to iron and steel production.

Keywords: Ironmaking, cokemaking, sustainability, environmental impact, energy efficiency, waste management

ISM_177

Biocoke as a sustainable alternate carbon reductant for ferroalloy production.

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Abstract

Ferroalloys are alloys of carbon with leading elements like chromium, manganese, silicon etc. Ferrochrome is used in the production of stainless steel. They are vital components in the production of all types of steels including stainless steel. The iron and steel industry are the highest environment polluter accounting for nearly 26% of the global industrial CO_2 emissions and 11% of total anthropogenic emissions. India manufactures 5.15 million tons of ferroalloys annually, requiring 1.54 million tons of carbon reductants every year. One solution for this industry is to replace fossil-based carbon (Coal and Coke) with bio-based alternatives. The biggest advantage of bio-carbon is that it is carbon neutral. Thus, substitution of conventional coke reductants with biochar has the potential to drastically reduce the greenhouse gas (GHG) emissions from the heavily polluting industry. This study focuses on the partial substitution of the conventional carbon reductants used in smelting of ferrochrome with bio-based alternative leading to the use of biocoke reductants.

Fig. 1: Babool based Char.

Keywords: Alternate carbon reductants, Ferrochrome, Biocoke, Carbonization, Ferroalloys, Smelting, Submerged Arc Furnace, Biocarbon, Sustainability, Green Ferroalloys, Substitution.

ISM_168

Impact of parameters derived from crude gas temperature measured at gooseneck level on coke quality and oven push force.

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Abstract

Coke is one of the most significant raw materials in Blast Furnace to produce hot metal and it itself accounts for almost 50% of the total cost of hot metal from Blast Furnace. It serves three main functions inside blast furnace; Thermal Function: It provides heat required for chemical reactions to occur. Chemical Function: It provides reduction potential in form of carbon monoxide. Also, it carburizes hot metal. Physical and Mechanical Function: It supports the overlying burden. At the lower part of blast furnace, where the charge melts, it provides high permeability zone for drainage of molten metal and slag while providing gas distribution in BF. Considering all these aspects, it is important to consistently supply good quality coke to blast furnace. Quality of coke primarily depends on coal blend parameters and extend of carbonization process in coke ovens. The carbonization of coke gets complete once the center coke mass temperature reaches 1000°C. However, it is not reliable to measure the center coke mass temperature during carbonization process. The crude gas temperature measured at gooseneck level by thermocouple has become a reliable process parameter to assess the completion of carbonization process. Typical temperature profiles exhibit temperature remaining constant between 600-650°C for 75-80% of coking time, reaching a peak value followed by decline. The peak value in temperature reaches when the crude gas evolution is maximum which coincides with plastic layers from both ends of coal charge meeting at the center. The commencement of decline in temperature shows decrease in evolution of volatile matter which is an indication of entire coal mass being transformed to coke or semicoke. Also, it is observed that raw gas temperature achieves a value in specific range 1 hour before complete carbonization process in coke ovens which in turn was assessed by visual observation of smoke coming from coke while being pushed out of oven and temperature gradient between coke at center and close to walls of a coke oven. This paper discusses the three parameters derived from gooseneck temperature profile, namely, Time to Reach Maximum Gooseneck Temperature (TRPGT), Coking Time post Peak Gooseneck Temperature (CTpPGT) and Gooseneck Temperature 1 hour before scheduled coking time (1 hr prior GNT) and its effect on coke quality and oven push force.

Keywords: Carbonization process, TRPGT, CTpPGT, 1 hr prior GNT, Coke quality, Push force.

ISM_198

Optimisation of Coal Blend in JSW Dolvi Coke Ovens

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Abstract

JSW Steel Ltd., Dolvi plant have two stamp charged coke ovens with annual capacity of 1 MTPA & 3 MTPA respectively which supplies coke to two blast furnaces. Coke quality plays a significant role in achieving stable and consistent blast furnace operation. The coke quality in turn depends primarily on coal blend characteristics like Crucible Swelling Number, Fluidity, MMR, Vitrinite Content, Crushing Index and Carbonization Process in coke oven. A proper blending strategy needs to balance the inclusion of medium and soft coals along with the costly prime or hard coal. Hard coking coal (HCC) is traditionally the preferred raw material for its superior coking properties and contribution to high-quality coke production. JSW Dolvi unit continuously exploring opportunities to optimize coal blend in the coke oven process to enhance our production processes for cost advantages. The preliminary analysis carried out in Dolvi suggests that a controlled reduction in the percentage of prime HCC in coal bend can be achieved without compromising the quality of our coke and overall operational performance of BF. In the present work, we have conducted various in-house tests on the different available coals to optimise coal blend characteristic and HCC percentage effectively reduced from 45% to 32%. By improving coal blend crushing index from 84% to 90% and restriction on high fluidity coal percentage from up to 40% in coal blend. The poor coal blend mix can deteriorate the coke cold strength (M40), coke hot strength (CSR) and mean particle size. Various field test results confirmed that reduction of HCC percentage is possible by optimising coal blend and coke oven process parameters. Very low HCC percentage can deteriorate coke quality.

Key words: Hard Coking Coal, MMR, Fluidity, Crushing index, Vitrinite etc.

MPR_114

Impact of Coal Blending and Charging Techniques on Coke Microtexture and Quality

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Abstract

Numerous studies have investigated conventional coke making through top charging, correlating the proportion of various microtextural features with coke properties. However, limited research has been conducted on coke produced by increasing bulk densities using stamp charging technology on both single and blended coals. In this study, indigenous and imported coals, along with their blends, were used to prepare cokes via both stamp charging and top charging methods. Five coals, ranging from high volatile to low volatile, were selected for this study. Among these, one coal is of imported origin. The reflectance values of the samples range from 0.68% to 1.44%, and reactive macerals vary from 44.2% to 96.5%. The five coals were blended in different proportions to create five blends (Blend I: 20:30:50, Blend II: 40:20:40, Blend III: 25:40:35, Blend IV: 60:40, and Blend V: 10:40:50), with reactive macerals of 51.1%, 60.0%, 72.8%, 74.6%, and 57.7%, respectively. These blended coals were charged using both top charging and stamp charging methods. Variations in the coke properties of the charges were observed with changes in the proportion of different coal types in the blends, stamping pressure, and top charging. This variation was also reflected in the cokes prepared from the different blends in both charging cases. The coke microtexture analysis revealed that, without stamp charging, the coke contained a higher percentage of isotropic and anisotropic carbon. Anisotropic carbon is less reactive to carbon dioxide compared to isotropic carbon, and the Coke Strength after Reaction (CSR) depends on its anisotropic carbon content. An increase in isotropic carbon deteriorates the cold strength and increases the Coke Reactivity Index (CRI). A comparative evaluation of the study revealing significant differences in properties between coke samples produced by stamp charging and top charging. Improvements in coke quality parameters, such as hot strength (CRI, CSR) and cold strength (M10, M40), were found to be related to the microtextural patterns of the cokes.

Key words: Coke Microtexture; Stamp Charging Technology; Top Charging Method; Coal Blending; Coke Quality Parameters

MPR_146

Process optimization and operational control measures for reduction in charging emission in Coke ovens

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Abstract

The significance of emission control in coke oven operation has changed substantially in recent times. Today, the foremost task of a modern coke plant is to operate in an environment friendly atmosphere with emissions as low as possible. Despite having best available technologies (BAT) of high-pressure liquor aspiration (HPLA) and charging gas transfer (CGT) car, there are several instances when charging emission happens and large volume of raw coke oven gas is released in the environment. During the study it was found that synchronization of CGT operation, HPLA valve opening position with charger plate are some key steps which results in better emission control. Monitoring of HPLA pump pressure during charging, roof carbon monitoring and implementation of automation logic with foul gas main suction also works very effectively. The paper describes all these various process and operational controls which plays vital role in charging emission control in coke ovens.

Key words : Coke oven, Charging emission, HPLA, Roof carbon, CGT car

ISM_209

An efficient process for producing low phosphorous steel in induction furnace using a novel compound

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Abstract

The steel industry is a cornerstone of economic development globally. India exemplifies this by emerging as the world's second-largest steel producer with an annual output surpassing 100 million tonnes. As reported by the Ministry of Steel around 35% of India's steel is produced through the Induction Furnace (IF) route, utilizing DRI and scrap as primary raw materials.

Various global disruptions like Covid-19 Pandemic & Russia-Ukraine crisis pose significant challenges & impact the import of scrap, severely hitting India's secondary and scrap-based steelmakers. As a result, IF route steelmakers have to use higher % of DRI coupled with poor quality scrap from local market, which increase the input phosphorus in their charge mix. Thus induction furnace being a melting & non-refining furnace is not being able to meet the quality norm set by the Bureau of Indian Standards (BIS) IS.1786.2008 which restricts Phosphorous limit in rebars to less than "0.055%. Owing to this, there is a safety & sustainability risk to buildings and other structures made with construction Steels as higher Phosphorus decreases the ductility of steel severely due to the embrittlement and thus increases the tendency to produce crack during cold working. Hence, there is an imminent need to develop a process to produce steel with low Phosphorus.

Recognizing this critical need, JAMIPOL has developed a pioneering solution that combines a special reagent with an optimized process to reduce phosphorus levels in steel produced through the IF route. This solution has undergone extensive laboratory testing with a 20kg induction furnace, followed by successful industrial trials in a 15 MT induction furnace at BMM ISPAT.
BMM ISPAT and JAMIPOL collaboratively overcame the application challenges and optimized the process to meet the stringent phosphorus requirements for quality construction steel.
JAMIPOL's innovative reagent and process provide a significant opportunity to collaborate and contribute to the creation of "Safe Steel," thereby together constructing a safer and resilient construction in the emerging Indian economy.

Key words: Dephosphorisation, refining.

ISM_045

Strategy for production of low phosphorus steel in BOF from low silicon high phosphorous hot metal

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Abstract

High phosphorous in iron ores and high ash content in coke generally causes higher phosphorous in hot metal from blast furnaces at Tata Steel. On the contrary, there is an ever-increasing demand of low phosphorous steel by the customers. In recent times, improved blast furnace practices result in low silicon in the hot metal. Therefore, to meet the demand of low phosphorous steels from relatively high phosphorous (average 0.17%) and low silicon (≤0.5%) hot metal with Si/P ratio <3 through Basic Oxygen Furnace (BOF) is a great challenge. Some factors which influence dephosphorisation in BOF include end blow (EB) temperature, slag basicity, slag fluidity, slag oxidizing potential. Along with these factors addition of higher amount of lime has been a practice in one of the steelmaking shops to treat such hot metal. But how much lime is appropriate needs to be understood hence, a detailed analysis was conducted with plant data. The analysis indicated that a scope exists for lowering lime addition and thus saving natural resource and production cost. Accordingly, systematic trials were conducted with reduction in lime from the existing level. The results showed that 12% reduction in lime had no effect on end blow (EB) P but further reduction in lime increased EB P. Moreover, time of lime addition during blow and number of batches also found to impact EB P. Slag samples from trial and regular heats analysed using SEM-EDX techniques revealed morphological changes and reduction in free lime in trial heats. The paper will discuss these aspects in detail.

Keywords
Basic oxygen furnace, Dephosphorization, Hot metal, Slag basicity, Free lime, Low silicon

ISM_051

The Synergistic Role of Calcium and Barium in Non-Metallic Inclusion Modification for Enhancing Steel Cleanliness

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Abstract

Non-metallic inclusions significantly influence the mechanical properties and quality of steel. These inclusions, predominantly oxides and sulfides, are critical factors in the formation of fatigue cracks, tensile failures, and various defects in steel products. The presence of inclusions also leads to clogging of sub-entry nozzles (SEN) during the continuous casting process leading to abrupt failures and production stoppages.

Calcium treatment, a widely used method to modify and remove inclusions, involves adding calcium alloys like calcium silicide, CaFe, and pure calcium metal-based wire into the steel. This process transforms solid alumina inclusions into calcium aluminates with lower melting points and alters MnS to (Ca, Mn)S. Benefits include enhanced steel flow characteristics, smoother continuous casting, improved steel purity, reduced nozzle blockages, better machinability and ductility, and increased impact strength.

However, the effectiveness of calcium treatment faces challenges due to calcium's properties, such as low solubility and high vapor pressure at steelmaking temperatures. Despite these challenges, optimized calcium injection techniques, such as injecting calcium at greater depths in the ladle to counteract vapor pressure, have shown improvements. Nonetheless, inconsistent calcium recovery and resultant incomplete inclusion transformations pose ongoing issues.

This research explores an alternative approach using barium-bearing calcium cored wire (CaSiBa). Barium, with a higher boiling point and lower vapor pressure than calcium, reduces the latter's vapor pressure and enhances its solubility in the steel matrix. Plant trials demonstrated that CaSiBa cored wire significantly improved calcium recovery and inclusion modification. The introduction of CaSiBa led to the formation of smaller, more spherical inclusions, which are easier to remove and less likely to cause defects. The trials showed a notable reduction in MnS and FeS inclusions and an increase in small, uniformly distributed D-type inclusions.

Mechanical tests on steel samples treated with CaSiBa showed enhanced properties, particularly in terms of impact resistance. The addition of CaSiBa improved Charpy impact values at room temperature by about 15% compared to CaSi treated steel. The study concludes that the use of CaSiBa alloys in steel refining provides superior results in inclusion modification and overall steel quality improvement, presenting a promising alternative to conventional calcium treatment methods.

Keywords: Steel cleanliness, non-metallic inclusions, calcium treatment, barium addition, inclusion modification
ISM_073

Evolution of inclusions during the ladle refining of tyre cord steel

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Abstract

Tyre cord steels are one of the most extensively developing rubber frame work material. Tyre manufacturers demand the tyre cords with higher breaking strength to reduce the weight of the tyre. The typical tyre cord steel of ϕ0.12-0.25mm is produced by drawing the ϕ5.5mm as hot rolled wire rod coil. The presence of non-deformable inclusions with the incoherent boundary, centre segregation of some elements, and centre porosity causes breakage of tyre cord during the drawing. The deformable inclusions in tyre cord steels are MnO-SiO_2 with Al_2O_3 content of ~10 to 20% because of their low melting temperature. The deformability of the inclusions is greatly affected by Al_2O_3 content and the inclusions with up to 20% have better deformability. The undeformability index decreases with increase in Al_2O_3 content and reaches the best at 20% Al_2O_3. The presence of dissolved aluminium in steel directly affect the formation of deformable inclusions and the lower aluminium content favors the formation of deformable inclusions. To achieve the plastic inclusions in tyre cord steels, the slag basicity (CaO/SiO2) has to maintained at about 1.0 and the slag Al_2O_3 has to be less than 10%. Typically, the basicity range of 0.8 to 1.5 is used in this case to produce the plastic inclusions.

These low basicity slags have very poor desulphurization capability and it can be reflected in the Sulphur removal during the ladle refining and also during the vacuum degassing. In case of higher sulphur content in the hot metal, without sulphur pretreatment facility, the slag basicity needs to be maintained higher than 1.5 to achieve better desulphurization during the ladle refining process and it can be adjusted in the middle of the ladle refining process. In the present work, the effect of slag with the basicity level of ~2 on the inclusion composition is studied in detail. Results of the study with respect to size, area, density and type of inclusion formed will be presented.

Key words : Tyre cord steel, Secondary steel making, Automated inclusion analysis

ISM_145

Enhancing Steel Cleanliness in SBQ Grades: A Comprehensive Approach to Inclusion Control through Slag Engineering and Deoxidation Optimization

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Abstract

In Special Bar Quality (SBQ) steel, maintaining high cleanliness standard is essential. The detection of larger inclusions, known as macro inclusions, during ultrasonic testing (UT) often leads to rejection, resulting in significant internal losses. To meet the stringent cleanliness requirements for SBQ grades, an in-depth study was conducted to understand the formation of these inclusions. A SEM-EDS analysis revealed alumina-based inclusions as the primary type. The process study further revealed that the existing slag had poor inclusion absorption capacity, necessitating modifications in slag composition. To address this, the steel deoxidation method and slag composition were adjusted. Thermodynamic studies using FactSage were done to arrive at an optimal slag composition that enhances inclusion absorption capacity of the slag. By implementing the new tapping addition module and refining slag engineering, UT rejections due to inclusions were reduced by 68%.

Keywords: SBQ, UT rejection, Steel Cleanliness, slag.

ISM_167

Operational and Metallurgical Strategies for Inclusion control in Electro Slag Remelting

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Abstract

Electro Slag Remelting (ESR) is a specialized secondary steel making process developed particularly for removal of Non-metallic inclusions namely Sulphides(A), Aluminates(B), ~Silicates(C), and Globular Oxides(D) from liquid metal by passing electrically generated metal droplets through a customized slag layer made up of CaF2,CaO and Al2O3 wherein inclusions get absorbed to obtain clean inclusion free steel. This process requires both metallurgical as well as operational strategies for better performance in terms of inclusion removal. Metallurgical control consists of mainly control of slag composition and chemistry alongwith purity and composition of the metal electrode. Whereas operational control involves various measure like Melting rate control by adjusting current and cooling water flow, slag metal interface control & slag pool depth by adjusting amount and time of addition of slag, Mould design namely round vs round cornered square, Inert gas atmosphere using Argon and Advance monitoring & control systems using Model controlled system having user friendly HMIs. Series of experiments were done using different feed material of variable purity and composition and use of deoxidisers vis-a-vis varying the process variables to obtain different results.It was seen that the cumulative effect of both type of control strategies helped to remove NMI to the optimum level possible and obtain thick and thin inclusions in the level of <1 and ~1 respectively as per ASTM E45-18A norms. .

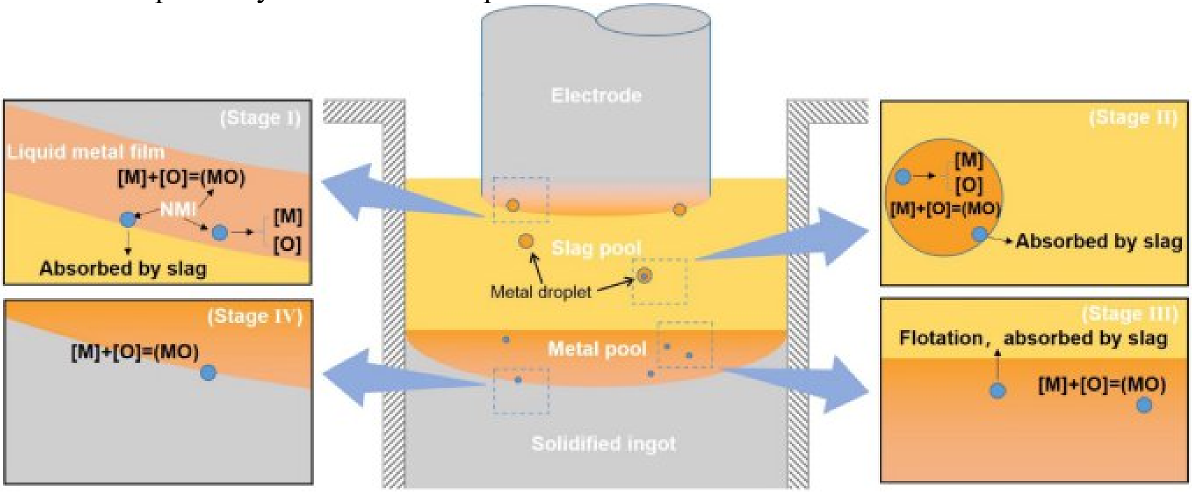

Fig. 1: Process of inclusion removal in ESR

Key words: Electro Slag Remelting, Inclusion, Slag, melt control

MPR_080

Quality enhancement of high carbon billet grade for tyre cord application through process re-engineering at SMS

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Abstract

Steel cord wire used in automobile tire reinforcement requires exceptional strength and durability, typically drawn from high-carbon billets with 0.7-0.95% carbon and a pearlitic structure. However, wire supplied by VJNR has faced frequent breakages during the final drawing stage at the customer's production line, causing substantial disruptions. Investigations identified the primary causes of failure as grain boundary cementite (GBC) phases and macro inclusions ranging from 20 to 80 µm. Specific GBC phases, including C, D, and E-types, introduced brittleness along grain boundaries, while macro inclusions of TiN and Al_2O_3 served as potential failure points.

The root cause was traced to an initial slag window with high basicity (B2) of 2.2-2.4, exceeding the optimal range of B2 ≤ 1.5 with less than 5% Al_2O_3 content. This imbalance led to poor inclusion capture, allowing TiN and Al_2O_3 impurities to remain in the final steel product. Analysis pointed to the ferroalloys and raw materials used during heat making as sources of these inclusions.

To enhance inclusion capture, the slag composition was re-engineered using thermodynamic calculations with FactSage, resulting in a more suitable slag window. The introduction of high-purity ferroalloys and raw materials reduced TiN inclusions to below 1 per sample and minimized Al_2O_3 inclusions to under 5 µm. Additionally, optimization of secondary steelmaking and continuous casting parameters, such as superheat, casting speed, spray cooling, and EMS current, improved the formation of desirable A and B-type GBCs, reducing the likelihood of fractures.

These comprehensive improvements led to a significant increase in the Quality Factor awarded by the customer, from <600 to 926. By addressing slag chemistry, raw material purity, and process parameters holistically, substantial gains in product quality and customer satisfaction were achieved.

Keywords: High Carbon Billet Grade, Tyre cord, GBC, inclusion, slag re-engineering

ISM_170

Evolution of oxide inclusions in Interstitial free (IF Grade) Steels during RH process

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Abstract

Interstitial free (IF) grade of steel, commonly produced through RH route, is of utmost importance due to their critical applications for home appliances and automobiles, which requires very high cleanliness and surface quality. Additionally, deposition of non-metallic inclusions (NMIs) inside the casting nozzles (tundish and submerge entry nozzle (SEN) is an inherent problem of continuous casting for such grades of steels, restricting the passage of liquid steel flow through the nozzles from tundish-to-mold. A prerequisite knowledge of the inclusion evolution is therefore important for taking necessary steps in controlling the steel cleanliness level.

The present study is aimed at studying the inclusion evolution behavior in Ti bearing ultra-low carbon IF grades and tracing the inclusions during the secondary metallurgy (RH) process and at tundish. The study shows the formation of majorly Aluminate type of inclusions after Al killing and mostly Aluminum Titanate type of inclusions after the addition of FeTi. A common trend of inclusions (type and amount) has been established with processing steps of the RH and at tundish. Additionally, the amount of initial Al addition has shown to affect the initial Al2O3 inclusions formation. The effect of slag behavior on inclusion behavior has also been investigated and evidence of reoxidation due to oxidizing slag has been found.

Keywords: Interstitial Free (IF) Steel, Non-metallic Inclusions (NMIs), RH process, Al killing, oxidising slag

ISM_023

Inclusion Modification and Separation During Steel Making Process in a Si-Mn Killed Tyre Cord Grade Steel

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Abstract

Steel and slag samples were taken from a Si-Mn-killed SWRH82A grade tyre-cord steel at various stages of its processing through Electric Arc Furnace (EAF) à Ladle Refining Furnace (LRF) à VD (Vacuum Degassing) à Tundish. Many types of inclusions were found, and their evolution was studied. During tapping from the EAF, inclusions like Al_2O_3 and $MnO-SiO_2$ were present. At the initial stage of LRF, they evolved into $MnO-Al_2O_3-SiO_2$. During LRF refining, the inclusions became more complex, including $CaO-SiO_2-Al_2O_3-MnO-MgO$ and $CaO-SiO_2-Al_2O_3-MgO$ with low MgO content. After VD treatment, the inclusions were predominantly $CaO-SiO_2-Al_2O_3$ with very small amounts of MgO. During casting in the tundish, $MnO-Al_2O_3-SiO_2$ inclusions were detected. The size range of observed inclusions were in between 5-45 µm. Moreover it was observed that, $CaO-SiO_2-Al_2O_3-MgO$ type of inclusions were common. Therefore, its origin, formation, evolution and morphology during different refining stages were analysed by conducting SEM/EDS analysis of steel samples. Thermodynamic software FACTSAGE was used to study the inclusions in $CaO-SiO_2-Al_2O_3$ ternary systems with varying MgO content as per the steel slag chemistry during steel making process. It is understood that $CaO-SiO_2-Al_2O_3-MgO$ inclusions originated from $CaO-SiO_2-Al_2O_3-MnO-MgO$ inclusions due to collision and coalescence of $MnO-Al_2O_3-SiO_2$ inclusions and emulsified slag particles in LRF operation carried out by maintaining a high flow rate of Argon(g) stirring along with lime addition during desulfurisation. From the slag-steel-inclusion multiphase equilibrium, the concentration of Al_2O_3 in the inclusions as a function of slag composition will be studied to find out a compositional window of slag for obtaining low melting point deformable inclusions with varying levels of soluble Al in steel up to 10 ppm. Additionally, the study will examine the effects of several factors on inclusions. This includes the forces acting on inclusions as they cross the slag-steel interface and the interfacial tensions between slag-steel, slag-inclusion, and steel-inclusion. The intensity and duration of Argon(g) rinsing as well as the physicochemical properties of both slag and steel will also be considered. These factors collectively impact the separation, assimilation, and size of inclusions. A detailed study of the above experiments and calculations will be presented, along with the results of these modifications and their implications for optimising inclusion control in Si-Mn-killed Tyre-Cord steel processing.

Key words: Tyre-cord steel, Inclusions, Inclusion-separation, Si-Mn Killed Steel

MPR_308

Low Grade Iron ore in Pelletizing –Consistent Productivity and Chemical Physical Quality of Pellets

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Abstract

In the last years, pelletizing has been playing an important role for iron ore mining and ironmaking. Some factors have contributed to this fact like as: depletion of high-grade iron ore reserves, expansion of Chinese steel production, growth of direct reduction, better performance of pellets in the reduction reactors, and environmental restrictions in sintering.

In this scenario, the world pelletizing capacity grew from 350 Mt/year in 2000 to more than 650 Mt/year in 2024.

As good quality iron ore deposits are depleting very fast beneficiation technologies must be adopted to meet iron ore demand. Treatment of lower grade ores with high combined moisture (LOI) with optimal thermal energy and achieving the desired pellet quality has become a challenge.

This paper gives an insight to the treatment of lower grade iron ores in pelletizing with the optimal productivity and thermal energy with the goal of minimizing the CO_2-emissions.

Key Words: Iron Ore, Decarbonization, Pelletizing, Productivity

Oxygen Enrichment in Sintering for Superior Quality Sinter and Reducing Return Fines Generation

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Abstract

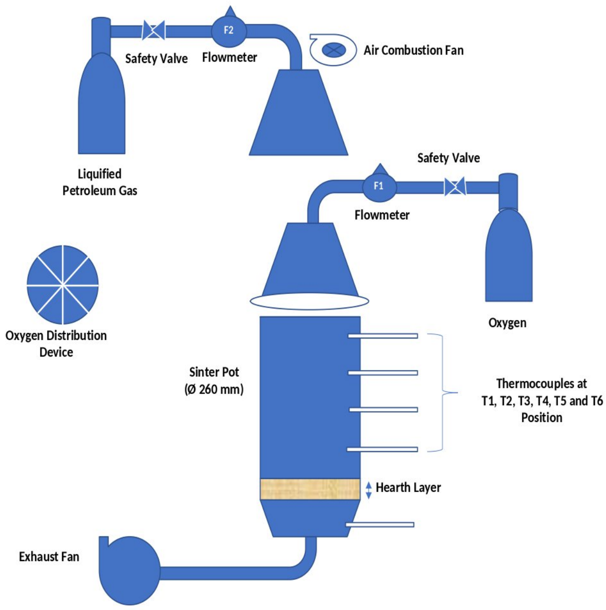
In the conventional iron ore sintering process, during ignition, the top bed experiences lower temperature and retention time than the deeper layers of the bed due to the practical limitation of achieving high sintering temperature and dwell time in the top layer because of the absence of preheating of the reactants, in contrast to the middle and bottom parts of the sinter bed, where flue gases preheat the green mix since, as reaction proceeds from top to bottom, flue gases from the top layer provide the heat required for drying. Therefore, the top part of the sinter bed yields weak and friable sinter, leading to poor sinter properties, and hence, the major source of internal return fines is the fragile top layer or top bed of the sinter.

This paper relates to the development of a method for achieving high sintering temperature and dwell time at the top layer by performing oxygen enrichment of the incoming air on the top part of the sinter bed, which improves heat accumulation along the sinter raw mix bed and overall sinter quality. The effect of oxygen enrichment with varying oxygen percentages of 0 to 12 vol% at the top layer of the sinter bed was investigated to obtain oxygen-enriched agglomerates with improved physical and high-temperature metallurgical properties. Oxygen enrichment increases hematite mass% at the expense of magnetite due to the suppression of reduction reaction and increased secondary oxidation at higher concentrations of oxygen in the incoming air, which will improve the bonding efficiency and overall sinter quality at the top layer, decreasing the internal return fines generation.

As oxygen is enriched by 6%% to 12%, the peak temperature in the top layer increases by 45°C to 103°C, respectively, and the sinter yield increases from 75.6 to 79.1% and the shatter index increases from 76.6 to 83.5%. This effect is attributed to higher rates of combustion due to a higher oxygen concentration, resulting in an increased degree of sintering with a higher FFS.

The enhanced oxidizing atmosphere during sintering caused by the increased oxygen enrichment load increases the sintering liquid phase, which is conducive to the agglomeration and mineralization of the sintered ore, resulting in an increased phase fraction of silico-ferrites of calcium and aluminium (SFCA), thereby improving the strength and yield of the sinter, especially at the top layers. This work also revealed that an excessive increase in oxygen enrichment does not contribute much to the sinter properties and softening melting performance of the sintered ore.

Fig. 1:



Schematic diagram of the sintering pot device and oxygen enrichment device.

Key words: sintering; oxygen enrichment; dwell time; top layer properties; FFS; SFCA-I.

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ISM_040

Reduction In Sinter Return Fine from Top Layer of Sinter Bed by Solid Fuel Redistribution

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Abstract

In the sintering process, top part of the sinter bed is weak and fragile compared to middle and bottom layer as the top layer undergoes sudden quenching by the ambient air pot combustion. This restricts the sintering reaction which leads to generation of return fines. To overcome this issue, a fraction of fuel from total fuel (5.05%) is redistributed on the top layer of the sinter bed. Pot grate experiments shows that the overall improvement in return fine generation is 4.6% and tumbler index by 1% with 2.1% fuel redistribution. The improvement is attributed to the change in thermal state (FeO%) and the combustion efficiency of the top layer of the sinter bed indicated by increase in the sintering temperature and the calcium ferrite phase, and the time spent by flame front above 1100°C. Section wise analysis also shows improvement of the top layer return fine generation. Saturation in return fine generation is observed beyond 2.1% fuel redistribution.

Fig. 1: Change in the top layer of the sinter bed with varying fuel redistribution

Key words: Top layer sinter bed; return fines; sinter yield; combustion efficiency

ISM_046

Effect of Adjustable Segregation Plate on sinter quality and productivity

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Abstract

To improve the sintering process at IISCO Steel Plant (ISP) has designed an adjustable segregation plate with the help of internal resources. The same has been installed after feed drum over the sinter machines. The significance of the adjustable segregation plate in iron ore sintering can be better granulometry control over the sinter bed. In existing system, fixed type segregation plate was provided after drum feeder. Thereafter the charge mix is fed to sinter furnace. Fixed segregation plate modified with adjustable type in both the plant during capital repair. Height and angle of inclination/repose can be adjusted with turnbuckles to handle variable size iron more micro fines. After commissioning, a comparative study was carried out for studying the effects adjustable seggregation plate. Study showed adjustable seggregation plate provides flexibility of charge different type of raw materials with varied angle of slope. Also, the segregation of material on sinter machine was proper. The objective of this study was to envisage the actual benefits from adjustable seggregation plate. Improvement in productivity has been observed inline with increased waste utilization. Further reduction in total amount of coke breeze, with process optimization, can help in reduction in production cost of sinter.

Fig. 1: Adjustable seggregation plate

Keywords: Segregation plate, return fines, sintering, productivity, permeability
ISM_062

Production of Green Sinter – Iron ore sintering using Biomass

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Abstract

Mechanized mining of iron ore mines produces a range of size of raw materials. Sintering of iron ore fines is the key to utilize the fines ranging from 3mm to 7mm . The fines less than 1 mm is further used for pelletization . Iron ore sinter is an important raw material for Blast Furnace . It replaces Iron ore to the extent of 70- 75 % and decreases the coke rate of the Blast Furnace . It is referred to as the Half Prepared Burden . The sintering process involves the agglomeration of iron ores and concentrates along with fluxes and fuels to form porous agglomerate . Metallurgical coke breeze has traditionally been the preferred fuel , however increasing environmental concerns and the quest for sustainability have spurred interest in alternative fuel sources such as biomass.

Biomass , renewable organic material from plants, can substitute coke breeze it terms of fuel quality .In this project teak wood dust was used as a fuel for its ready availability. The biomass has ash to the extent of 1.5% and fixed carbon of 70%.In this project four experiments were carried biomass replacing coke breeze by 0%, 30%, 50% 70%. The biomass size fraction was comparable to coke breeze. Results such as yield of sinter produced , Reducibility Degradation Index(RDI) , Reducibility Index(RI), Tumbler Index were evaluated. Phase analysis by XRD, microstructure was also carried out of the samples. The yield of sinter remained 90% for 30% replacement and decreased to 85% and 50 % respectively for %0and 70% replacement. The RDI and RI achieved was 26 and 67 for 30 % replacement of coke breeze while the RDI increased with decrease for further replacement of Coke breeze.

The sinter basicity was maintained at 1.2 for sinter without biomass. The decrement of the strength and yield of sinter quality was taken care of by decreasing the basicity from 1.2 to 1.0 of the sinter. Other measures such as double layer sintering was incorporated to keep the strength unchanged with replacement of coke breeze with biomass. It can be concluded that replacement of coke breeze by biomass to the extent of 42% produced sinter of requisite quality ie yield 92% , RDI 25, RI 72, TI -75.

This paper deals with the experimentation and action taken to produce green sinter thereby saving energy and emitting less greenhouse gases in the atmosphere.

Key words:Green Sinter , Reducibility, Biomass, Coke breeze , Greenhouse gases
ISM_101

Novel sensor application to increase Sinter Productivity at Tata Steel

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Abstract

Sinter Plant agglomerates iron ores into sinters which forms primary component (~55%) in Blast furnace feed. Sinter bed charging system is critical to maintaining consistency in quality and machine productivity. The green mix is charged over moving pallets through feed roll and segregation pad. The material plane formed by green mix over the pallet gives an indication of bed compaction that ultimately governs bed permeability. Contact type sensors were historically used to capture this material plane movement. However, it could not be used continuously due to frequent requirement of maintenance ultimately resulting in lower accuracy.
A novel Non-contact Frequency Modulated Continuous Wave (FMCW) radar sensor was used to replace the earlier version of contact probes. Tremendous increase in reliability (>95%) was achieved after which the output from the sensor was utilised to develop PID control to run Feed roll in autonomous mode. This reduced fluctuations in sinter bed permeability by ~25% eliminating operator intervention and enabled increase in sinter productivity by 6%. Additionally, Tumbler Index (+6.3mm%) of sinter increased by 1%. Altogether, Coke Rate in Blast furnaces reduced by 4% with higher input of superior sinter in Blast Furnaces.

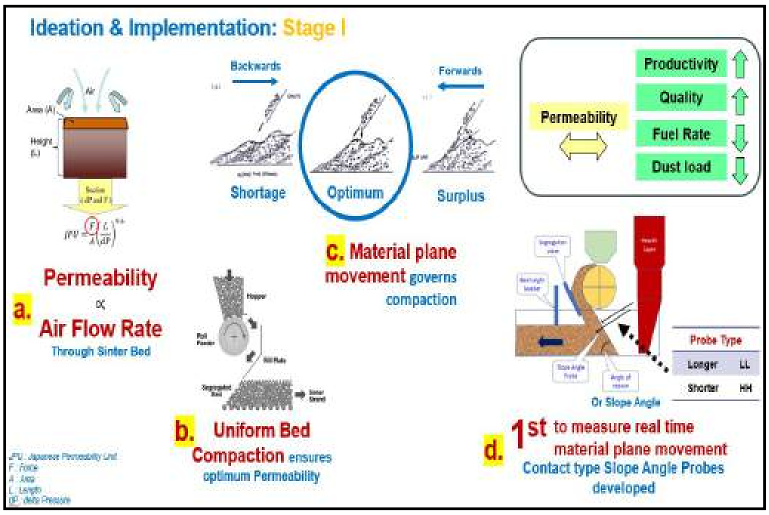

Fig. 1: Genesis of Slope Angle Probe

Key words : Sinter bed permeability, Machine speed, Productivity, FMCW radar.

ISM_114

First Ever Electromagnetic Segregation Process in Iron Ore Sinterig

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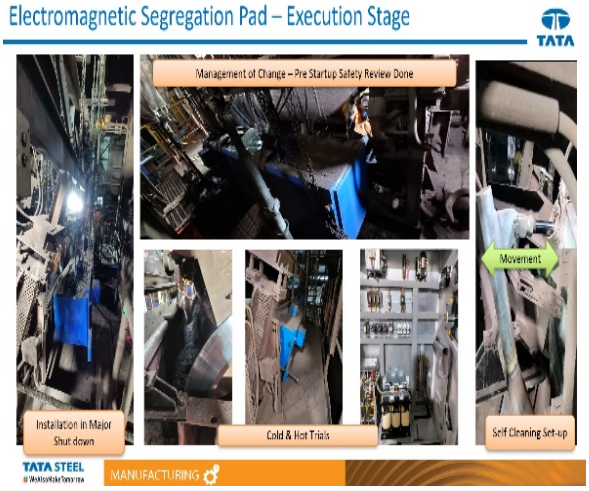
Abstract

Sintering is a solid-state agglomeration process of beneficiating iron ore fines and other steel plant revert materials that contains appreciable amount of Iron content. Modern day blast furnaces run with 75-80% sinter burden (superfluxed sinter) and rest being lump ores (units with pellet plants run with 50-55% sinter burden). Sinter serves as the key factor in enabling blast furnaces to reduce its coke rate while enhancing its productivity, meanwhile reducing the overall carbon footprint, where the blast furnaces contribute to ~70% of CO2 emissions in an integrated steel plant. With the upcoming steel demand for the Indian economy, ~300MT by 2030 and increasingly stringent CO2 norms, it is quintessential to produce steel in a sustainable method.

Conventional sintering process involves charging of the raw material over the sinter bed with particle segregation enabled by means of momentum transfer using feed roll or drum. Charging process is the heart of sinter productivity as it decides the bed permeability, that controls the movement of heat and flame front through the porous sinter bed, ultimately affecting the overall productivity of the sinter plant. Our work explores a novel first-of-its-kind electromagnetic segregation of particles on the sinter bed, overcoming the design constraints of conventional charging system. In an endeavour to establish the effect of electromagnetic field on the green mix coming over the sinter machine, an inhouse simulation setup was created by the R&D team and Sinter Plant #2 of Tata Steel Jamshedpur (SP2, TSJ). The electromagnetic field will give a “braking effect” over the finer paramagnetic particles of the raw material which slows down its descent and directs it over the upper surface of the sinter bed which will ignite first. This enhanced segregation coupled with conventional feed drum design improves bed permeability, further increases the heat and flame front speed thus enabling increase of machine speed, ultimately enhancing productivity. Our team has successfully established electromagnet enabled particle segregation and has achieved 4% increase in plant productivity.

ISM_126



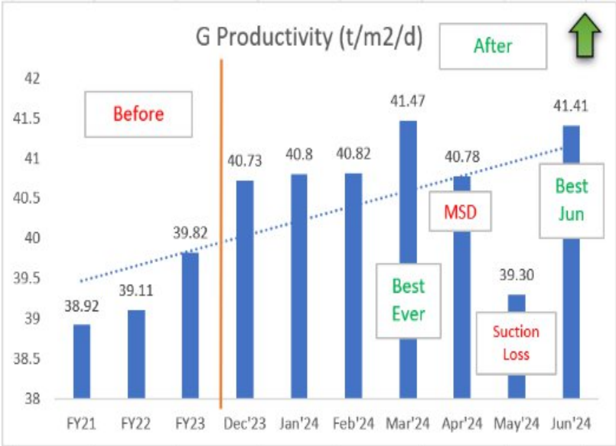


Fig.1: Plant implementation stages. Fig. 2: Gross Productivity of SP2, TSJ.

Keywords: - Iron ore sintering; Electromagnetic Segregation, Productivity; Iron Making and Steel Making

Three-dimensional Modelling of Gas-Solid-Fines Flow in an Ironmaking Blast Furnace

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Abstract

The ironmaking blast furnace is a counter-current reactor[1] in which iron ore in the lump, sinter, or pellet form and coke is charged from the top and the hot air is injected from the tuyeres located around the periphery at the bottom. As the hot blast air enters into the coke bed it forms a recirculating zone known as the raceway[2]. The coke particles burn in this zone and as a result, reducing gases are generated. These reducing gases while moving up reduce the downward descending solid burden of iron ore. Over the years it has been found that the injection of pulverised coal fines into the blast air can reduce the coke consumption [1]. However, the unburnt pulverised coal, and coke fines generated by the mechanical degradation of it, reduce the permeability of the coke bed in the dropping zone affecting the production and smooth operation of the furnace[2].In addition, the molten metal/slag also flows discretely[3] from the cohesive zone, making the blast furnace a complex multiphase reactor. Thus, it is imperative to study the gas, solid and fine flow behaviour & interactions in three dimensions in the presence of the cohesive zone.

In this work, the gas, solid fine flow behaviour in 3D in the presence of the cohesive zone is investigated. All three phases i.e. gas, solid and fines are modelled as a continuum. The impact of various operational factors, including gas flow rate, solid flow rate & size, fine flux & size, tuyere opening size, and selective tuyere shutdowns is presented. The analysis is substantiated by validation using data from the literature. This model forms a basis for implementing the heat and mass transfer phenomena for the full-scale ironmaking blast furnace.

Keywords: Three-dimensional modelling, Raceway, Cohesive Zone, Selective Tuyere Shutdowns

References:

[1] Y. Omori, Joint Society on Iron and Steel Basic Research, The Iron and Steel Institute of Japan, Blast Furnace Phenomena and Modelling, Springer Netherlands, Dordrecht, 1987. https://doi.org/10.1007/978-94-009-3431-3.

[2] Smita Kamble, Ferdin Donbosco, Govind Gupta, Effect of raceway shape and size on gas and fines flow behaviour in a packed bed, Metallurgical and Materials Transactions B, April 2022, Vol. 53, pp 2117-2131, DOI: 10.1007/s11663-022-02512-7

[3] Venkat Arunchaitanya GADI & Govind Sharan Gupta, Discrete Liquid Flow Behavior in a 2D Random Packed Bed, ISIJ International, Vol.63 (2023), No. 5, pp. 810-821, https://doi.org/10.2355/isijinternational.ISIJINT-2022-529

Improvised system for real time coke surface temperature measurement at COB

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Abstract

Temperature of coke pushed from oven is one of the critical parameters in assessing coke oven heating operation and thereby the quality of coke. Accurate measurement of coke temperature is desirable when coke is just pushed out from an oven and before it starts getting cooled as it is loaded in to the quenching car.

An innovative system for real time measurement of Coke Surface Temperature has been conceptualized and implemented COB, ISP, Burnpur by RDCIS in association with ISP. The system is based on a fibre-optic radiation pyrometer that directly focuses on Coke Surface, through a small cutout made on the wall of the guide car (Refer Fig.1). As coke is being pushed out from the oven after carbonization, a complete profile of the coke surface temperature is obtained and stored. The information is integrated with Level 1 & 2 system of Coke Ovens for oven wise mapping and MIS. The Coke surface temperature thus measured is more useful as measurement is being taken when coke is just pushed out from oven when temperature drop and other measurement noises are minimum. This real time coke surface temperature profile can be extrapolated to understand about combustion efficiency and thermal status of the ovens to facilitate corrective actions as required for improving heating operation.
Trials were also carried out to develop correlation between Coke surface temperature reading, Centre coke mass temperature and Coke quality for different soaking times which facilitated in providing Oven-specific recommendations on optimum battery heating and adjustment of soaking times to achieve desired quality.

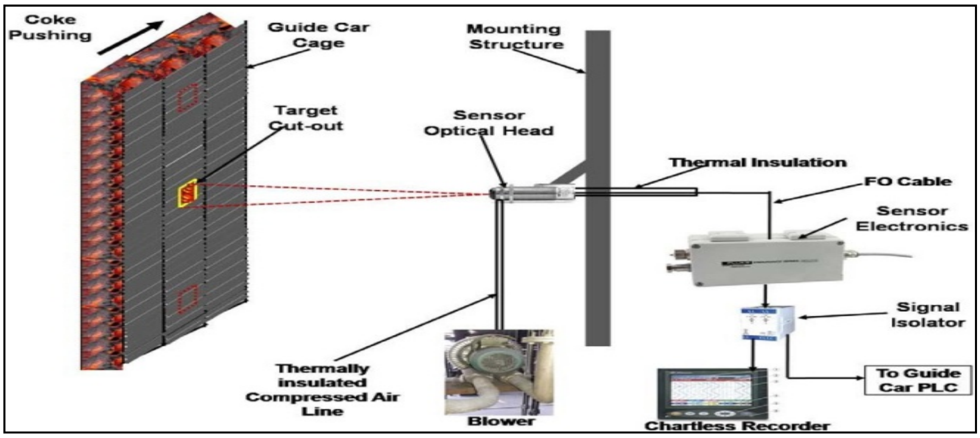

Fig.1 Coke surface temperature measurement scheme

Keywords: Coke Oven Battery; Fibre-optic radiation Pyrometer; Coke Surface; Coke Mass; Temperature

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.

Increasing Scrap Potential in BOF: A key Decarbonization Initiative

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Abstract

The global steel industry indeed relies heavily on coal, primarily for the reduction of iron ore in the blast furnace (BF) process. The BF-BOF (Basic Oxygen Furnace) route, which involves the use of hot metal from BFs, is associated with approximately 2T CO_2 emission per ton of steel produced. Efforts are being made to reduce these emissions through various strategies including increasing scrap rate, adopting alternate technologies and improving energy efficiencies in existing processes. At JSW Steel's SMS#2 in Vijayanagar, the scrap rate was increased from 11.9% in FY23 to 13.8% by FY24-Q2 through partial substitution of hot metal with Direct Reduced Iron (DRI) and Hot Briquetted Iron (HBI) and optimising the blow pattern. The scrap potential is significantly influenced by temperature and silicon content of hot metal. While higher Si content can provide additional heat through exothermic reactions during oxidation in BOF, higher hot metal temperature enhances the melting capacity for scrap materials. At JSW Steel's Vijayanagar facility, the Si content varies between 0.5% and 1.5%. A higher silicon content in hot metal is associated with a lower hot metal temperature. To counter the challenges, avenues were explored to minimize temperature loss during the transportation of hot metal from ironmaking units to the SMS. Through several in-house improvements, it was possible to increase the hot metal temperature by 12°C per heat which directly contributed to an increase in the scrap content by 4 tonnes per heat. As a result, the scrap rate increased to 14.5% by FY24-Q4 and the plant achieved an overall reduction of 0.24 tons of CO_2 emissions per day. By continuing to explore and implement such strategies, JSW Steel is in the path of making significant strides towards more sustainable production practices.

Key words : BOF, Scrap rate, HBI, Decarbonisation, CO_2 emissions

Influence of heating rate on Coke Quality

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Abstract

In integrated steel plant coking coal is heated in the absence of air in coke oven to produce coherent mass called coke. Coke acts as reducing agent, provide heat and support burden in blast furnace operation. Coke quality in terms of hot strength and cold strength plays an important role in smooth operation of blast furnace. Coke quality depends upon pre carbonization technology, carbonization and post carbonization treatment of coke. Coke quality mainly depends upon the properties of coal blend is being used and heating condition of coal blend in the oven. The heating of coal blend in an oven is termed as carbonization period and the rate of heating of coal blend highly influenced the coke quality. Under this scientific work individual coal were subjected for different heating rate in dilatometer and plastometer. It was seen the plastic properties and dilatometric properties improves when coal is heated at higher heating rate. Pilot oven carbonization tests carried out at Research and Development Centre for Iron and Steel (RDCIS) and industrial trial were carried out at one of the SAIL plant to find out the effect of heating rate on coke quality. Coke pore radius and coke porosity was analyzed with heating rate. It was seen that coke quality improves with the increase in heating rate.

Key words: Coal, Carbonization, Dilatometer, Plastometer

Improvement in steel cleanliness in central strand of a billet caster using water modelling

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Abstract

In continuous casting, the size and design of tundish has changed significantly, over the years. Multi-strand, billet casters are now commonly used in large integrated steel plants for achieving higher productivity, but have difficulty in controlling the flow dynamics in the tundish. JSW Steel, BPSL operates a 13 T, 3-strands billet caster. This tundish has trapezoid shaped turbo stopper and have side dam of only 90 mm height. The close proximity of central strands to the ladle shroud results in increased amount of inclusions and have inferior internal soundness. It is expected that, there is possibility of improvement the steel cleanliness in the existing practice and used tundish designs. With an aim to improve the steel cleanliness in central strands, water modelling studies carried out on 0.5 scale perpex model using Froud no. similarity. Based on water modelling results, Trapezoid shaped turbo stopper was replaced with circular turbostopper, inverted V dam introduced at central strand and height of side dam was increased from 90 mm to 130 mm. Full scale plant trial has been taken at JSW Steel, BPSL. Plant trials demonstrated reduction in inclusion area percentage of 53 % at billet stage. These reductions were achieved without any adverse effects on the internal structure of the billet, confirming an improvement in the steel cleanliness at the central strands.

Key words : Steelmaking, Continuous casting, Water modelling, Tundish, Billet

Decarbonization & Green Steel Technologies to handle industrial growth and rising decarbonization targets

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Abstract

On one hand, global warming is a concern, on the other hand economies like India must grow with industrialisation. Global warming is to be controlled within the limit of 1.5°C but consumption of steel in India must increase to the world average consumption of 250 kg per capita, a growth indicator for the economy. Developed countries are consuming steel at this average and hence recycling the steel also. But in countries like India the consumption is less than half of world's average hence, scrap generation is not enough, and we need to produce Iron from Ore and then convert it to steel. Means, even if we have sufficient renewable energy for melting, we still need some reducing agent for Iron ore, which is traditionally "Carbon", that we must restrict considering environmental factors. Since Iron Ore is reduced either for making DRI or for making Hot Metal, we need to amend both the processes i.e. DRI and BF to minimise the use of carbon, if not zero. Steps are already taken and amended DRI process with modified melting process are already under implementation. But for India we need to think differently. Since modified processes of making DRI as well as Hot Metal are available, we need to compare both and implement suitably based on social, geographical, and economical factors. Some assessment shows that perhaps Blue Blast Furnace and EasyMelt can be the game changer for India.

Key words :
Alternative Iron Making, Decarbonisation, Green Steel, Blue Blast Furnace, EasyMelt

Millscale to sintered iron-alloy compact by using hydrogen as reductant

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Abstract

This research work focuses on transforming mill scale, a high-iron-content industrial waste generated during hot rolling mill operations, into usable steel powder via a one-step thermo-chemical treatment using pure H_2 gas as the reducing agent. This method, which targets steel production without greenhouse gas emissions, involves reducing mill scale (comprising approximately 72% iron in the forms of Wustite, Hematite, and Magnetite) at 500℃ for 90 minutes in a tubular furnace. The produced iron powder is characterized by using X-ray diffraction, optical microscopy, scanning electron microscopy, and microhardness measurements. Such reduced mill scale powder was sintered using spark plasma sintering. To understand the effects of stable oxide impurities and the porous nature of mill scale on reduction and sintering reactions, a comparative analysis is conducted with oxidized pure iron powder. Additionally, the study investigates the impact of pre-oxidation on the conversion of magnetite to hematite and discusses the reduction kinetics of various iron oxides using thermodynamic and kinetic data. This environmentally friendly approach not only recycles industrial waste but also supports sustainable manufacturing practices, providing valuable insights for future steel production.

Key Words: H_2 reduction; mill scale; spark plasma sintering.

A novel approach for using dri bag filter dust at jsw raigarh pellet plant

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Abstract

An innovative strategy is being tried to utilize DRI bag filter dust as a waste material that is easily available and used as fuel in a pellet plant. The pellet plant's challenges are increasing the use of waste products such as bag filter dust from DRI plants and finding low-cost input materials. Anthracite coal is a typical fuel in pellet making, and its combustion provides the heat needed for pellet making. Other fuels that can partially replace anthracite coal incorporate DRI bag filter dust, which is considered solid waste and is produced in massive quantities at DRI plants. In this study, DRI dust is used as a partial replacement for anthracite coal. Based on the laboratory trial results, DRI dust is combined with anthracite coal in a 1:2 ratio in the pellet plant coal yard and fed into the Bradly Mill along with lime for grinding. There was no significant negative effect of the use of DRI dust, and pellet quality was consistent throughout the usage. However, the use of DRI dust reduces costs for the company. With the addition of DRI bag filter dust, anthracite consumption of coal was reduced by 20% of total fuel, while dust consumption increased to 36 MT/day. The vision of making "clean & green steel with zero waste" can be realized for the survival and growth of the steel business in the future, and the main goal of the companies is now to transform solid waste into wealth for the benefit.

Keywords: DRI bag filter dust, solid waste, anthracite coal, wealth.

High productivity operation of blast furnace – Technology to increase productivity and reduce carbon emissions.

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Abstract

Productivity of the blast furnace is defined as tons/day/m3. Productivity is directly linked with the efficiency of the blast furnace, more the productivity more the efficiency. In this subject use of Direct Reduced Iron (DRI) is a promising solution to increase the productivity and decrease the fuel rate, hence reducing the carbon emissions. Charging DRI in the burden has an impact in the process like lowering of top gas temperature, decrease in bosh and belly wall temperatures, lowering of gas utilization (Eta CO). In Tata steel F blast furnace charging of DRI at 10% is done which is an Indian benchmark. This DRI charging resulted in fuel rate of less than 500 kg/thm and coke rate as low as 285 kg/thm, (lowest among Indian blast furnaces) and an increase in productivity of 0.2 tons/day/m3. In this paper we will be getting into the details of process controls, like burden distribution, heat loss control, maintaining lower wall temperatures with higher percentage of DRI in the burden.

Keywords: Direct Reduced Iron (DRI), Productivity, Fuel rate, Decarbonization.

Improved Deoxidizer and Slag Former

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Abstract

Aluminium (Al) deoxidation is indeed a critical step in the steel refining process, primarily because it plays a significant role in improving the cleanliness and overall quality of the final steel product by removing oxygen from molten steel. Prime Al in the form of bar, wire, shots are widely used as deoxidizer during tapping and secondary steelmaking process. The deoxidation using Al Bar typically occurs in the teeming ladle, where molten steel is transferred after basic oxygen furnace (BOF) or electric arc furnace (EAF) treatment. In the present study, a novel low cost Al-deoxidation compound containing 30-35% Al, 32-42% Al_2O_3, 16-26% CaO and 0-10% SiO_2 was used as the killing material has been used as an effort to reduce the production cost of these grades. The primary objective of this compound was to efficiently reduce the consumption of Al bars used during tapping of steel from BOF. While the Al in the compound acts as a deoxidiser, Al_2O_3 present in it helps in early formation of slag by reacting with lime (CaO) and forming low melting Calcium-Aluminate phases. As a result, Al bar consumption got reduced by 40 kg/heat with every 100 kg addition of the compound. It also reduced lime+Synthetic slag consumption by approx. 100 kg/heat. Early slag formation helped in reducing the arcing time by 25% and thereby lowering down the power usage by 23%. This compound's ability to lower prime Al usage, reduce flux and power consumption, and maintain product quality makes it a promising development for improving the sustainability and cost-effectiveness of steelmaking processes.

Keywords : Al-deoxidation compound, Prime Al, Cost reduction, Primary steel making, Killing agent,

Optimization of Annealing Parameters for High Silicon Non-Oriented Electrical Steels

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Abstract

Electrical steels play a critical role in reducing CO_2 emissions due to their superior energy conversion efficiency compared to other magnetic materials. To produce high-quality non-oriented electrical steels with minimal core loss, precise control over factors such as grain size, impurities, residual stresses, and texture is essential across the entire production process—from steelmaking and hot rolling, through hot band annealing, cold rolling, to final annealing. The present study focuses on getting better properties with the optimization of annealing parameters. The primary objective was to identify the optimum annealing processing conditions that minimize core loss while increasing line speed to increase productivity. Annealing experiments were conducted such that it replicates the continuous annealing line conditions of the plant cycle. Hence the design of experiment was planned with variations in line speed as 60 mpm, 80 mpm and 100 mpm, and annealing temperatures as 800 °C, 900 °C, 1000 °C, 1050 °C, and 1100 °C. Experimental results demonstrate that there is a significant influence of annealing conditions on the microstructure and magnetic performance of the steel. Characterization techniques including Optical microscope, SEM-EBSD used to analyse the recrystallization behaviour and texture evolution in the annealed material and the magnetic properties has been characterised using Brockhaus MPG200D. Experimental results were utilized to generate contour maps to elucidate the best operating window during annealing by illustrating the relationship between line speed vs annealing temperature with respect to minimizing the core loss. The results reveals that the annealing temperature is most critical than the line speed to achieve the desired magnetic properties. Additionally, an empirical equation was developed to predict optimal processing conditions for achieving desired magnetic properties.

Key words : Non-oriented electrical steel, Coreloss

Development of a DeS Simulator for external desulphurisation of blast furnace hot metal by powder injection

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Abstract

Sulphur is an undesirable element in steel owing to its serious impact on mechanical properties and leading to hot shortness during hot rolling. Sulphur originates primarily from the coke used in the blast furnace (BF). Sulphur removal in blast furnace is restricted due to thermodynamic and operational conditions, even though conducive environment does exist in the furnace. Favorable conditions for sulphur removal do not exist in the basic oxygen furnace (BOF)(due to oxidizing environment), so an intermediate operation, external desulphurization of blast furnace hot metal by powder injection is a well-established process practiced worldwide. The process involves chemical reactions between injected fluxes and dissolved S in hot metal. In this regard, co-injection of Mg and CaO, with N_2 as a carrier gas, is widely practiced. In desulphurization (De-S) stations, considerable uncertainties exist about the optimized ratio of these fluxes which should be added for a given set of input and output conditions. Models developed from a mechanistic viewpoint have an edge over the regression-based approach, since they provide insights about reaction mechanisms and can also be used for prognosis of future scenarios different from the conventional operation. In this work, a kinetic model for the external De-S process by powder injection has been developed from a fundamental viewpoint. This model is developed using two approaches– the first is a reaction interface approach developed using MATLAB and the other utilizes a FACTSAGE-based effective equilibrium reaction zone (EERZ) approach. The MATLAB based approach considers contribution only from the transitory reaction zones while the FACTSAGE-based approach considers both the transitory and the permanent contact reaction zones. The developed kinetic model can predict compositional evolution of a wide range of hot metal and top slag chemistries during the external De-S process. Model predictions have been tested with sampled plant trials and laboratory-scale injection data, published in the literature, and reasonable agreement between the two could be obtained. Furthermore, the model has been simulated for some futuristic scenarios and it can serve as a guide for optimizing the flux consumptions in external De-S of newer and challenging hot metal chemistries.

Keywords: Sulphur; Blast furnace; Effective Equilibrium Reaction zone; External Desulphurisation; Process Modelling

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

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,

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

MATERIAL FOR STARTEGIC SECTORS

Oral Abstracts

Advanced investment casting technology for production of aero engine single crystal blades

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Abstract

The turbine and nozzle guide vane blades in an advanced Aero engines for military and civil Aircraft are the heart of the engine and responsible for production of thrust. These blades operate at very high Turbine Entry Temperatures (TET) which are in the order of 1200 Celsius to 1400 Celsius. The more the TET, the more the thrust.
Aircraft engineers always tried to achieve higher TET by various means to increase Thrust. The materials which can withstand these temperature are the choice of the materials.
Nickel based alloys or super alloys are the choice for these blades and is widely used as raw materials for these blades. The general composition of these materials are nickel based alloys with alloying elements such as chromium, vanadium, tungsten, cobalt, aluminium are present in these alloys and offer good tensile strength ,fatigue, and creep properties at elevated temperatures.
The presentation will cover details of working principles of a jet engine, the evolution of aero engine single crystal blades over a period of time, advantage over the equi-axed and directionally solidified blades.
Details on Advanced Investment casting technology including ceramic core technology to produce hollow cast blades, western and soviet technology for production of single crystal blades, leaching process to remove the ceramic cores, quality requirements and the production facilities available in India will be presented in this seminar.

MSD_030

Bulk superplasticity in a Medium alloyed Nickel base Superalloy using a Combination of Multi-axial Forging and Heterogenization.

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Abstract

Medium alloyed nickel base superalloy DMR SN 742 is widely used as high-pressure compressor and turbine rotors in various aeroengines. To refine the microstructure and achieve superplasticity in bulk material that reduces the flow stress and load during secondary processing, a combination of high temperature multi-axial forging (MAF) and heterogenization annealing (HA) has been employed in this study. High temperature MAF is intended to refine the size of matrix gamma (γ) phase, while HA is intended to coarsen the gamma prime (γ′) phase. A combination of the aforementioned processes is expected to assist in producing fine grained equiaxed duplex microstructure comprising of gamma (γ and gamma prime (γ′ that exhibits superplasticity. The material was subjected up to 4 cycles of isothermal hot MAF in the super and sub solvus regime i.e., 1150 to 1050°C. First two cycles of MAF were performed in super solvus regime (1150°C & 1100°C) with a constant true strain rare of 10^{0}/sec. Subsequently, the material was subjected to HA in order to coarsen the γ′ precipitate followed by further MAF in the sub solvus regime at 1075°C and 1050°C respectively. Detailed microstructural evaluation revealed that the g grain size was refined from ~ 80 µm to ~1µm while the g¢ precipitate size was increased from ~ 0.25mm to ~ 0.65mm resulting in a micro-duplex equiaxed microstructure. The strain rate sensitivity (m) of the material was evaluated by carrying out isothermal hot compression jump tests at 1000°C and 1050°C by varying the strain rate from 10^{-4} to 10^{0}/sec. The micro duplex structured material exhibited a strain rate sensitivity of 0.33-0.60 indicating superplastic characteristics.

Key words: Superalloy; High temperature MAF; Heterogenization; Microstructure; Strain rate sensitivity

MSD_032

Indigenous Development of Superalloy 41 for Aerospace Application

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Abstract

Superni 41 is a precipitation hardenable Ni-Cr base superalloy with additions of Co-Mo-Ti-Al-B. It possesses extremely high room temperature & high temperature (upto 870^{o}C) mechanical strengths and excellent resistance to heat/ oxidation upto 980^{o}C, acid, stress corrosion & H2 embrittlement. It is used for manufacturing many of the critical aircraft engine components like turbine nozzle partitions & blades, combustion chamber liners, fasteners and springs for guided missile & rocket applications. The alloy 41 is indigenized in Mishra Dhatu Nigam Limited (MIDHANI) to export one of most critical superalloy materials for furthering the Aatmanirbhar Bharath Mission of Govt. of India. Superni 41 is one among few superalloys which are very difficult to hot work because of the extremely narrow thermo mechanical processioning window. This alloy mechanical properties are very sensitive to heat treatment parameters. Manufacturing route involves Vacuum Induction Melting (VIM) to produce an electrode followed by either Electro Slag Refining (ESR) or Vacuum Arc Re- melting (VAR) to get a sound ingot which is then press forged at multiple stages followed by hot rolling. Further, the solution treating and aging heat treatment cycles have been optimized to obtain homogenous microstructure and equiaxed grains to meet stringent requirements of various metallurgical properties

Keywords: Superalloy, Age Hardenable, VIM, ESR, & VAR.

MSD_035

Effect of post-processing on tensile properties and microstructure of additively manufactured Gamma-prime strengthened Nickel-based superalloy used in rocket engines

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Abstract

XH67MBTЮ is a Russian-grade Gamma prime strengthened Nickel-based superalloy used in various parts of semi-cryogenic engines. In this study, XH67MBTЮ alloy powder for additive manufacturing was realised and processed by the laser powder bed fusion (L-PBF) technique. Process parameter optimisation was carried out to produce defect-free samples. Samples were produced without solidification cracking during the L-PBF process. Tensile properties evaluation and microstructural analysis were carried out in as-printed and various post-processing conditions. Post-processing conditions include solution treatment, hot isostatic pressing, ageing, and their combinations. Also, the effect of the quenching medium on tensile properties was studied. This study brought out that the additively manufactured XH67MBTЮ superalloy produced superior properties than conventionally processed wrought and cast alloys.

Keywords: XH67MBTЮ, nickel-based superalloy, laser powder bed fusion, post-processing

MSD_063

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.

MSD-27

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.

Ti6Al4V (ELI) Ti5Al2.5Sn (ELI)

Fig. 1: Titanium closed die forgings developed for liquid engine

Keywords: closed die forging, forging, ELI, liquid engine, Titanium

MSD_027

Strengthening by primary, secondary and tertiary gamma prime in 720*Li* alloy

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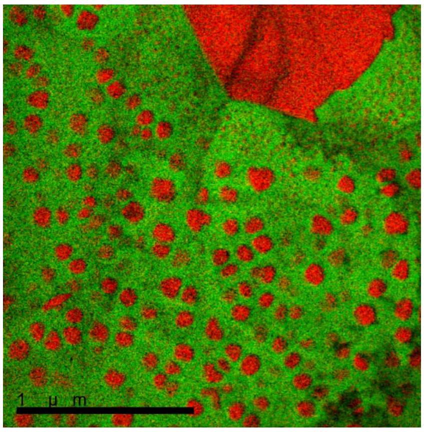
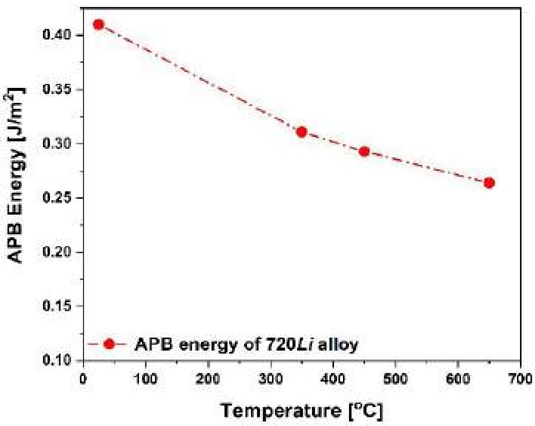
Abstract

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 (τ_{CRSS}) required to shear the primary, secondary, and tertiary γ' was determined to be $\tau_{CRSS}^{Primary}$ = 81.54 MPa, $\tau_{CRSS}^{secondary}$ = 24 MPa, and $\tau_{CRSS}^{tertiary}$ = 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 g', and (b) APB energy of 720Li alloy with respect to temperature.

MSD_093

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.

References

[1] F. Hosseini Mohammadabadi, S. M. Masoudpanah, S. Alamolhoda, and H. R. Koohdar, "Electromagnetic microwave absorption properties of high entropy spinel ferrite $((MnNiCuZn)_{1-x}Co_xFe_2O_4)$/graphene nanocomposites," J. Mater. Res. Technol., vol. 14, pp. 1099–1111, 2021, doi: 10.1016/j.jmrt.2021.07.018.
[2] S. H. Siddiki, K. Verma, B. Chakraborty, S. Das, V. K. Thakur, and G. C. Nayak, "Defect Dipole-Induced HfO_2-Coated $Ti_3C_2T_x$ MXene/Nickel Ferrite Nanocomposites for Enhanced Microwave Absorption," ACS Appl. Nano Mater., vol. 6, no. 3, pp. 1839–1848, 2023, doi: 10.1021/acsanm.2c04793.
[3] L. Ren, Y. Wang, X. Zhang, Q. He, and G. Wu, "Efficient microwave absorption achieved through in situ construction of core-shell $CoFe_2O_4$@mesoporous carbon hollow spheres," Int. J. Miner. Metall. Mater., vol. 30, no. 3, pp. 504–514, 2023, doi: 10.1007/s12613-022-2509-1.

MSD_056

Microstructural characterization of heavy ion irradiated Nb-1Zr-0.1C alloy

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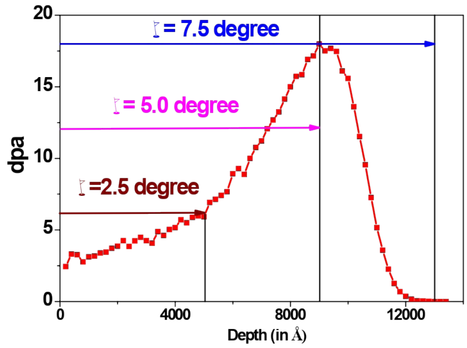
Abstract

Niobium (Nb) and its alloys are promising candidates for structural materials in compact high-temperature nuclear reactors due to their excellent properties, including high-temperature strength, corrosion resistance against various coolants, and favourable thermal properties [1]. However, assessing radiation damage is crucial before using these materials in reactor environments. In this study, Nb-1Zr-0.1C alloy was irradiated with 1.6 MeV O^{5+} ions at room temperature upto three different doses. The ion penetration depth was calculated to be 1.3 μm, with a maximum displacement per atom (dpa) of 7.7, as determined by SRIM-2013 for the highest dose [2]. X-ray diffraction (XRD) line profile analysis was employed to characterize the irradiated samples. The damage profile, in terms of dpa, was found to be inhomogeneous along the ion penetration depth (Fig. 1a). To elucidate this profile, XRD data were collected at three different incidence angles, allowing for the determination of various microstructural parameters, such as domain size and microstrain, along the ion penetration depth. The analysis indicated a reduction in domain size and an increase in microstrain after irradiation compared to the as-received sample. In the highest irradiated sample, domain size increased while microstrain decreased with depth, suggesting that defect annihilation, possibly due to interactions between dense cascades during heavy ion irradiation. Additionally, electron backscatter diffraction (EBSD) analysis was performed on the polished surfaces of both the as-received and selected irradiated Nb-1Zr-0.1C alloys (Fig. 1b). The kernel average misorientation (KAM) distribution revealed a shift in peak maxima towards lower misorientation angles after irradiation, indicating the formation of low-angle boundaries. The density of geometrically necessary dislocations (GNDs) was also assessed, showing an increase with irradiation dose. The formation of irradiation-induced clusters or loops, which introduce small misorientation within the matrix, likely contributes to the observed rise in GND density.



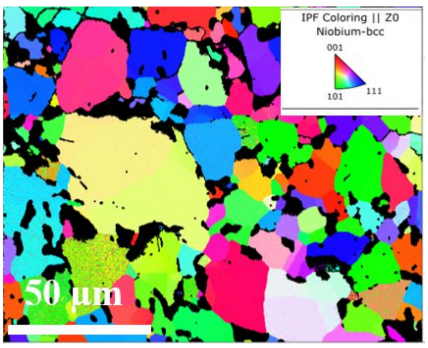


Fig. 1: a) Displacement per atom (dpa) for highest irradiated Nb sample as a function of penetration depth calculated using SRIM-2013 and b) IPF image of Nb-1Zr-0.1C alloy

MSD_080

Key words: Radiation Damage, XRDLPA, EBSD, Nb alloy, Nuclear reactor

References:

[1] K.J. Leonard, Radiation effects in refractory metals and alloys, in: R. Konings, T.R. Allen, R.E. Stoller, S. Yamanaka (Eds.), Compr. Nucl. Mater., Elsevier Science, UK, 2012: pp. 181–213.

[2] J.F. Ziegler, M.D. Ziegler, J.P. Biersack, SRIM - The stopping and range of ions in matter (2010), Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms. 268 (2010) 1818–1823.

MSD_080

Characterisation of weld joint of T91 and Zircaloy-4 for fabrication of double clad tube

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Abstract

Metallic Fuels are future fuel for Fast Breeder Reactors (FBRs) as they have higher densities of fissile and fertile materials than any other forms of fuel. One of the design concepts being considered in India for metallic fuel clad tube for FBRs is mechanically or metallurgically bonded tube having Zr-4 liner inside the T91 steel[1]. T91 grade steel is a 9Cr-1Mo-V-Nb type steel. Manufacturing of this T91 & Zr-4 double clad tube is highly challenging due to their differences in their flow stresses and thermal properties. Circumferential welding of T91 and Zr-4 tube is essential for manufacturing of mechanical bonded double clad tubes by co-pilgering. The present work describes the characterization of weld joint for optimisation of weld parameters. The welding is critical, as filler is not acceptable considering the irradiation stability and thus, welding parameters needs to be optimized to reduce the formation of inter-metallic at the interfaces of two alloys. Welding is also critical considering thin wall tube (2.2mm) having dissimilar thickness of alloys (T91:1.4mm and Zr-4:0.8mm) causing differential heat sink. Trials on semi-automatic Tungsten metal arc welding with different weld parameters such as current, welding speed, argon flow rate were carried out for circumferential joining of these tubes. The weld and heat affected zone were characterized using electron microscopy techniques. In the weld region, dendritic structure was obtained in both Zr-4 side and T91 side. EDS analysis was carried out, which indicated the formation of two phase structure, rich in Zr and other being Fe, Cr rich. Fine flower structure (intermetallic) were also observed in the weld region, with size of the order of 2-5µm. Development of microstructure and formation of intermetallic phases like Zr_3Fe, $Zr(Fe,Cr)_2$, $ZrCr_2$, with different welding parameters were analyzed. Detailed analysis of the same is presented in the paper.

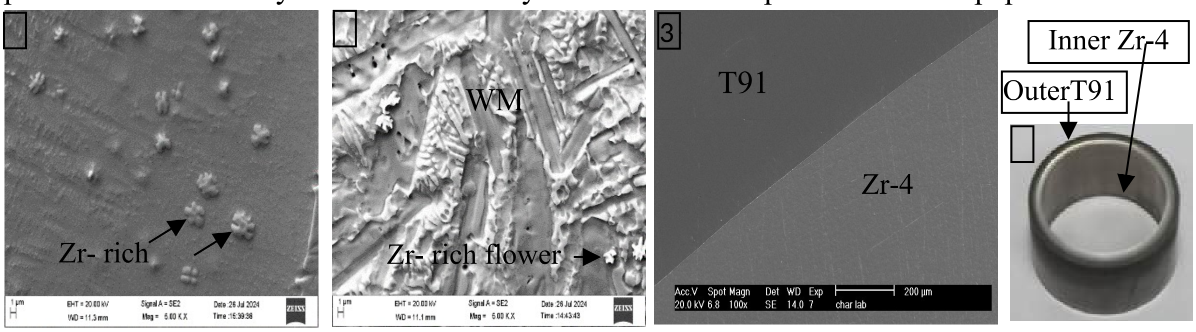

Fig (1) SEM of Zr-4 side (2) SEM of T91 side (3) & (4) Mechanically bonded as pilgered tube

MSD_034

Keywords: Diffusion, Inter-metallic compounds, Welding, Electron microcopy

References:
1. Joy Dipta Banerjee, Santu Katiya, K. Ravia, M. R. Naira, M. T. Saify, Rajeev Keswani, Arun Kumar, Prasad G. J., "Out-of-Pile thermophysical properties of metallic fuel for fast reactors in India" IAEA publication. pp 1-11
2. Sanjeev Kumar, Chandan Pandey, Amit Goyal, "Microstructure and mechanical behavior of P91 steel dissimilar welded joints made with IN718 filler. International Journal of Pressure Vessels and Piping. 190 (2021) 104290.

MSD_034

Directional dependent plastic flow characteristics and work hardening behavior of refractory alloy Nb-10Hf-1Ti

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Abstract

The Nb-10Hf-1Ti alloy is a refractory alloy used in aerospace structural applications like expendable nozzles, satellite thrusters. The sheet form of alloy Nb-10Hf-1Ti is extensively used to manufacture expendable nozzles of rockets using the process of metal spinning which requires sufficient ductility and workability. Therefore, this article investigates the directional dependency of the tensile plastic flow and work-hardening behavior of a cold-rolled plus annealed sheet made of the refractory alloy Nb-10Hf-1Ti. Three tensile test directions such as 0° to the rolling direction (RD) (sample-S0), 45° to the RD (sample-S45), and 90° to RD (sample-S90) have been used in this investigation. When the tensile test is performed along 0° and 90° to RD, both the α- and g-fibres evolve, and the overall texture intensity decrease while testing in the direction 45° to RD, the starting g-fibre changes to α-fibre and the overall texture intensity remains unchanged. The lowest value of the Schmid factor of the primary slip system in the presence of $(111)[0\bar{1}1]$ texture component of g-fibre results in the highest value of yield strength of sample S90 as compared to samples S0 and S45. The presence of texture components $(111)[1\bar{1}0]$ and $(111)[0\bar{1}1]$ of g-fibre strongly influences the deformation mechanism of the S90 sample by lowering the Schmid factor of slip systems resulting in grain fragmentation and lower value of strain to fracture. The plastic flow curves of the tensile deformed samples in all three directions follow the Ludwigson relationship. The work-hardening rate of the alloy Nb-10Hf-1Ti displays its directional dependence and is well explained by the Kock-Mecking-Estrin analysis.

Keywords: Nb-10Hf-1Ti alloy, Cold-rolled plus annealed sheets, Directional tensile properties, Work-hardening.

MSD_040

Micro-structural characterization on proton irradiated W-3.5Ni-1.5Fe heavy alloy using X-ray and Electron diffraction and first principle DFT calculation

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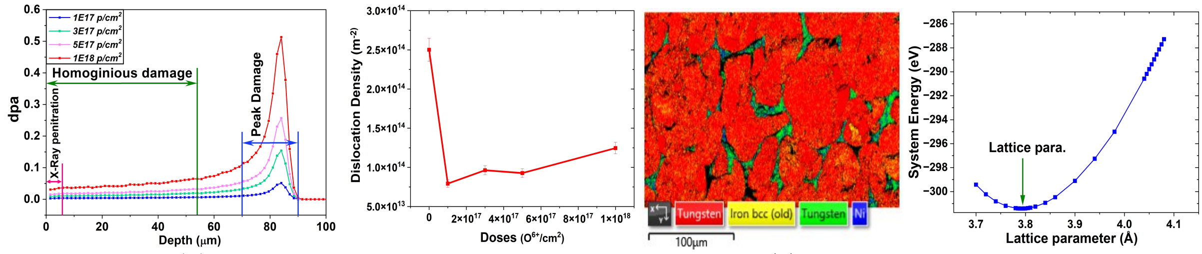
Abstract

Tungsten (W) and its alloys have been considered as one of the candidate structural materials for nuclear fusion reactors due to its various superior properties [1]. For the application of W and its alloys in a radiation environment, it is necessary to understand the effect of irradiation on the microstructure and the related changes in various properties of these materials. Irradiation induced micro-structural changes in W-3.5Ni-1.5Fe heavy alloy have been assessed here. This alloy consists of bcc W grains embedded in ductile (Ni,Fe) rich fcc matrix as observed by optical microscopy and FESEM-EDX. Four doses of H^+ irradiated (6.3 MeV; 3 μA) alloy were characterized using XRD, EDX and EBSD techniques. XRD line profile analysis (XRDLPA) based on Modified Rietveld method (using MAUD) revealed variations in coherent domain size (Ds), micro-strain (Ms) and dislocation density (DD) with doses. The initial dose showed increase in Ds and reduction in Ms indicating annihilation of pre-existing defects present in the un-irradiated alloy. With increasing doses, the competition between defect production and annihilation in sinks resulted micro-structural saturation. DD showed decrease at the initial dose and saturation at higher doses. EBSD was used to measure the variation of Band Contrast (BC), Local Misorientation (LM), Pattern Misfit and GND density. Decrease in the low angle LM fraction and improvement in BC at initial dose indicate defect annihilation, followed by microstructural saturation at higher doses.

Point defects produced by irradiation may significantly contribute to the loss in the ductility of the present (Ni,Fe) rich fcc ductile phase. Thus the estimation of defects stability in this material is crucial and first principle DFT study using VASP software has been utilized for this purpose in both the bcc and ductile (Ni,Fe) rich fcc phases. Initially lattice parameter, K-mesh and ENCUT have been optimized for this study. Finally the system energy and the defects formation energy have been calculated for both phases, demonstrating the feasibility of defect production in both the phases during irradiation.

MSD_061



(a) (b) (c) (d)

Fig. 1: (a) dpa variation with depth for different irradiation dose using SRIM, (b) Dislocation density with irradiation dose, (c) EDX mapping on As-received sample and (d) lattice parameter optimization by DFT

Key Words: Optical-microscopy, XRDLPA, FESEM-EDX, EBSD and DFT

Reference:

[1] B.I. Khripunov, V.S. Koidan, A.I. Ryazanov, V.M. Gureev, S.N. Kornienko, Study of tungsten as a plasma-facing material for a fusion reactor, Phys. Procedia. 71 (2015) 63–67. https://doi.org/10.1016/j.phpro.2015.08.313.

Development of Thick Pore-free Cr Coating on Zircaloy-4 by Magnetron Sputtering for Accident Tolerant Fuel Clad Applications

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Abstract

Post Fukushima accident in the year 2011, worldwide nuclear community has adopted consensus to either replace the zirconium-based fuel clad by alternate one or to protect the Zircaloy-4 (Zry-4) surface using a suitable coating so that under loss of coolant (LOCA) accidental situation water or water vapor does not react with Zry-4 and prevent hydrogen generation. Among various alternatives, Cr-coating has been identified as one of the most promising coating candidate in PWR applications because of its strong oxidation resistance till 1200 ºC with matching thermal expansion coefficient. In India, for the first time, we report successful deposition of ~20-25 µm thick pore-free highly adherent Cr coating on Zry-4 coupons by magnetron sputtering utilizing both DC as well as RF power sources. As-deposited Cr coatings were characterized in detail by GIXRD, AFM and FESEM for crystal structure, surface morphology and cross-section microstructure investigation. GIXRD confirmed deposition of bcc-Cr with a strong texture along (110) direction. Cross-section FESEM investigation revealed compact pore and crack free microstructure with columnar grains. Excellent adhesion of the deposited coating with Zry-4 substrate was confirmed by scratch adhesion test with first cohesive failure Lc1 » 27 N for the RF coated specimen. No adhesive failure was detected till 80N load indicating excellent adhesion with Zry-4 substrate. Steam oxidation of Cr-coated Zry-4 specimen at 1000°C for 1h showed very good oxidation resistance as compared to bare substrate. Post steam oxidation, measured weight gain for bare Zry-4 sample was ~30 times more than the Cr-coated samples. The Cr-coated Zry-4 samples showed a slight greenish color oxide layer of Cr_2O_3 as confirmed by GIXRD investigation. The cross-sectional FESEM analysis revealed relatively thin (~4 µm) highly adherent oxide layer on RF coated sample in comparison to DC coated sample (~6 µm). No delamination of the oxide layer was detected. The present study highlights sputter deposited Cr coating can be a plausible solution towards ATF clad application under LOCA situation.

MSD_064

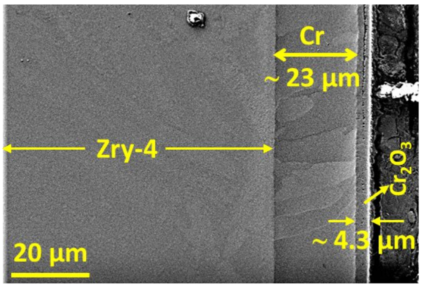

Fig. 1: FESEM cross section image of RF sputtered Cr-coating on Zry-4 substrate after steam oxidation at 1000°C for 1h.

Keywords: ATF, Magnetron sputtering, Cr-coating, LOCA.

Micro-structural characterization on proton irradiated W-3.5Ni-1.5Fe heavy alloy using X-ray and Electron diffraction and first principle DFT calculation

Santu Dey[a*], N. Gayathri[a,b], P. Mukherjee[a,b]

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Abstract

Tungsten (W) and its alloys have been considered as one of the candidate structural materials for nuclear fusion reactors due to its various superior properties [1]. For the application of W and its alloys in a radiation environment, it is necessary to understand the effect of irradiation on the microstructure and the related changes in various properties of these materials. Irradiation induced micro-structural changes in W-3.5Ni-1.5Fe heavy alloy have been assessed here. This alloy consists of bcc W grains embedded in ductile (Ni,Fe) rich fcc matrix as observed by optical microscopy and FESEM-EDX. Four doses of H^+ irradiated (6.3 MeV; 3 μA) alloy were characterized using XRD, EDX and EBSD techniques. XRD line profile analysis (XRDLPA) based on Modified Rietveld method (using MAUD) revealed variations in coherent domain size (Ds), micro-strain (Ms) and dislocation density (DD) with doses. The initial dose showed increase in Ds and reduction in Ms indicating annihilation of pre-existing defects present in the un-irradiated alloy. With increasing doses, the competition between defect production and annihilation in sinks resulted micro-structural saturation. DD showed decrease at the initial dose and saturation at higher doses. EBSD was used to measure the variation of Band Contrast (BC), Local Misorientation (LM), Pattern Misfit and GND density. Decrease in the low angle LM fraction and improvement in BC at initial dose indicate defect annihilation, followed by microstructural saturation at higher doses.

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MSD_067

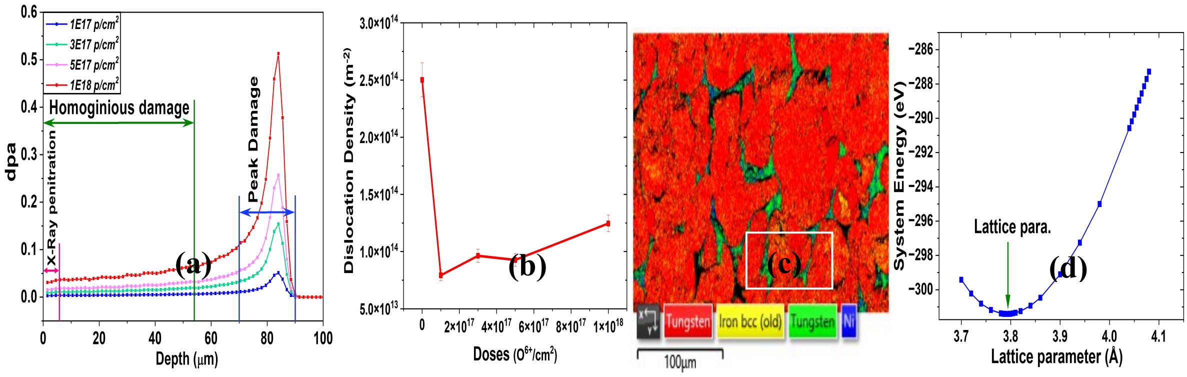

Fig. 1: (a) dpa variation with depth for different irradiation dose using SRIM, (b) Dislocation density with irradiation dose, (c) EDX mapping on As-received sample and (d) lattice parameter optimization by DFT

Key Words: Optical-microscopy, XRDLPA, FESEM-EDX, EBSD and DFT

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Behavior of refractory magnesia against high temperature melt impingement in sodium environment

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Abstract

Core Catcher (CC) is a passive device for safe retention of core debris during a hypothetical core melt accident in a sodium cooled fast reactor (SFR). For future SFRs, refractory magnesia is being considered as the protection liner for the CC against the melt ablation and high decay heat load during a whole core meltdown scenario. Sodium compatibility of the magnesia was found satisfactory through long-term exposure tests conducted at IGCAR. However, the magnesia lining needs to be tested against thermal shock resulting from corium impingement towards qualification and future deployment. In this context, an experimental study has been conducted to evaluate thermal shock resistance of magnesia under simulated core melt relocation. In the experiments, a high temperature melt jet at ~2400 °C simulating the corium was released on to magnesia test specimens in sodium environment. The temperature evolution across the thickness of the specimen was measured using embedded thermocouples. The melt impingement was imaged using real time X-ray radiography. The X-ray images showed melt fragmentation and settlement of the solidified fragments on the specimens. After the experiment, the specimens were retrieved, cleaned and examined visually. No surface open cracks were observed. Internal degradation was investigated by the reduction in Ultrasonic Pulse Velocity (UPV). Further, Modulus of Rupture (MOR) was measured for the sub-specimens as per ASTM C133 and compared with the reference specimens.

Melt impingement resulted in instantaneous temperature rise of the sodium pool and specimen surface by 250 °C and 145 °C, respectively. However, the corresponding temperature rise was only 30 °C at 15 mm depth beyond which, the temperature rise was negligible. During the test, peak temperature difference across the thickness (~ 50 °C) was found to exist only for ~500 s. No thermal shock induced fracture/ crack was observed from the tests, which can be attributed to the absence of large temperature gradient across the specimen thickness.

Post-test UPV measurements indicated no reduction in ultrasonic velocity. Instead, a marginal increase (7-8%) in pulse velocity was observed (measured range-6800-7000 m/s) due to sodium intrusion into the pores of specimens which enhances the transmission of ultrasonic waves. The flexure tests on sub-specimens extracted from the exposed specimens revealed a reduction of ~ 78% in MOR for the upper zone of the specimen, whereas no reduction in MOR was found for the sub-specimens extracted from interior zones of the specimen. Small surface cracks developed by thermal shock during the melt impingement are attributed to result in large reduction of MOR at the upper zone.

MSD_081

Experiments indicated that during corium relocation on sacrificial lining, fragmented debris would acquire temperatures near saturation point of sodium, and thermal shock imparted to the lining will be benign. Moreover, as no thermal spallation was observed, the magnesia lining's functionality remains intact. Hence, refractory magnesia can be considered as a promising sacrificial material for CC of SFRs.

Keywords: core catcher, core melt accident, magnesia, sacrificial material, thermal shock

MSD_081

Microstructural analysis using Electron Backscattered Diffraction of Proton Irradiated Incoloy – 800H

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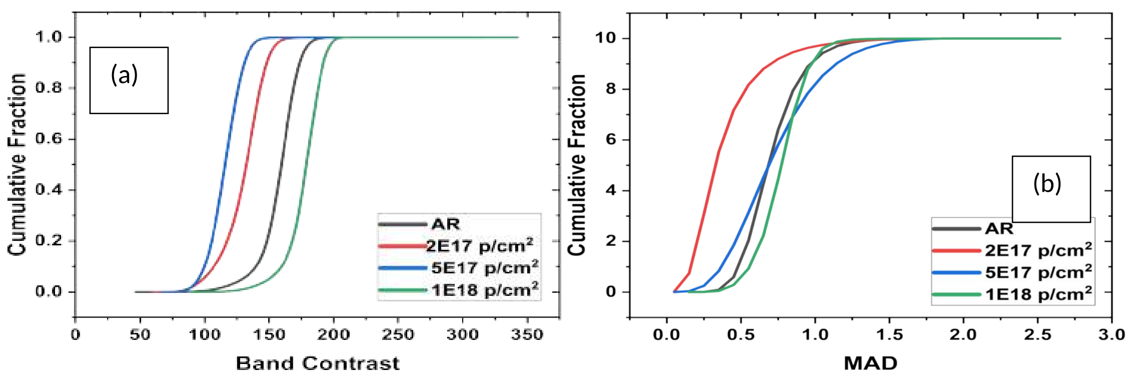
Abstract

Nickel-based alloys are candidate structural material for molten salt reactors where the resistance to corrosion by molten fluoride salt and high temperature creep strengths are prime requirements. Incoloy 800H has been considered as one of the structural material for Molten Salt Breeder reactor (MSBR) applications. To understand the irradiation response of the material, proton irradiation at Room temperature (RT) has been carried out in this alloy. The samples were irradiated with doses 2E17, 5E17, 1E18 p/cm^2 & the microstructural changes were evaluated and compared with the AR sample. In this work, the irradiated samples have been characterised by Electron Backscattered Diffraction (EBSD) technique which helps in evaluating the microstructural changes in the sample at a local scale in comparison to the XRD technique which gives a statistically average information over considerable volume of the sample. EBSD analysis has been carried out in terms of Band contrast (BC), Mean Angular Deviation (MAD), Grain size distribution etc. BC decreased initially but showed increase in highest dose. It signifies possibility of production of radiation induced (isolated) defects initially & then annihilation of defects resulting in improving the band contrast in EBSD pattern. MAD value showed an initial decrease & gradual increase with irradiation dose. It may be due to annihilation and subsequent production of new (correlated) dislocations.



MSD_082

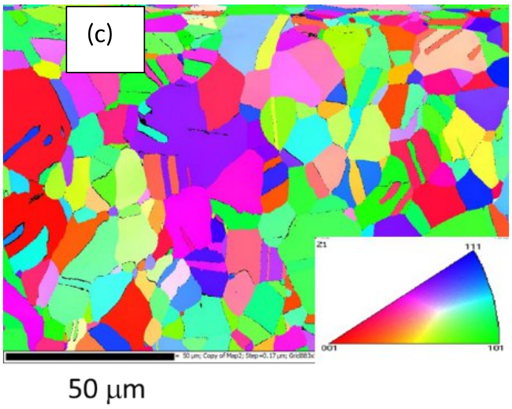


Fig.(a) Cumulative Fraction vs Band contrast, (b) Cumulative Fraction vs MAD with increasing dose of Incoloy 800H at RT, (c) IPF_z image of AR sample

Key words : Irradiation, Band contrast, Mean Angular Deviation, Incoloy 800H.

Quality Control through Destructive testing during manufacture of Complex & Critical Nuclear forgings

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Raju Vaghamashi, R Raj kumar, Amit Gupta
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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:

1. Tensile tests (RT and elevated temperature)
2. Impact tests at various temperature
3. 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

MSD_076

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.

Development of Slurry / Paste Based Coating for High-Temperature Thermal Protection

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Abstract

High temperature oxidation and thermal barrier coatings on various substrates starting from lightweight aluminum metal to refractive metals like tungsten, are the prime requirement for defence and aerospace applications. Currently, conventional thermal spray (TS) coating techniques fulfils the vast majority of the strategic applications. However, the TS techniques has its own limitations with respect to complex component geometry and sensitive materials such as tungsten, molybdenum and niobium base alloys. In order to address the above issues, metal and ceramics based slurry was prepared for a) surface modification, b) fused slurry and c) overlay coatings for various high temperature applications. The schematic of various slurry-based coating under development is shown in Fig. 1.

In this presentation, development of slurry for aluminizing, derived from well-known halide activated pack process on mild steel is discussed. Further, indigenized silicon based slurry for niobium silicide formation on C-103, a niobium base alloy for oxidation resistance at 1400 ◦C is also discussed. Moreover, thermal barrier paint (TBP) protection at very high temperature for applications requiring short-term exposure such as radome bulkhead and supersonic combustion engine has been demonstrated using alumina and zirconia based paste and slurry, respectively. Further, necessity and future requirement of such coatings and processing for domestic applications and strategic sectors are discussed.

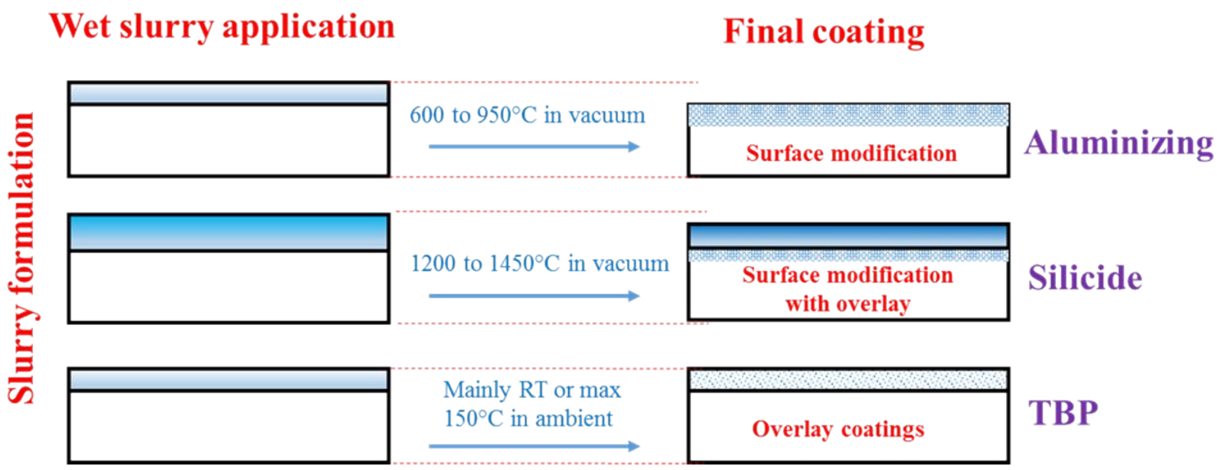

Fig. 1. Schematic of various slurry based coatings.

Key words : Slurry, coatings, thermal protection, oxidation resistance.
MSD_010

Oxidation behavior of Cr-Ta alloys at 900◦C

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Abstract

Oxidation resistance is a critical concern for materials operating at high temperatures due to its potentially catastrophic consequences. Traditionally, elements like Cr, Al, Si are incorporated into materials to form protective oxides such as Cr_2O_3, Al_2O_3, and SiO_2. However, these oxides are only effective up to 1100°C before they begin to decompose and disintegrate. Therefore, there is a pressing need to explore new-generation protective oxides capable of providing protection at temperatures above 1200°C. In this context, the AlCrMoTaTi alloy has demonstrated remarkable integrity, even when oxidized at 1600°C, outperforming traditional superalloys. This superior high-temperature performance is attributed to the formation of CrTaO4, a complex oxide scale that forms over a wide temperature range of 500-1600°C. CrTaO4 effectively hinders the formation of other non-protective oxide scales, making it a promising candidate for high-temperature applications.

To design high-temperature-resistant alloys, it is essential to thoroughly understand the nature of this new-generation protective oxide under high temperatures and prolonged exposure. As a first step in understanding CrTaO4, we prepared Cr-10Ta and Cr-20Ta alloys using vacuum arc melting, followed by homogenization at 1100°C for 24 hours. These specific alloy compositions were selected based on computational thermodynamic predictions indicating the formation of CrTaO4. Phase identification and microstructural characterization revealed a hypo-eutectic microstructure consisting of a Cr solid solution and Cr2Ta Laves phases. These alloys were then oxidized at a high temperature of 900°C for an extended period of 96 hours. Techniques such as X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), and energy-dispersive X-ray spectroscopy (EDS) were employed to identify the oxides present on the surface and in the cross-sections of the samples.

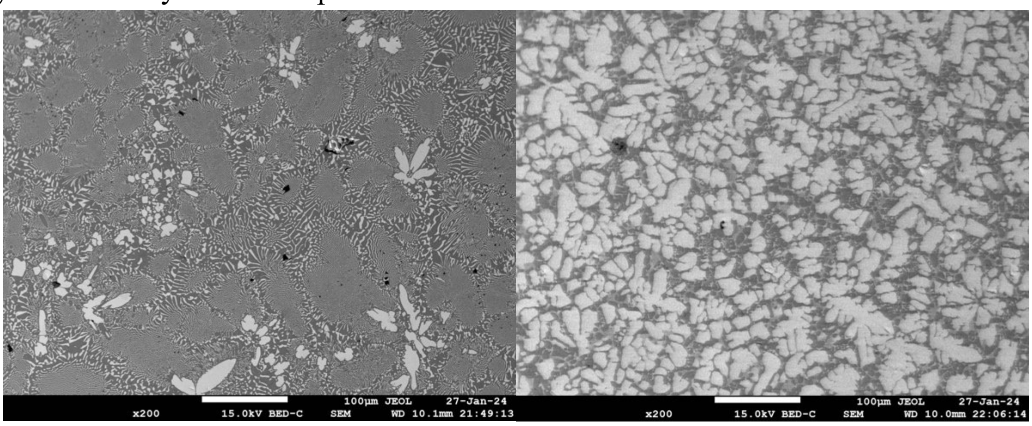

Fig1. Microstructure of Cr-10Ta and Cr-20Ta showing hypo-eutectic microstructure.

Key words: Oxidation, Cr-Ta alloys, $CrTaO_4$

MSSD_012

Characterization of U-Ti Alloys for Wear Application

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Abstract

Indian uranium ore processing mills use chrome steel balls as a grinding media. The annual consumption of which is very large. Therefore, material with better wear properties is required for uranium ore grinding application. Uranium based material with high hardness like U-Ti alloys can be a potential alternate option for this application. This will also likely to reduce the impurities introduced by chrome steel balls.

Present work is about the development of U-Ti alloy for the application of grinding media. Uranium titanium (U-Ti) alloys of different compositions were prepared using nuclear grade uranium (C~800 ppm) by arc melting under inert atmosphere. Hardness evaluation of the alloys in different heat-treated conditions was carried out by Vickers hardness measuring equipment. Various characterization equipment like optical & scanning electron microscope, and X-ray diffraction were used for the observation of microstructural features and analysis of phases present in alloys in different heat-treated conditions.

The effect of titanium on hardness was found to be pronounced for lower titanium compositions whereas smaller changes in the hardness values were observed beyond 1.5 wt. % of titanium. Aging heat treatment of 1.5 wt.% Ti alloy was done at 400 °C, 450 °C and 500 °C for constant aging period of 60 minutes. The peak hardness value of 609 VHN was obtained at 450°C. Further, in order to optimize the peak hardness value, same alloy was subjected to aging heat treatment at 450°C for four different durations, 20, 40, 60 and 80 minutes. The alloy containing 1.5 wt. % titanium exhibited micro-Vickers hardness of 499 VHN in as-cast samples and 644 VHN after aging at 450°C for 40 minutes, which is similar to the already reported hardness of U-Ti alloy prepared by using high purity uranium. In the optical micrographs of alloy with 1.5% Ti, grain boundaries were diffused in as cast samples, whereas in water quenched as well as in aged conditions well defined grains network was seen. Electron micrographs in water quenched condition show that the precipitates, mostly present at the grain boundary junctions, have flower shaped morphology. They disappeared after aging heat treatment, and now, precipitates could only be seen along the grain boundaries with acicular morphology features inside the grains.

The specific wear rate and coefficient of friction of nuclear grade uranium and U-1.5Ti alloy were measured using reciprocative sliding wear test. Basically, tribo-oxidation, abrasion and delamination were the three wear mechanisms which were responsible for the wear of uranium

MSD_050

and U-Ti alloy. Obtained results showed that the specific wear rate of both increases on increasing the load, though the effect of increase in load on wear of uranium metal and the alloy was different.

Key words: Uranium ore, grinding media, hardness, grain boundaries, specific wear rate

Double Clad: Effect of a Liner in Improving Iodine-SCC performance

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Abstract

Double clad tube of Zircalloy with inner softer liner layer is being developed as a candidate cladding material for future pressurized heavy water reactors for better performance in view of reduced pellet clad interaction (PCI). In the nuclear reactor core, the fuel pellets are stacked inside the clad tube which prevents pellet-coolant contact and acts as containment of radioactive fission products without release into the coolant. Thus clad tube should have excellent mechanical properties and high corrosion resistance. Undesirable failure of clad tubes at high burn up can result from either PCI mechanism with localized mechanical stresses or through hydride embrittlement [1-3].

Zr-Sn lined Zr2 double clad tube was produced by co-extrusion followed by cold pilgering and annealing in multiple steps. In order to probe the effect of soft liner in iodine induced stress corrosion behavior (SCC), samples of i) single Zr4 alloy clad tube and ii) Zr-Sn lined Zr2double clad tube were pressurized up to 98% of the burst pressure for generating internal stressed condition. One end of the tube was closed by end plug welding and after filling required amount of iodine crystals (obtained from literature), other end was sealed. Gas Tungsten Arc Welding was used as welding process. The pressurized samples were kept inside furnace at 380 °C for 72 h. Tubes were slit opened for comparison study under SEM (scanning electron microscopy). The ID surface of the Zr4 tube had several pits with coalescence but double clad tube ID surface was observed to have very fine features free from any localized coalescence showing mild reaction only. Further, the transverse section of the Zr4 tube was found with localized deep 'U' shaped attacked zones whereas the double clad Zr-Sn liner edge was found with shallow wavy appearance. The study clearly showed the beneficial effect of a softer liner in PCI performance of a reactor clad tube.

Keywords: Double Clad, PCI, Iodine-SCC, SEM

References:

1. Vincent Macdonald, David Le Boulch , Arthur Hellouin de Menibus , Jacques Besson , Quentin Auzoux, JérômeCrépin , Thomas Le Jolu, Fracture of Zircaloy-4 fuel cladding tubes with hydride blisters, Procedia Materials Science 3 (2014) 233 – 238
2. TeruoFuruta, Satoru Kawasaki, Reaction behavior of zircaloy-4 in steam-hydrogen mixtures at high temperature, Journal of Nuclear Materials, Volume 105, Issues 2–3 (1982) 119-131
3. TanweerAlam , Mohd. Kaleem Khan, , Manabendra Pathak , K. Ravi , Ritu Singh, S.K. Gupta, A review on the clad failure studies, Nuclear Engineering and Design 241 (2011) 3658–3677

MSD_062

Laser Cladding of CoNiCrAlY bond coat on Inconel718 for improved mechanical properties and high temperature oxidation resistance

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Abstract

Laser cladding has noteworthy potential in the modern additive manufacturing (AM) industry due to its wide range of applications. In this, metal powder is introduced through nozzle into the laser source which melts the powder and solidified it thereafter rapidly. The thermal barrier coating (TBC) (made of two layers: bond coat and top coat) is applied on superalloy to increase operating temperature which is conventionally deposited by thermal spraying method. In this study, CoNiCrAlY bond coating was deposited using laser cladding process on the IN718 superalloy substrate. The microstructural morphology, phases formed and residual stress of the cladding were characterized by Field emission gun – scanning electron microscopy (FE-SEM) and X-ray diffraction (XRD) spectroscopy techniques. Variation of Microhardness of the cladding from top to the substrate was analyzed. High-temperature isothermal oxidation properties of the cladding were investigated at 1000 °C for 1-100 hours. The microstructural morphology revealed that the CoNiCrAlY cladding on IN718 prepared by laser cladding was thick, uniform and free from cracks and pores. The height and width of the cladding tracks were varied with the laser parameter like laser power and scan speed due to interaction time of laser source and feeding powder. XRD analysis showed that the cladding was consisting of mainly γ and γ' phases along with the β phase. The longitudinal dendritic microstructure has been observed in the cross-section of the cladding which has a strict direction from the substrate surface to the top of the cladding that is perpendicular to the scanning direction and surface. The microhardness of the cladding was varied from 425-625 HV. The average microhardness of the surface clad was dependent on the laser process parameter. The oxidation kinetics was calculated and shown in the curve through the measurement of cumulative weight loss of the sample after every time interval. The high temperature oxidation resistance property of the clad surface was superior to the same developed by high velocity oxy fuel spraying.

Key words : Laser processing, Microhardness, Bond Coat, Oxidation

MSD_091

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 (γ'' and δ) 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

MSD_024

Development of heat treatment on 12Cr21 duplex stainless steel used in liquid rocket engine

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Abstract

Duplex stainless steels have higher strength compared to austenitic stainless steels, higher toughness than ferritic stainless steels, good weldability, and possess high resistance to different forms of corrosion in a variety of aggressive environments. Divergent section of a liquid rocket engine consists of three segments which are welded together. Each segment consists of two shells (inner copper and outer steel) which are brazed together. Outer steel shell is brazed to inner copper shell by vacuum brazing process. Inner shell of first segment is of copper alloy while the inner shell of second and third segment is of Ti-stabilized austenitic stainless steel. Weldability of copper alloy and austenitic stainless steel is poor. Duplex steel 12Cr21 ring is used to weld first segment to second segment, owing to better weldability of duplex steel to both copper alloy and austenitic stainless steel. Maintaining balanced phase fraction in duplex stainless steel is important to achieve balanced mechanical properties. During brazing of inner and outer shell, 12Cr21 steel also undergoes brazing heat treatment at 1230°C and aging at 510°C which increases the ferrite phase from ~50% (initial solution treatment) to ~70%. Due to an increase in ferrite phase in usage condition, decrease in impact toughness was observed from 20 kgf.m/cm^2 to 3 kgf.m/cm^2. Present work is to understand the reason for embrittlement and develop a heat treatment cycle to avoid embrittlement. Solution treatment (ST) was carried out at 955, 975, 1000, 1025, 1050 and 1075°C. The tensile properties, hardness, microstructural analysis and ferrite phase were measured in all these heat treatment conditions. 955 and 1000°C solution treated samples were subjected to brazing-aging heat treatment and evaluated mechanical properties and microstructure. Fractograph of tensile and impact tested samples were analysed to identify the mode and distribution of fracture features. Microstructure and fractograph of samples in various heat treatment condition are shown in Figure 1.

SPC_161

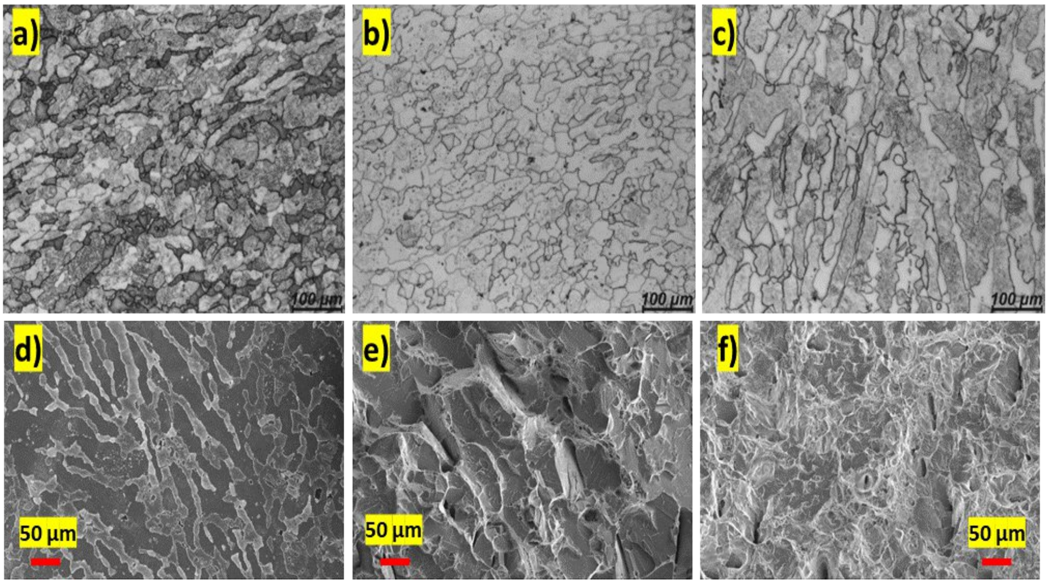

Fig. 1: Optical microstructure of 12Cr21 steel in a) ST at 955°C, b) ST at 1075°C, c & d) ST at 1000°C and brazing heat treated, e) fractograph of 12Cr21 in ST at 955°C and brazing heat treated & f) fractograph of 12Cr21 in ST at 1000°C and brazing heat-treated condition

Key words: 12Cr21 duplex stainless steel, ferrite percentage, brazing, embrittlement

METAL FORMING

Oral Abstracts

eHRC: a "game changer" product in steel flat products.

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Abstract

Since the development of rolling technology, steel flat products are traditionally divided among the two big families of Hot rolled (HRC) and Cold rolled (CRC) coils.

The introduction of Arvedi ESP process made possible the development of a new class of products, the endless-Hot Rolled Coils (eHRC) that, for the first time, dramatically extended the domain of hot rolled material into domains and applications that have been traditionally served by cold rolled products only.

This comes with evident economic savings in transformation costs and a significant reduction of environmental impact (lower energy consumption, lowest direct and indirect greenhouse emissions).

One of the first goals that historically promoted the development of the "endless" process in casting and rolling of flat products, was to produce thinner and thinner gauges as HRC and overcome the limit that even "best in class "conventional mills operating in coil-to-coil mode have, located at about 1,2 mm.

The "game changer event" has been the development of the endless process that allowed to link in an uninterrupted sequence casting and rolling for the first time, overcoming the "flying head" problem on the run-out table. Thus, the massive production of coils with thickness below 1 mm becomes possible even in sequences of hundreds, even thousands of kilometers, making obsolete also semi-endless process.

Present min. thickness record is set at 0,6 mm reached in Rizhao plant, China.

The Arvedi ESP, specifically conceived for endless process, has been the first plant concept making endless possible since 2009 and, with present 12 references, 9 of them in full production and more than 110 million of tons cumulatively produced to date, represents the "standard setter" on the thin slab casting and rolling plants of new generation.

Together with minimizing coil thickness, the endless process also allows a real improvement in coil quality concerning geometrical tolerances, metallurgical and mechanical properties: the eHRC is in fact completely uniform from head to tail, due to the absence of the coil-to-coil transitions during casting and rolling.

The advantages of the endless process in terms of coil quality appeared so evident that, soon, a new market segment emerged as a profitable target:

not only thin and ultra-thin gauges for commodity applications are now possible, but also high-added value grades in thinker gauges of superior and uniform quality.

MFR_086

This is well materialized by the present product mix of the Arvedi ESP plant in Acciaieria Arvedi in Italy where the automotive market represents almost 30% of the total production, out of a total of 43,5 % of HSLA grades, with thicknesses ranging from 1 to over 8 mm.
Similar features are considered for the next ESP plant that will be put in operation in October 2024 for Unites States Steel, Big River plant in USA, specifically conceived to produce the XG3 AHSS grades that USS is at present producing for the automotive market in conventional plants, featuring high strength and high formability.

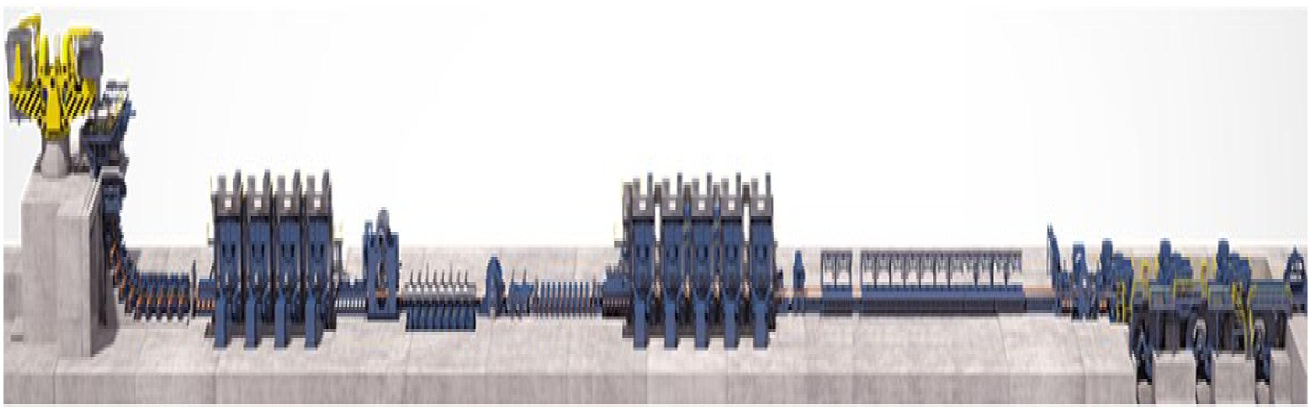

Fig. 1 Unites States Steel ESP plant.

Hot deformation behavior and influence of Inclusions in mischmetal-treated low carbon aluminum-killed Steel

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Abstract

The hot deformation behavior of low carbon aluminum killed (LCAK) steel treated with mischmetals was investigated under strain rates ranging from 0.01 to 10/sec and temperatures 950 to 1250 ℃ to a true strain of 1.0. The flow characteristics were analysed based on deformation parameters. The constitutive equation for flow stress of LCAK steel was established. The activation energy required for the hot deformation process was estimated to be 344 kJ. Strain was incorporated into the Arrhenius-type constitutive equation, resulting in an excellent fit between the predicted and experimental flow curves, with a correlation coefficient (r) of 0.99349. The effects of microstructural changes with varying deformation parameters were examined, along with the morphological changes of rare earth-based dual-phase complex inclusions. The processing map, utilizing strain rate sensitivity (m) contours, was used to correlate with the deformed microstructure. Since m is directly related to temperature and strain rate, higher deformation temperatures and lower strain rates result in higher m values. However, higher deformation temperatures and lower strain rates also lead to the coarsening of dynamically recrystallized (DRX) grains due to the greater driving force available for grain boundary migration, which is detrimental to the steel's properties. Hence, it is essential to consider the average grain size parameter also, as DRX grain growth occurs with higher deformation temperatures and lower strain rates. It was found that higher m value (>0.10) should be utilized for a safe processing zone, provided excessive DRX grains coarsening is avoided.

Key words: Hot deformation behaviour; LCAK Steel; rare earth elements; inclusions; DRX grains

MFR_100

Development of API X65MS Grade Steel Plate for Sour Service Application in Oil and Gas Industry

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Abstract

Development of high strength and higher thickness API sour service grade steel plates for linepipe applications possesses series of challenges from the steel making to continuous casting and hot rolling stages. The stringent requirements and harsh operating conditions need that steels must withstand which makes every step of the development critical. At JSP trials were taken to develop API X65MS grade steel for sour service applications through the Plate Mill-Angul using thermomechanical controlled rolling (TMCP) process for up to 40mm thickness. This sour service API grade steel is currently imported into India and the development for this specification will serve as import substitution and contribute towards Atmanirbhar Bharat.Besides the standard requirements of the mechanical properties, the API X65MS grade steel must also pass the Hydrogen Induced Cracking (HIC) and Sulphide Stress Corrosion Cracking (SSCC) tests in an acidic environment with Hydrogen Sulphide (H_2S) in solution and the most challenging Drop Weight Tear Test (DWTT) at -11° C and Crack Tip Opening Displacement (CTOD) test at -29° C.The development process went through a detailed step-by-step analysis and understanding of the material properties and micro/macro structural analysis of the steel from steelmaking to final TMCP rolling. The stringent requirements of this X65 sour grade was achieved by controlling the alloying elements for achieving the optimal composition to ensure the mechanical properties, corrosion resistance, and resistance to HIC and SSCC of the steel. The cleanliness and inclusion control in steel was also taken care through optimised secondary steelmaking processes. The final microstructure was carefully managed through the TMCP rolling route to ensure a homogeneous distribution of fine grains to prevent the crack propagation and ensure the impact and DWTT properties at sub-zero temperatures. The complete step-by-step manufacturing processes and the modelling capabilities adopted for this development will be presented of this work.

Key words: API X65MS, Sour service application, line pipes, HIC, TMCP, Impact properties.

MFR_105

Texture evolution during hot rolling of 0.3 CrMoV steel: Role of strain path

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Abstract

In this work, we interpret the effect of strain path (i.e., unidirectional (UDR), Reverse (RR), and Multi-step cross rolling (MSCR)) during hot rolling on the texture and microstructural evolution of 0.3 CrMoV steel. The average grain size reduces drastically when the sample is subjected to a 90% thickness reduction. The grain refinement is primarily governed by the combined effects of grain fragmentation and continuous dynamic recrystallization (cDRX) of the ferrite phase. The extent of grain fragmentation is dependent on the texture. While grains pertaining to the γ-fiber, i.e., <111> ||ND, more easily convert to equiaxed morphology from elongated morphology, the grains pertaining to α-fiber (<110> || RD) require higher plastic strain for such conversion. The volume fraction of α-fiber is found to be the highest in all the conditions, and the maximum intensity is found at {112} <1-10> texture component, while γ-fiber evolves as the second strongest texture fiber having a maximum intensity at {111} <1-23> component. The strength of these texture components is strongly influenced by the strain path. The MSCR samples have the least intensity, while UDR samples have high intensity. MSCR condition further indicates the formation of {110} <001> texture component, which is not found in UDR and RR. The texture intensity of these fibers is found to be comparatively weaker at the surface and attains the maximum at the mid-thickness region.

Keywords: 0.3 CrMoV steel; Hot-rolling; strain path; grain fragmentation; Texture.

MFR_119

Hot Deformation Behavior of Fe-16Co-7.5Ni-3.5Cr-1.75Mo-0.1C Carburizing Steel

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Abstract

The Fe-16Co-7.5Ni-3.5Cr-1.75Mo-0.1C alloy is a high-performance gear steel known for its superior core strength, enhanced surface fatigue resistance, excellent hardenability, and high temperature stability, making it ideal for demanding applications such as in aerospace and automotive industries. This study explores the hot deformation behavior of this alloy using isothermal uniaxial hot compression tests (HCT) conducted with a Gleeble-3800 thermomechanical simulator. The tests were performed over a temperature range of 850°C to 1150°C and at strain rates of 0.01, 0.1, 1, and 10 s^{-1}. The samples used were cylindrical, with a diameter of 10 mm and a length of 15 mm, and were compressed to achieve a 50% height reduction, corresponding to a true strain of 0.69. Post-deformation, the samples were quenched in water to preserve the microstructure at the deformation temperature.

Microstructural analysis revealed that dynamic recrystallization (DRX) is the dominant deformation mechanism across the investigated conditions. Strain rate sensitivity map has been generated based on the strain rate sensitivity parameter. In particular, at temperatures ranging from 1025°C to 1150°C and a strain rate of 0.01 s^{-1}, the strain rate sensitivity parameter "m" reached a maximum value of 0.28. The positive values of "m" observed across the studied domain indicate that the alloy can be thermo-mechanically deformed without flow instability, suggesting good workability under the tested conditions.

The flow stress data generated from these hot compression tests were subsequently utilized as input material data for DEFORM 3D, a finite element-based forging simulation software. Simulation studies using the generated data were carried to optimize the forging process of gear in transmission assembly of a helicopter. This study provides valuable insights into the hot deformation characteristics of the Fe-16Co-7.5Ni-3.5Cr-1.75Mo-0.1C alloy, supporting its application in high-performance gear manufacturing through optimized forging processes.

Key words : Hot compression test, Carburizing steel, Strain rate sensitivity map, Forging simulation, DEFORM 3D

MFR_130

Hot deformation characteristics and microstructural evolution of Ti-900 alloy

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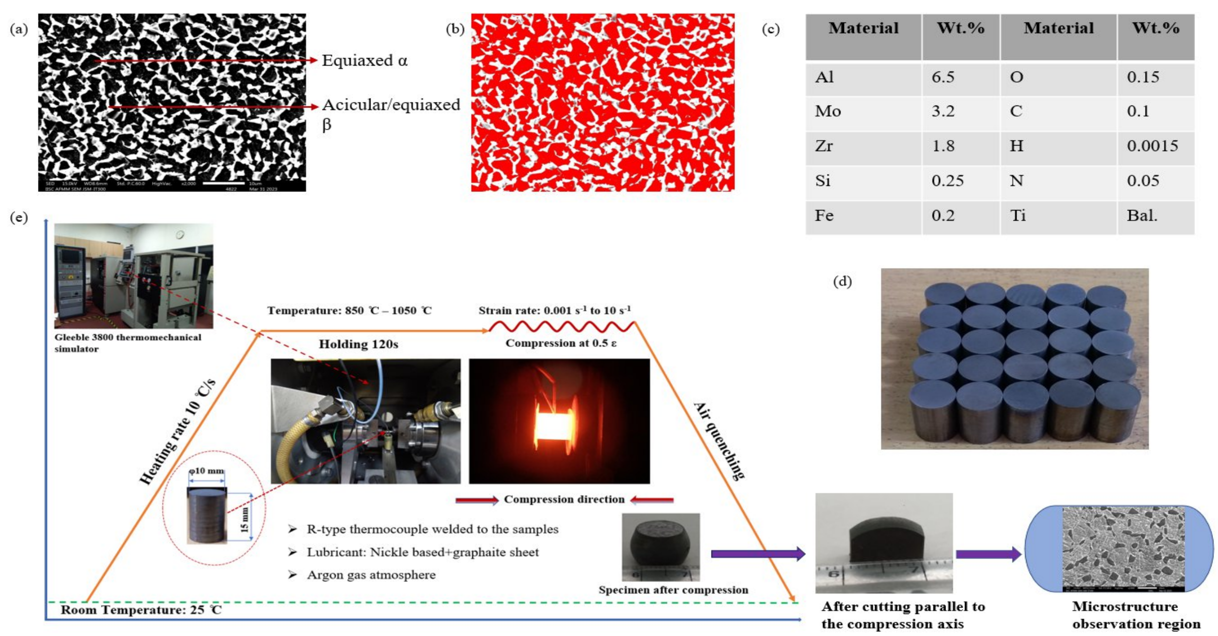
Abstract

Hot deformation behavior of Ti-900 (Ti-6.5Al-3.2Mo-1.8Zr-0.25Si) alloy has been analyzed by conducting an isothermal hot compression test at 850 °C to 1050 °C temperatures and strain rates between 0.001 s−1 to 10 s−1. The effect of strain rates and deformation temperature on flow stress is investigated. The processing maps are constructed, and constitutive equations are studied to understand the formability of the novel titanium alloy in the different temperatures and strain rates regimes. Results suggest that temperatures and strain rates between 880 °C to 950 °C and 0.001 s−1 to 0.01 s−1 are the optimal processing window for this alloy. The kinetic rate equation indicates that the apparent activation energy for deformation is 531 kJ/mol in the α + β region. Post deformation microstructure formation is also studied.



Material	Wt.%	Material	Wt.%
Al	6.5	O	0.15
Mo	3.2	C	0.1
Zr	1.8	H	0.0015
Si	0.25	N	0.05
Fe	0.2	Ti	Bal.

Figure 1. As received GTM-900 alloy (a) microstructure, (b) phase volume%, (c) chemical compositions, (d) specimens for hot compression test, (e) schematic view of hot compression process flow

Key words : GTM-900 alloy, Hot deformation, Constitutive equation, Processing maps, Microstructure

MFR_137

Development of Heavy Guage S355MLO Steel Plates for Off-Shore Wind-Tower Application

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Abstract

S355MLO (EN 10225 - Part 1:2019) grade steel is an offshore structural grade and is in demand for offshore wind tower applications. The client requirements came with strict control of chemistry and demanding requirements in mechanical properties with Yield Strength ≥ 335 MPa, Tensile Strength of 470-630 MPa, and Charpy Impact Toughness guaranteed at mid-thickness position when tested at -50°C. In the development of thicker plates (80mm) of this grade, achieving the desired mechanical properties like sufficient strength and toughness throughout the thickness is a manufacturing challenge due to the insufficient strain penetration to the core during hot rolling and as a consequence, inadequate grain refinement which usually leads to inferior properties at the core. This structural grade also requires the steel plate to be easily weldable and hence comes with a thorough weldability testing at various locations near the Weld Fusion Line, including the Crack Tip Opening Displacement (CTOD) tests. Currently, this grade at such higher thickness is only imported into India and this development will serve as an import substitution and contribute towards Atmanirbhar Bharat. The development methodology for this grade included optimization of the alloying elements for grain refinement during the TMCP (thermomechanical controlled processing) rolling at Plate Mill using 300 mm thick slabs produced at Slab Caster at Angul. Rolling trials were conducted through judicial use of roughing and finishing pass reductions along with optimum rolling process parameters to achieve the required mechanical properties and impact toughness at the mid-thickness position.The influence of various process parameters like change in alloying elements and change in the rolling parameters like finish rolling temperature, cooling rate, reduction ratios, hold thickness ratios in roughing and finishing passes etc. were evaluated and their effect on the mechanical properties and microstructure will be presented.

Key words: Off-shore structure, High strength steels, TMCP, Impact properties.

MFR_104

Optimized Hot Rolling Process for Thinner Gauge Rolling of Steel Strips and Coils for Tubular Structures

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Abstract

The use of tubular steel structures have gained prominence in wide range of industries, such as construction, logistics, utilities, and several engineering applications. The present work is aimed at developing thinner gauge rolling process for E250 (YS ≥ 250 MPa) and E350 (YS ≥ 350 MPa) structural steel strips intended for fabrication of lighter, stronger, and durable hollow structural. An attempt to optimize rolling parameters to achieve thinner gauges while maintaining the mechanical properties required for structural applications has been made. Field scale rolling trials were conducted for both the steel grades in a modern high speed hot strip mill. The microstructure and tensile properties were analyzed. Results indicate that both E250 and E350 steels can be successfully rolled to thinner gauges (down to 2.0 and 2.5 mm respectively) without significant loss of strength or ductility when using optimized rolling schedules. Special considerations have been made for keeping the carbon content in the range of 0.10-0.15 %, and microstructural aiming for fine-grained ferrite-pearlite structure.

The rolling parameters were fine-tuned based on the specific mill configuration, exact steel composition, and desired final properties. The steel slabs were heated to a temperature of 1200-1250^{O}C with a soaking time of 3-4 hours which were subsequently rolled to strips of 2.0-2.5 mm thicknesses through series of roughing and finishing stands. The rolling start and finish temperatures were maintained in the range of 1100-1120^{O}C and 800-850^{O}C respectively with the coiling temperatures in the range of 600-650^{O}C. The total reduction from slab to coil were planned to be in excess of 95% while maintaining the transfer bar thickness in the range of 30-35 mm. The rolling force and speed are determined by the mill automation system based on the reduction in various roughing and finishing stands, total reduction, and transfer bar thickness. The key challenge in rolling thinner steel strips is maintaining tight thickness tolerances and good flatness while achieving the required mechanical properties.

Keywords: Tubular sections, Thinner gauges, Hot Strip Mill

MFR_107

Silicon Steel Production Lines for Grain Oriented (GO) and Non-Grain Oriented (NGO) Electrical Steels

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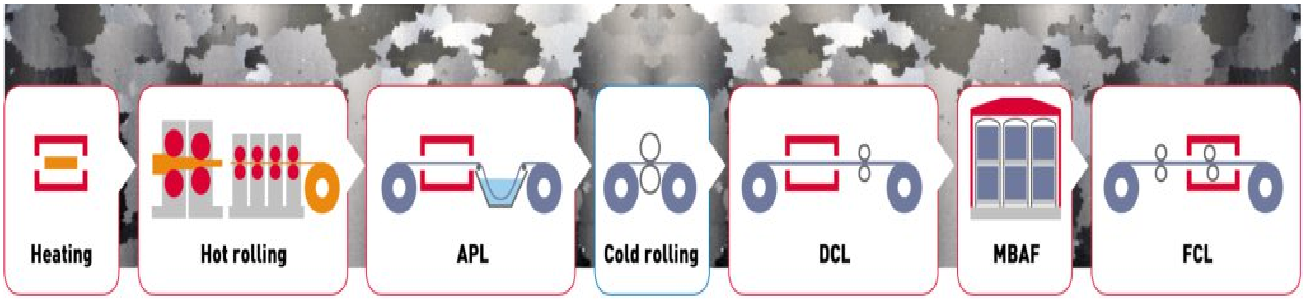
Abstract

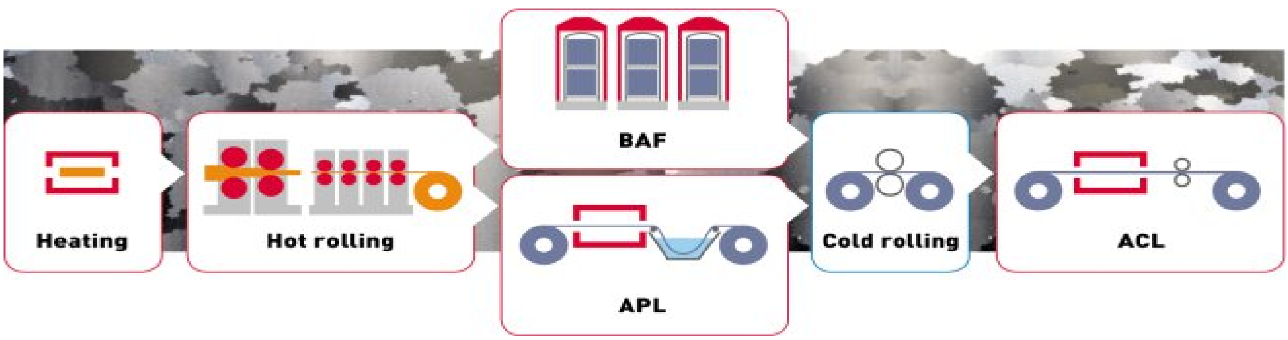
Decarbonization of the steel industry and electrification initiatives are leading to further growth in application of non-grain oriented (NGO) and grain oriented (GO) electrical steels.
Driven by the developing of the Electrical Mobility, the Cold Rolling area design is rapidly evolving to produce electrical 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

DM_07

Production line for grain-oriented electrical steel strip



Production line for non-grain-oriented electrical steel strip



Development of Cold Rolled Complex Phase Steels sheet with 590Mpa Tensile strength for Automotive Seat components

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Abstract

Automotive seat components typically have complex profiles and higher strength requirements to meet the design criteria. Stretch flange ability is one of the prime property requirement for this application to avoid any flange crack in the component. The purpose of this study was to develop a cold rolled complex phase steel sheet that is high strength and stretch-flangeable for automotive applications. Literature study was conducted to understand the design requirements and found combination of Si and Al addition to the steel composition to facilitate the formation of bainite, which enhance precipitation hardening, and control austenite grain sizes. Several process parameters like CAL SS temperature, SCS temperature, Line Speed etc., are investigated in this study in order to determine how they affect final microstructures and mechanical properties. This study determined the austenite grain growth behavior during heating and soaking of cold rolled steel sheet on a continuous annealing line, the recrystallization kinetics, and the transformation curves during continuous cooling.

The first set of parameters was tested in the Gleable Simulation lab and confirmed that the best elongation properties were obtained with homogeneous bainitic lath/granular microstructures, which can be produced with a SS temperature of 760 – 820°C and a line speed of more than 130 mpm. The production CAL trial yielded a microstructure consisting of at least 25% homogeneous lath/granular bainite, 60-75% Ferrite and 0-5% Retained Austenite that presented a tensile strength of 590 Mpa and more, yield strength of 350-500 Mpa, Total Elongation of 25% or more, Strain Hardening coefficient of 0.18 or more, and Hole Expansion Ratio of 65% or more for improved crash performance.

Key words : CP Steels, H

Mfr_029

Cold Rolling and Its Impact on Mechanical Behavior in Maraging Steel-250 Grade

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Abstract

The softer martensitic matrix of Maraging steel-250 strengthened with Ni rich precipitates possess atypical combination of high strength and ductility. However, ageing above 480 ℃ result in reduction in its strength in conventionally hot rolled conditions. This is attributed to coarsening as well dissolution of Ni-rich precipitates which promotes the formation of softer reverted austenite (RA) phase, and accompanying incoherent Fe-Mo precipitates. Cold rolling deformation induces a texture in the martensitic matrix which is able to stabilize the Ni rich precipitates even up to higher ageing temperatures and reducing RA formation. Cold rolling (CR) on the as received Maraging steel in solutionized condition was carried out at 20%, 40% and 60% to understand the evolution of texture involvement and its implications on the mechanical properties. Ageing was compared at 540 ℃ for 3 hr. A combination of <111> and <100> planes over <110> resulted in suppression of the reverted austenite from 35 % in as received to 7% in CR. The low angle grain boundaries formed during rolling are pinned by the coherent precipitates, preventing their dissolution, and reducing the RA fraction. This in turn resulted in 1950 - 2000 MPa in strength and 15 - 9 % elongation to fracture, while continuing to be dominated by planar slip.

Keywords: Maraging steel, Reverted austenite, Cold rolling, Ageing.

MFRr_055

Effect of Wet Skin Pass Mill Roll Cleaning Parameters on Surface Quality of Cold Rolled Annealed Strip for Automotive Application.

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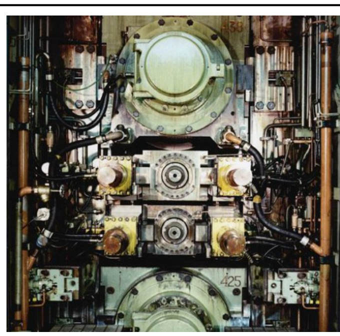
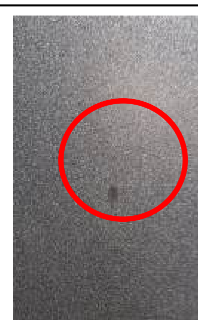
Abstract

Skin Pass Mill/ Wet Temper mills are widely used by cold rollers to improve CRCA surface finish by imparting optimum Ra, strip shape correction and suppressing yielding phenomenon for Automotive Outer Panel Application. As name of the process suggesting, skin pass rolling highly affects the strip surface morphology, thickness & hardness and can be distinguish by Surface, Shape & strength of strip by Testing & characterization of Skin Passed material. The strip surface and other characteristics controlled by various skin pass rolling parameters like Strip elongation, work roll Ra, strip tension, etc.

Current Study is about a Surface Defect generating on strip in one of the Skin pass mill of Tata steel-India. Defect prevention also studied wrt input strip surface parameter and skin pass roll coolant spray system.

The defect is very superficial and appears in work roll pitch. Defect named as Matless Spot/Soot





mark as the defect location has low roughness as compared with rest of the good surface and generating by particle stick on Work Roll which is coming in strip contact during skin pass.

Fig. 1: Skin Pass Mill

Fig. 2: Matless Spot Defect on strip

Key words : Skin Pass Mill, Temper Fluid, Detergency of Temper Fluid, Temper Fluid Spray System, collision, roughness, Automotive Outer panel Application

MFR_108

Analysis of Cold Mill Gauge Variation in High Speed Rolling Passes

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Abstract

Automatic Gauge Control (AGC) for Cold Rolling Mill (CRM) works on hydraulic gap control with different mechanisms such as feedback/feed forward/mass control to achieve the target gauge set for cold rolling. In Feedback control, the mill actuator controls based on the X-ray measurement of actual thickness depends on the sensitivity of the control tuning. Rolling process data was analysed for coils rolled at high speed in back-to-back rolling configuration to correlate the rolling parameters with gauge deviation observed. The analysis showed a strong correlation of the gauge variation with rolling parameters of uncoiler speed, rolling load and exit tension. This was hypothesized to be due to self-excitation of a mechanical feedback loop due to an unstable neutral point within the roll bite resulting from frictional variations as a result of higher entry sheet temperature effect on bite lubrication film thickness.

Fig. 1: iba Correlation matrix analysis for coil with gauge variation

The sensitivity of this mill bite instability was quantified using a numerical rolling model. Trial plan was developed and the hypothesis was validated with rolling trials at high speed with both coils rolled back-to-back and with intermediate cooling. The lower input temperature coils showed a better gauge performance.

To allow for back-to-back higher speed rolling for increased productivity, trials with AGC parameter controls were conducted for these back-to-back passes to control the gauge variation. Based on the effect of AGC control settings on thermal trim, Roll Eccentricity Compensation (REC) and low frequency disturbances, recommendations for customized tuning of AGC control parameters for specific passes were shared with OEM for implementation.

Keywords : Gauge variation, rolling model, process data analysis
MFR_111

Optimisation of Cold Reduction for Controlling the Recrystallisation Kinetics for HSLA 550 Galvanised Steel

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Abstract

The cold reduction process plays a critical role in influencing the recrystallization kinetics during continuous galvanizing. The relationship between cold reduction and recrystallization kinetics is crucial for optimizing the mechanical properties of steel products. High strength HSLA 550 galvanised steel strip was developed with optimising cold reduction and annealing parameters to precisely control the recrystallisation kinetics. By controlling the cold reduction percentage and annealing parameters, the microstructure was tailored to achieve desired characteristics such as strength, ductility, and texture, which are essential for various applications. This relationship between cold reduction and recrystallization kinetics underscores the importance of precise process control in the production of high-quality steel material.

Key words: Cold reduction, Recrystallisation, Continuous galvanizing, microstructure, HSLA Steel

MFR_118

Discreet Techniques of Cold Rolling Ultra-Thin Stri

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Abstract

The production of cold rolled ultra-thin strip has always been a challenge and has attracted numerous research on the subject. To date, major emphasis has been on work roll diameters for cold rolling of thin strip. This paper discusses and analyses various parameters to be considered and controlled to roll quality ultra-thin gauge high strength and electrical grade steel on 6HI cold rolling mills.

Key words : Cold Rolling Mills, 6HI, 4HI, Thin Strip Rolling, Strip Shape, Roll Profile, Advanced High Strength Steel, AHSS, Silicon Steel

MFR_002

Impact of Two-Stage Cold Rolling Reduction and Intermediate Annealing Temperature on Final Texture and Magnetic Properties of Thin Gauge Non-Oriented Electrical Steel

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Abstract

Fe-2.7% Si non-oriented electrical steels were produced using a two-stage cold rolling process that included hot rolling, first cold rolling, intermediate annealing, second cold rolling to a thickness of 0.25 mm, and final recrystallization annealing in an industrial continuous furnace. The samples were metallurgically characterized for microstructure and texture evolution using optical microscopy, EBSD technique, and bulk texture XRD analysis. The results indicated that the final recrystallization texture of the two-stage cold rolled samples exhibited a higher zeta <011>//ND fiber volume with a near Goss {011}<100> component orientation, leading to improved magnetic properties. After the first cold rolling, the fully cold rolled samples were intermediate annealed at various temperatures. The effect of intermediate annealing on the final magnetic properties was systematically investigated, revealing that watt loss decreased with increasing intermediate annealing temperatures. This reduction in watt loss is attributed to the coarse hot band microstructure formed during the intermediate batch annealing stage. Upon second cold rolling, the coarse-grained intermediate annealed samples developed ingrain shear bands, which served as nucleation sites for favorable Theta fiber<001>//ND and Goss grains {011}<100>, resulting in better magnetic properties compared to samples annealed at lower intermediate temperatures. The evolution of microstructure and texture in two-stage cold rolled samples with a thickness of 0.25 mm was compared to single-stage cold rolled samples with a thickness of 0.5 mm to demonstrate the effect of cold rolling reductions on the final magnetic properties. This study provides evidence that magnetic properties can be improved by reducing cold rolling reductions and increasing intermediate annealing temperatures.

Key words :Intermediate annealing, Two stage cold rolling, Thin gauge CRNO, Crystallographic Texture.

SPC_019

Technology Advancement in Rolling & Drawing using Hard & Super Hard Materials.

Hyperion Materials & Technologies

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Abstract

In present world steel manufacturers are immersed in an environment of daily challenges related to productivity, innovation, and sustainability. In applications such as automotive or construction, for example, it is essential to achieve a technically outstanding product, which is highly competitive and with clear connotations in the care of the environment in which we live. For the steel industry, meeting these challenges requires the use of increasingly specialized and specific materials which have been studied, selected for each application and whose production scrupulously maintains excellent quality standards. Choosing low-profile materials can be extremely counterproductive if we want to create a better company.

Starting with the process of rolling Tungsten Carbide can play a significant role in increasing mill output by lowering the operational costs, significantly reducing the mill stops and improving rolled material surface finish and tolerances owing to its high wear resistance as comparing to conventional roll materials like Cast Iron & HSS.

Cast in Carbide (CIC®) is a unique technology which leverages a metallurgical bond between Cast Iron and Tungsten Carbide. CIC® eliminates the need for external clamping system to guarantee a positive torque transmission while offering flexibility to accommodate more no. of pass forms on the barrel. These rolls find applications in different areas of the rolling mill: from roughing to finishing stands. We would be presenting a case study of such an application highlighting a direct comparison of performance eventually resulting in reduction of cost/ton along with the importance of roll cooling and machining to maximize the performance.

Going further to the process of wire drawing where Tungsten Carbide dies are used, for wet or dry drawing, it is not enough just to use any carbide and have it cased in any way in its housing. Our presentation is about what is a good carbide, how to detect that our die works well and how casing affects drawing process and die life.

The use of a high-performance Tungsten Carbide in specific wire drawing applications has shown an increase in die life by 30% - 50%, while proper casing can reduce drawing die breakages by half, thus increase die life by 15% - 25% along with better stability in the drawing process. All these results are backed up with a high level of innovation and development effort where, initially, simulation techniques and knowledge of materials science guide us where to take our first steps and then collaborate with the customer on implementation and direct problem solving.

Currently, the use of Polycrystalline Diamonds (PCD) is gaining prominence in the world of steel drawing especially when it comes to wires with reduced cross-sections, very high tensile

DM_058

strength, and specific coatings. Knowing what a PCD is and when to choose one or the other

type is crucial for a plant that wishes to increase its productivity and quality. Likewise, we will give the keys to understand this material and what each producer should base his choice of candidates on.

Key words :Tungsten Cabide Rolls,Mill Productivity,Tungsten Carbide Dies, PCD Dies

Development of 1X7, 15.70mm, 1960 grade Low Relaxation Prestressed Concrete (LRPC) Strands for Metro Girders.

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Abstract

Low Relaxation Prestressed Concrete (LRPC) is a specialized material extensively utilized in civil engineering and construction to significantly enhance the strength and durability of concrete structures. It is prominently employed in projects where long spans, high load capacities, and minimal maintenance are essential criteria. LRPC is characterized by its high tensile strength, low relaxation properties, corrosion resistance, and ductility. It finds applications in various sectors including bridges, flyovers, buildings, and infrastructure project. This study focuses on development of 1X7, 15.70mm LRPC strand with the breaking load of 294 KN, targeting a tensile grade of 1960. A mathematical model was developed, achieving 85% accuracy compared to actual test results of manufactured LRPC strands. The model recommended the use of 14.00mm HC86BCr wire rods over conventional 13.00mm HC82BCr rods. The process began with casting heats containing HC86BCr, ensuring precise chemical composition and steel purity. These heats underwent controlled rolling to achieve a diameter of 14mm from billets sized at 165X165mm, guaranteeing optimal mechanical properties and microstructure for LRPC applications. Subsequently, utilizing the same wire rod, a 15.70mm strand was produced, surpassing the required breaking load of 294KN. This successful development not only meets customer demands but also expands production capabilities, enabling high-performance applications in construction projects

Key words : Low Relaxation Prestressed concrete (LRPC), Breaking load,Hole-Expansion Ratio and Annealing.

MFR_037

Development of HC82A Pearlitic steel for Tyre cord application

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Abstract

The automotive industry's rapid expansion has significantly increased the demand for high-quality tyre cords. High carbon pearlitic steel wire rods particularly the non-alloy HC82A grade, renowned for their superior strength and toughness, are extensively utilized in manufacturing tyre cords. Typically drawn into thin wire sizes ranging from 0.30 to 0.38 mm in diameter. However, the wire drawing operations for tyre cord manufacturing during fine drawing face considerable challenges due to the presence of grain boundary cementite and large, hard non-deformable inclusions. These inclusions and segregations can lead to increased failures, compromising the quality and performance of the final product. This paper explores comprehensive measures undertaken to reduce inclusions, segregation, and grain boundary cementite to enhance the performance of tyre cords. Through a combination of slag engineering which involves refining the composition and properties of slag used during the steelmaking process and optimized solidification practices. Additionally, the paper delves into the importance of increased specific water consumption based on the solidification length during the solidification process. The study presents a detailed analysis of how these measures contribute to reducing failures during wire drawing operations. The findings also highlight significant improvements in the cleanliness and mechanical properties of the SWRH82A grade steel, making it more suitable for high-performance tyre cord applications.

Key words : Grain Boundary Cementite

MFR_043

Development of LRPC grade wire rod at Vizag Steel : One more step towards leadership in long products

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Abstract

Pre-stressed concrete are essential components in construction where compressive stresses are induced in concrete during casting so that applied service loads can be counteracted effectively. This compressive strength is best induced by LRPC (Low Relaxation Pre stressed Concrete) multi wire (ply) strands. These high strength concrete members, having both compressive and tensile properties, are commonly used in bridges, fly overs, highways, high rise buildings etc. Ensuring quality, high strength steel wire rods with durability and reliability as a raw material for wire drawing and making multi ply (3, 5 or 7) LRPC strands remains on wire rod manufacturers.

Development of LRPC wire rod was attempted in Vizag steel using the state of art facilities of its Steel Melt Shop 2 and Wire Rod Mill 2. The grade is basically a high carbon 0.82-0.85 wire rod with superior UTS around 1170- 1200 MPa and 30-32 % RA. Total 16 heats were made to 150X150 mm2 billets and subsequently rolled into 10 and 12 mm dia wire rod following BOF-LF-RH-Hot rolling-Stelmore cooling process route. In few heats RH degasser was not used. Nitrogen and hydrogen control during steel making and control on Laying head temperature, stelmore speed during rolling are very important. Opening of all hoods and all blowers in stelmore lines was found beneficial. Natural ageing at room temperature for 20-24 days were done to increase % RA value. This happens due to hydrogen diffusion from the material with due time. Metallography characterization was done, in which fully pearlitic structure is revealed which is very essential for draw ability of the wire rod.

This initial attempt of developing LRPC grade is in line with the continuous effort of Vizag Steel to add value added grades in its product basket. Further trials will be carried out based on customer feedback.

Key words: LRPC, BOF, RH, Laying Head Temperature.
MFR_052

Elimination of Free Ferrite in rolling of SAE 9254 at Wire rod mill of TSG

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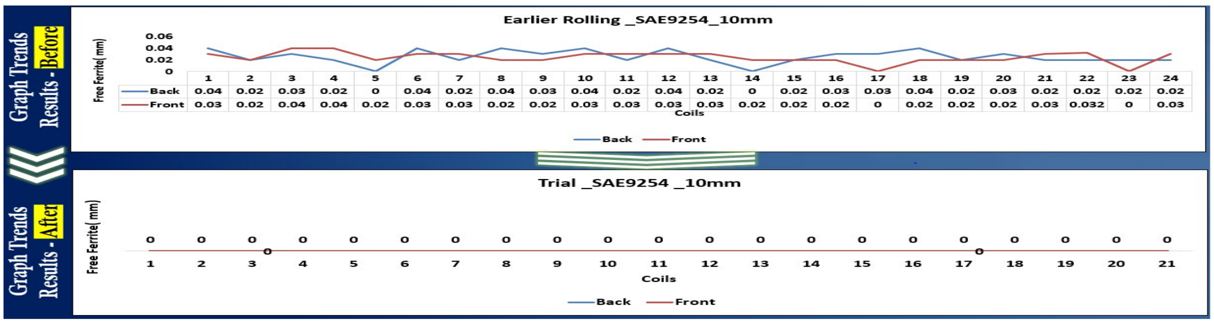
Abstract

SAE 9254 is a type of spring steel specified by the Society of Automotive Engineers (SAE). It's a high-quality alloyed carbon steel used primarily for production of automotive suspension, valve springs and much more. The function of spring requires high hardness and fatigue endurance, to meet the above mechanical properties, it is normally designed with a medium carbon high silicon composition. However, silicon is the stable element of ferrite, therefore when the rolling temperature of high-silicon steel falls into the ferrite precipitation temperature, a surface area with a low carbon concentration would easily become ferrite decarburization (DM-F). When DM-F occurs, it'll decrease strength leading to poor fatigue life of the steel.

Free ferrite has been a chronic problem in this grade, high amount of rejections were generating pertaining to this defect. This was solved using 10 step methodology. QA matrix was prepared for SMS & WRM. 4M Condition setting was done and survey was conducted to check whether SOP being followed or not. These 4M's were checked right from Billet Dressing to Cooling of Wire Rod stage.

So, factors were looked which impacted formation of Free Ferrite. It was found that there is definitely role of Furnace Atmosphere and Stay Time impacting the formation of Free Ferrite. So some measures were taken to standardize the parameters controlling the Furnace atmosphere. Soaking Zone Temperature was increased to 1200 C, reducing the stay time to 80 minutes, Descaler pressure was increased to 160 bar and laying head temperature was maintained between 870 - 880 deg C. This time 4M condition was standardized. Trials were conducted and Free Ferrite



was not found. This proactive approach has zeroed down Free Ferrite Issue in this grade. Revision of Standards was done and has been incorporated in SOP and Work Instructions.

Fig. 2: Results,

Key words: Free Ferrite

MFR_087

Optimization of manufacturing process for making High tensile crimping wire

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Abstract

High carbon & medium carbon steels wires are used for making screens used in quarries, mines for beneficiation process of raw materials. In order to form mesh, wires are bent severely in the form of sharp repeated sharp V-shape bends which is called as crimping operation. Breakages or fracture during crimping is one of the critical issues in the industry hampering the productivity & quality of mesh formed. The ability to sustain severe deformation during the crimping operation is greatly influenced by the mechanical properties of wire such as tensile strength, ductility (%

elongation) etc. which is ultimately achieved with careful selection of input wire rod chemical composition and wire drawing process parameters. This study focuses on impact of wire rod chemical composition and drawing parameters on the properties of the as drawn wire. Influence of parameters such as area reduction, drawing speed, wire cooling over drums and its impact on wire properties were studied. The traditional elongation measurement technique for ductility assessment is further modified to include the torsional ductility of wires which is found to be closely related to strain ageing effect. The performance of the wires was evaluated during the crimping operation at customer end to assess the crimping ability.

Keywords: Crimp wire, breakages, wire drawing, crimping ability

MPR_332

Effect of process parameters on the performance of rod during wire drawing

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Abstract

Copper is a fundamental material in various industrial applications due to its excellent electrical and thermal conductivity, corrosion resistance, and malleability. The production of high-quality copper rods is essential for numerous applications, including electrical wiring, cables, and other industrial products. Various technologies are employed to produce copper rods, such as Contirod, Southwire Continuous Rod (SCR), and the Properzi method. Each technology offers unique advantages in terms of efficiency, quality, and cost. In this study, the effect of different Contirod process parameters on the performance of copper rods during the wire drawing process at the customer end was investigated. Process parameters such as cathode quality, lambda, tundish temperature, caster pool level, stopper rod position, dam block temperature, and water flow rate were considered to determining the final quality of the copper rod. Variations in these parameters can lead to defects such as surface irregularities, dimensional inconsistencies, and wire breaks, this ultimately affect the performance and reliability of the final product. To comprehensively understand the impact of these parameters, production data analysis, wire break analysis and microstructural examination techniques were employed. By this analysis of the copper rods, the specific process conditions that led to poor performance at the customer end were identified. It was determined that variations in caster pool level, stopper rod position, and sudden changes in

tundish temperature are critical factors. This was confirmed by microstructure examinations, which showed higher porosity and lower density due to variations in these process parameters.

Key words : CCR, Tundish Temperature, Caster pool level, Stopper rod,Microstructure

MPR_376

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.

SPC_104

Development of high strength aluminium alloy forgings for fifth generation fighter aircraft

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Abstract

Aluminium is a crucial material in aircraft industry, primarily because of its exceptional strength to weight ratio, machinability, corrosion resistance, ease of fabrication and cost effectiveness. Aluminium alloy grade 2014 material is used for these forgings which is known for its good mechanical properties making it ideal choice for applications where durability and strength are critical.

In this study, development of forging is for fifth generation aircraft parts such as Rootrib, Baseplate for structural application and Hub for wheel assembly. These forgings are large in size with intricate shapes and developed for the first time in India for is for fifth generation aircraft by HAL-F&F division utilizing the available forging press capacity.

Forgings made from aluminium, especially those of substantial size and intricate shapes involve multiple stage manufacturing processes. These process often require multiple trials to perfect. To streamline and optimize these process, simulation studies are employed offering various advantages for intricate shaped forgings such as process optimization, faster development cycle, improved quality and efficient resource management.

Simulation study is carried out using DEFORM 3D software. DEFORM-3D is a finite element method (FEM) based simulation software that analyzes and models complex 3D metal forming processes to understand several key aspects of forging process such as visualizing the formation of the forging, load requirement, number of operations etc.

Multiple simulation iterations were carried out in finalizing the process parameters and validation is carried out by forging of the parts in hydraulic press available in HAL(F&F)

Key words: Forging, Aluminium alloy, Simulation, hydraulic press.

MFR_132

Evaluation of material formability of magnesium alloy AZ31 in friction stir incremental forming

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Abstract

To reduce emission of carbon dioxide and energy consumption in automotive industry, lightweight materials such as magnesium alloys and titanium alloys are increasingly used for body parts. Due to their poor ductility at room temperature these are difficult to deform and it is necessary to deform them plastically at elevated temperature. Applying them in innovative forming technologies offers the chance for various new products.

Flexible forming technologies such as friction stir incremental forming have been newly developed to meet the requirements of rising variety of products and design. Incremental sheet metal forming process is a die-less forming process and it can be called one kind of 3D printing in sheet metal forming. Since incremental forming process necessitates very long time especially in manufacturing large size products, the sheet should be heated during forming. Friction stir incremental sheet forming is a promising method for forming metal sheets, by which parts can be manufactured without the use of dedicated dies. In this work, to form lightweight magnesium alloy sheets without heating using energy sources such as furnaces, torches and laser beams, a new die-less digital flexible forming process, called friction stir incremental forming process is developed. This paper describes the behavior of material formability when forming under localized friction heating, caused by high tool rotation. The mechanical properties are investigated as well as the initial microstructure and texture. An experimental setup [Fig. 1 (a)] is developed in order to obtain a homogeneous sheet temperature distribution. Sheets will be formed into concave shape [Fig. 1 (b)] and forming trials are performed to determine the maximum wall angle. The maximum wall angle is the highest wall angle that can be formed without material cracking and is used as an index for formability. In this work, it is found that the maximum wall angle [40º] without crack is increased with increase in sheet temperature. Subsequently the sheet thickness distribution, the geometrical accuracy and the microstructure development are analysed. It is determined that the microstructure of the formed part at slightly elevated temperature with a wall angle of less than 25° is inhomogeneous and further investigations on the influence of process parameters are essential to apply to complex practical parts.

MFR_045

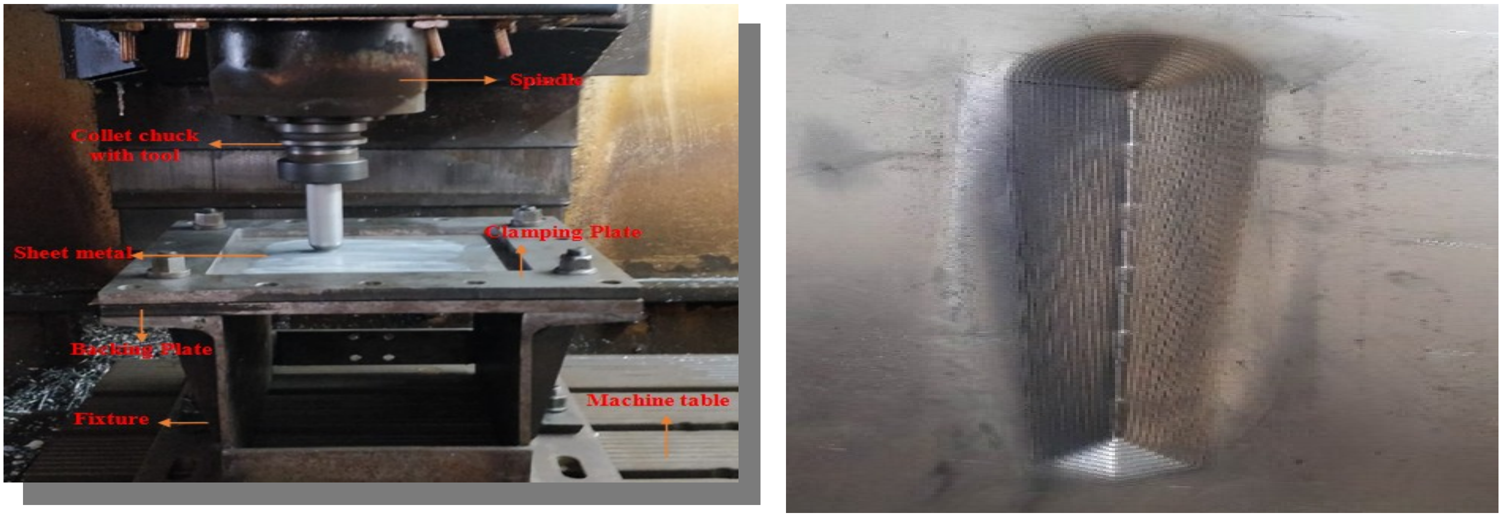

Fig. 1: (a) Experimental setup for friction stir incremental forming and (b) Formed part

Key words: Magnesium alloy, Friction-stir, Rolling, Formability

Influence of step depth on the formability, surface roughness and thickness distribution of commercial pure titanium sheets during the incremental forming process for cranium applications

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Abstract

Incremental sheet forming (ISF) has enhanced advantages over conventional forming and stamping processes due to the nature of die-less process, easy formation of non-asymmetric components, economical, and localised forming method. Titanium sheets are extensively used in cranial implantation due to its biocompatibility, corrosion resistance, and osseointegration with bone, however, the manufacturing of titanium cranium implants are very difficult because of the materials' poor room temperature formability. The aim of the present study is to analyse the influence of step depth on the room temperature formability, surface roughness and thickness reduction of commercially pure titanium sheets during the single point incremental sheet forming process for cranial applications. ISF experiments were conducted on a CNC vertical milling machine using a hemispherical end tool made of high speed steel. Spiral tool path was generated and fed into the CNC machine. Three levels of step depth with constant feed rate and tool rotation were used. The strain distribution of the formed component, surface roughness and thickness distribution were analysed after the ISF process. The results were compared and the step depth values were optimised to get high formability, low surface roughness and low thickness reduction in the formed titanium sheets for the cranium applications.

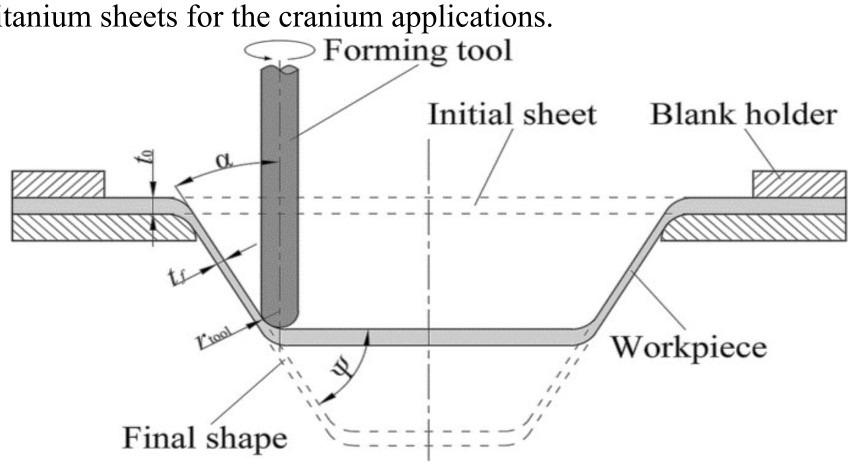

Figure. 1: Schematic of incremental sheet forming process [1]

MFR_070

Keywords: Titanium; Incremental sheet forming; Step depth.

Reference:

Hui Zhu, Hengan Ou, Atanas Popov (2020) Incremental sheet forming of thermoplastics: a review. Int J Adv Manu. Tech. 111:565–587

Micro-manufacturing of engineered Magnesium alloys: Technology development, experimentation and analysis.

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Abstract

The emerging demand for producing cost-effective micro-components in various industrial sectors, such as bio-medical, aerospace, micro-electromechanical systems (MEMS), etc., has motivated researchers to explore new micro-manufacturing solutions. Micro-manufacturing such sophisticated miniaturized parts requires a blend of the proper material selection, microstructural engineering, optimization of processing parameters, and micro tool designing/innovation. In this regard, the Microforming of Magnesium alloys (Mg alloys) transpires to be a game changer and impacts particularly the bio-medical section. However, there exists a twofold challenge in the proposed approach. Mg alloys are the lightest weight structural materials, but their formability is limited because of their HCP crystal structure. On the other hand, challenges related to microforming, such as size effect, complex tool design, and the need for a proper knowledge base, impact the feasibility of the proposed research. Therefore, to overcome these challenges, it is essential to develop a high-temperature equipped microforming technology to plastically deform materials that are difficult to deform at room temperature.

The present investigation is aimed at microforming technology development, mainly focusing on difficult-to-deform Mg alloys. This study includes micro extrusion tool development, detailed experimentation, and structure micro extrusion correlation. The scientific knowhow of microscale deformation behaviour and micromechanics during the micro extrusion process at varying temperatures and process parameters are established in this work via detailed microstructural characterization, including FESEM, EBSD, TEM tools, etc.

Keywords: Magnesium alloys, Light weight, Micro-extrusion.

MFR_11

Development of thick titanium forgings at l&t for submersible – deep ocean mission

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Abstract

Deep-sea mining is the process of retrieving valuable mineral like Manganese, Cobalt, Nickel, zinc and rare earth elements deposits available in the form of polymetallic nodules on the seabed. Depleting terrestrial deposits and rising demand for such metals drive the necessity of deep-sea exploration for these materials. The Cabinet Committee has approved the proposal of Ministry of Earth Sciences (MoES) on "Deep Ocean Mission" (informally known as Samudrayaan program) in June 2021, with a view to explore deep ocean for resources and develop deep sea technologies for sustainable use of ocean resources. Under Samudrayaan project a self-propelled manned submersible Matsya 6000 is being developed by National Institute of Ocean Technology (NIOT) to carry three people to a depth of 6000 metres in the Indian ocean with suite of scientific sensors and tools. Submersible consists of titanium alloy personnel sphere which is made up of several forgings.

Fig. 1: Personnel sphere made of Titanium alloy.

The project involves manufacturing of 4 types of thick forgings of titanium alloy, development and establishment of forging technology & duplex annealing heat treatment parameters for manufacturing of Titanium alloy forgings (Dia. 2.1 m & ~125 mm wall thickness) with critical mechanical properties requirements including fracture toughness (77 MPa. √m min.) and Ultrasonic Class A as per AMS2631.

To achieve desired quality, ingot made from VAR Technology is to be used. Ingot is then forged with controlled strain rate and narrow forging temperature range, requiring multiple reheating and forging operations to realize the near-net shape forged parts. These forgings, which are in form of profiled ring and dished end, pose a challenge to control the as formed dimensions in hot condition as they are shaped close to the finish profile. Shaping components to near net shape is planned with simulation of the forming process through simulation software (Simufact) for studying the material flow and stresses on tools & dies

MFR_117.

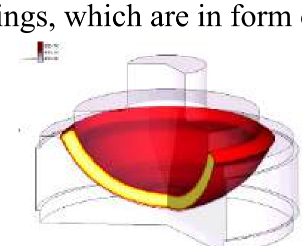

Fig. 2: Shaping technology

For this operation specially designed tools are used to address the issue of material availability. Property of titanium alloys depends on intermediate and final thermo-mechanical processing cycles thereby requires careful selection and control of the process parameters.

Process design and control are essential to obtain the desired properties during processing of Titanium alloys. There are many parameters that effect the product quality, temperature, strain rate, deformation at intermediate stages and thermal treatments at various stages. LTSSHF successfully developed the technology to make heaviest Titanium forgings in India and supplied it to customer for further processing.

Fig. 3: Titanium forging developed at LTSSHF.

Effect of insoluble elements on the microstructural and mechanical properties of light Al-Cu alloy produced by powder forging for high temperature applications

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Abstract

Present study investigates the microstructural stability during powder forging of Al-Cu alloys with stabilizers (1%Zr, 1%Nband 1%Y), its mechanical properties and strengthening mechanisms for high temperature with low weight applications. The powder forging was carried for the ball milled Al4.5%Cu1%Zr, Al4.5%Cu1%Nb and Al4.5%Cu1%Y alloys at 350, 450 and 550°C. The microstructural investigation through TEM analysis confirmed that average grain size was within the nanometer range that is less than 100 nm and corresponding excellent densification due to diffusion bonding is found to be 96%, 97% and 97 %, respectively, for all three samples, when the forging was carried out at 550°C. The yield strength (YS) and ultimate tensile strength (UTS) of all alloys (i.e Al4.5%Cu1%Zr, Al4.5%Cu1%Nb and Al4.5%Cu1%Y) powder forged at 550°C is considerably higher than that of the alloys forged at 350°C and 450°C, this is due to the fact of more amount Zr, Nb and Y dissolved in the matrix leads to obstruct motion of the grain boundaries. These mechanical properties (YS and UTS) also can be improved due to proper solid solution by alloying, grain size reduced from coarser to ultrafine grain or nanograin (i.e less than 100nm) and accumulation of dislocations during powder forging. The presence of fine dimples with uniform distribution at high temperature forging could lead to retain the strength and ductility at high temperature as compared to low temperature forging.

Keywords: Al-Cu alloys; Ultrafine/Nano structure; Powder forging; strengthening mechanisms; Mechanical properties; Electron microscopy.

MFR_126

High Tensile Strength Light Gauge Foil Development

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Abstract

Export of light gauge (LG) foils to US for flexible packaging, insulation, lidding and house foil from Mouda started in FY18. In the FY 2019-20 till August, high volume of foils were exported to US market of which LG foils contributed significantly. One of the reasons inhibiting the scaling up of the LG export is low UTS of Mouda foils. Customers in the US have high speed rewinding machines and laminators, which requires high UTS material to avoid web breakage during the operation. Typical requirement of UTS for these customers is higher than what is currently produced at Mouda and require the customers to run their machines at low speed, thereby lowering their productivity. In order to secure long term contracts from these customers, it is imperative to improve the UTS of LG foils from Mouda and the current project was taken up with that objective.
A revised rolling practice was devised by modifying the thermal treatments and pass schedule for production of LG foils. Trials were taken in small batches to validate the effect of these modifications on UTS as well as on other parameters like rollability, surface finish and cost. The results indicated significant improvement in strength without adverse consequence on surface finish, rollability, and recovery. The revised practice led to significant energy savings compared to current practice. Trials coils were sent to domestic customers for validation before ramping up the production. Based on the positive feedback, the production was scaled up for domestic customers as well as trial coils sent to US customers like All foils and Medalco. Due to the attractiveness of the revised route, trials have also been carried out for medium gauge blister and pharma products, ULG products.

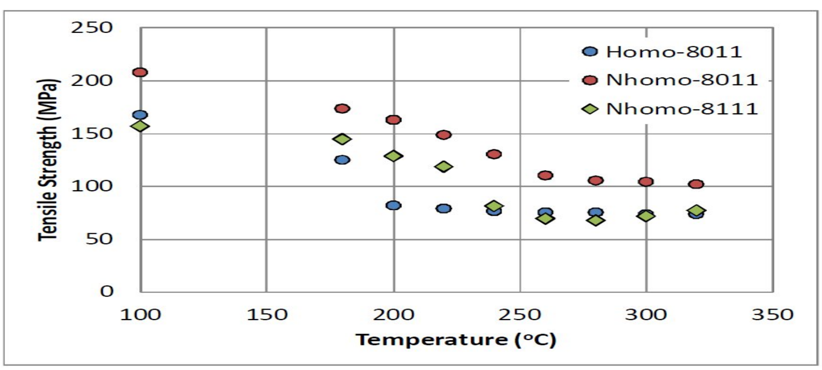

Fig. 1: Softening behavior of blister foil produced by homogenized and non-homogenized route. Non homogenized route leads to higher recrystallization temperature and consequently opportunity for higher strength.

Key words : High UTS Foil, LG, Export Customer, Revised Route

Abbreviations - LG – Light gauge & ULG – Ultra light gaugeUTS – Ultimate tensile strength

MPR_065

Effect of reduction per pass on texture, mechanical and corrosion properties of hot -rolled Mg-1wt%Gd alloy

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Abstract

Wrought processed Mg alloys when deformed through conventional process through rolling extrusion develops a strong basal texture i.e. the basal (0002) poles align themselves perpendicular to rolling direction limiting the formability. however, Mg rare earth alloys have shown an influence on the crystallographic texture in Mg alloys. Mg alloyed with Gd has the highest solid solubility among the rare earth-based alloys and led to changes in the texture. We want to explore how the per strain combined with rare earth alloying will influence the tensile and corrosion properties.

The effect of rolling reduction per pass on texture mechanical and corrosion properties were investigated on Mg1wt%Gd alloy in this work. The processing route was tailored to generate three different types of textures. These routes involved high temperature deformation. In Route 1, the as-received material was subjected to 20% per pass reduction, while in Route 2, the as received material was subjected 50% per pass reduction and in route 3, the as received material was subjected variable per pass reduction. For the rolling stage of processing, the alloy was heated to 470˚C for 30 mins before rolling from 12 mm to 1.2mm thickness (90% reduction).

The evolution of microstructure and texture in materials processed by the three processing routes were examined on the ND-RD plane of the sheet through OM, SEM, EBSD maps, and XRD pole figures. Microstructure of the material obtained through Route 3 led to higher grain refinement, and weaker basal texture compared to Route 1 & Route 2. A correlation was established between microstructure, texture, tensile and corrosion properties

Key words : Mg alloy deformation, texture, Mg rare earth textures

DM_084

Analysing upsetting in ultrasonically fabricated as-cast Al-7.3Zn-2.2Mg-2Cu alloys: FEM insights with Deform-3D

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Abstract

In this present study, a 3-dimensional finite element model was developed for upsetting of AA7068 aluminium alloy using DEFORM 3D software. The plastic behaviour during upsetting was investigated at temperatures of 350 °C and 400 °C at strain rates of $0.001s^{-1}$ and $0.1\ s^{-1}$ up to a true strain of 0.693. Validation of the model was conducted by comparing predicted load versus stroke curves with experimental data, demonstrating close agreement.

Results indicate that as the deformation temperature increases from 350°C to 400°C, or as the strain rate decreases from $0.1s^{-1}$ to $0.001s^{-1}$, the applied load for deformation decreases due to increased ease in dislocation annihilation and rearrangement. Finite element analysis (FEM) further reveals that under these deformation conditions, there is an uneven distribution of deformation parameters such as effective strain, strain rate, stress, and temperature. This non-uniformity in deformation parameter exhibited a lower magnitude near the centre of the top surface region and the highest values were observed at the specimen's edges. This behaviour is mainly due to the friction between the die and the specimen. Moreover, the study highlights that while two points within the deformed specimen may experience similar deformation parameters at the end of forging, their trajectories during the forging process may differ significantly, potentially impacting the final microstructure.

Keywords: Forging; Finite element analysis (FEA); DEFORM 3D; Deformation Trajectory

MFR_074

Split Edge Defects in HR Coils

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Abstract

The phenomenon of split edge generation in hot rolled (HR) coils, particularly in thin gauge mill edge HR coils conforming to IS 11513_2017 CR3 grade, has been a persistent issue of hot strip mills. This study investigates the root cause of serrated or heavy edge cuts observed during subsequent cold rolling processing at downstream. Metallographically analysis did not reveal any material abnormalities. However, further inspection of the hot rolled edges uncovered a peculiar split edge or split edge defect, suspected to originate from the hot rolling process. Detailed examination suggests that these defects are linked to the concave or M-type profile of the slabs produced through Thin Slab Continuous Rolling (TSCR) route. The differential cooling rates and thermal contractions during the slab casting process at high speed result in an uneven edge profile, leading to edge concavity. This concave profile, combined with potential guide misalignments and improper handling during hot rolling, exacerbates the formation of split edges.

The study highlights that implementing liquid core reduction (LCR) during the slab casting process yields the best results in mitigating these defects. LCR helps in achieving a more uniform edge profile by reducing the core of the slab while it is still in a semi-solid state, minimizing the differential cooling effects. Despite attempts to mitigate the issue by adjusting the guide settings, the defects persisted. The study concludes that addressing the root cause in the TSCR process, through optimizing cooling rates, employing liquid core reduction, and ensuring uniform slab profiles, is crucial. Additionally, maintaining precise guide alignment and roll conditions during hot rolling is essential to minimize these edge defects and improve the overall quality of HR coils.

Key words: Thin Slab Continuous Rolling (TSCR), liquid core reduction (LCR), split edge

MFR_069

Improving efficiency in Galvanizing Lines Operations with Automation and Real-time Data Integration at Tata Steel Sahibabad

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Abstract

Tata Steel Sahibabad has significantly boosted the efficiency of its galvanizing lines through significant automation and process optimisation. The facility, which produces various galvanizing and galume products, previously depended on manual tracking for welding processes, which often led to inaccuracies and operational challenges. To address these issues, four weld hole detectors and three tower lights at key locations were installed along the production line. This new system offers two major advantages, first, welding tracking is now automated and visible on the line SCADA system, eliminating the need for manual monitoring. Second, the new logic, based on the weld hole detector distances, automatically manages the opening and closing of rolls, reducing the risk of roll damage. In the second phase, a comprehensive dataset capturing critical process parameters such as furnace and strip temperature, line tension, zinc pot temperature and line speed was developed for different SKUs.These parameters will ensure optimal conditions for producing prime quality products. By integrating this dataset with the welding tracking system, the line now automatically adjusts furnace settings when the sheet reaches the furnace, significantly minimizing manual interventions and enhancing overall production efficiency.

Fig.1: Weld hole detector

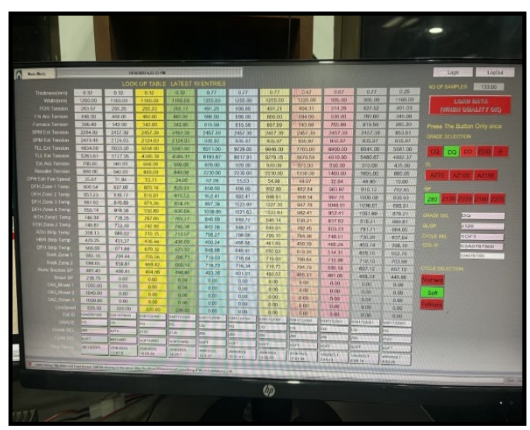

Fig. 2: Look up table

MFR_113

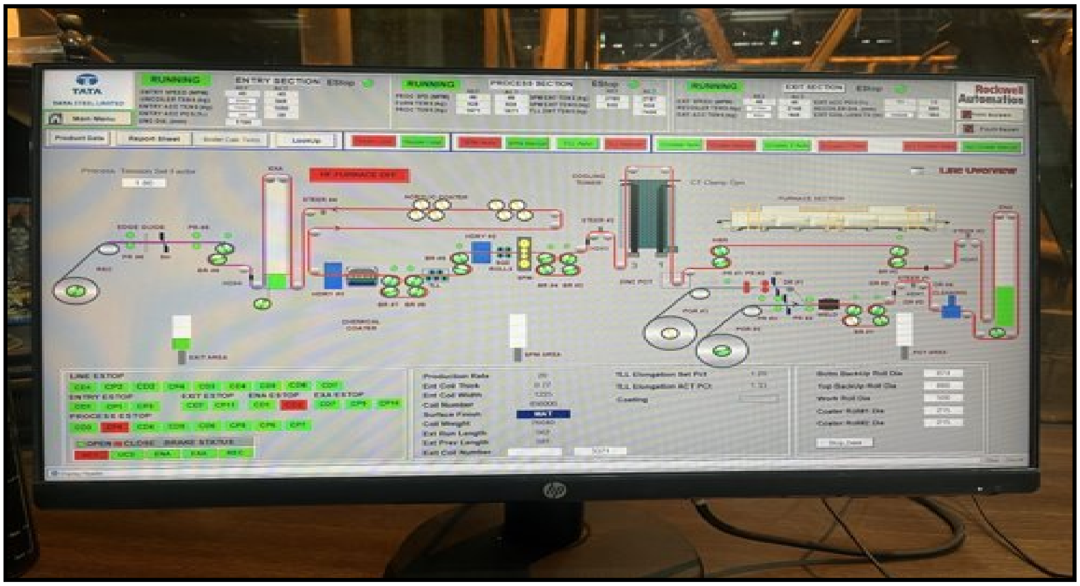

Fig. 3: Live tracking of welding

Keyword: : Galvanising lines, Tracking, Data Integration, Automation, Operational challenges

Mitigating Wire Breakage in Low Carbon, High Mn-Si Alloy Steel MIG Wires through Micro Alloying

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Abstract

Low carbon, high Mn-Si alloy steel is the preferred material for manufacturing MIG wires. The production process involves drawing wire rods with diameters of 5.5 mm drawn to 0.8-2.0 mm in two stages: initially drawing under dry conditions, followed by drawing under wet conditions. The presence of minor defects, discontinuities, or second phases significantly impairs the drawability, quality, and productivity of MIG wires. The samples were characterized for microstructure, phase and compositional analysis to find the root of wire breakage. The microstructural analysis revealed that presence of hard phase and compositional analysis showed that high nitrogen content in the wire rod of breakage samples. The presence of nitrogen will suppress the pearlite transformation start temperature in low C-Mn steels and also increase the martensite-austenite (MA) micro-constituent phase content, which increases brittleness and susceptibility to breakage. To reduce the free Nitrogen content in steels, trials were taken with the addition of Titanium and laying head temperature and subsequent cooling rates were optimized in wire rod mill. Ti-microalloyed steels showed that MA micro-constituents is completely absent in the microstructure, since Titanium removed the dissolved nitrogen by forming TiN precipitates. This study revealed that by incorporating Ti-micro alloying into the steel can counteract the negative effects of high free nitrogen, leading to improved wire quality and reduced production losses.

Key words : Wire Breakages, MIG wire , Micro-alloying

MFR_020

Impact of Phosphorous segregation on sheet metal forming of IFHS galvannealed steel and its prevention method

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Abstract

Currently ever increasing use of coated steel in India for automotive bodies with an aim to fulfil better service life in terms of corrosion prevention and dent resistance; promoting to use the interstitial free high strength steel for exposed quality applications such as automotive exposed (outer-body) panels. Typical function of this product are where dent resistant is required in the panel. Phosphorus or other solid solution strengthening elements are used to increase the strength of interstitial-free steels. But the effect phosphorus in higher ration as a chemical composition design is detrimental due to the variations in casting parameters leading to fine segregation after solidification in the slab cast process. The problem of Phosphorous segregation is in the final product is referred to as Ghost band mark. This fine segregation was investigated by scan electron microscope and segregation was confirmed on the grain boundary. Casting parameters influence on was studied interstitial free high strength steel and found that with the processing of lower (<1.2mpm) casting speed resulted in higher severity ghost band mark on the final product and with the casting speed (>1.2mpm) found the ghost band mark were relatively lower severity and it was acceptable at end component level. In order to judge the severity, an internal mechanism of a ghost band defect test was followed on a hot-dip galvannealed ultra-high strength steel, the result of the test is to indicate the visible in differences in the coating morphology thus overall surface quality of the automotive exposed (outer-body) panels was assured.

Key words : Segregation, Slab casting, Ghost mark

MFR_031

Experimental study of the warpage of plates in Special Plate Plant (SPP), RSP

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Abstract

Different grades of steel are rolled in New Plate Mill (NPM) of Rourkela Steel Plant (RSP) and heat treated for high hardness and strength at new online roller water quenching and tempering (RQ+T) unit of Special Plate Plant (SPP). Warpage occurs in most quenched plates, usually corrected during tempering or in the Cold Plate Leveller (CPL). However, plates that are only quenched and not tempered often have severe warpage that cannot be rectified.

Plates of the SAILWR grade were quenched with varying flow rates and timings. Despite different settings, the plates consistently exhibited waviness of 500-600mm, preventing them from entering the tempering furnace or Cold Plate Leveller.

To address this, the study explored various quenching modes and flow optimizations. A new "Continuous with oscillation" mode was developed, starting water flow 10 minutes before plate entry and oscillating the plate in the LP Zone. Experiments showed that an optimal plate entry speed of 15-30 m/min minimized distortion. For 14mm, 16mm, and 20mm thick plates of grades SAILWR 400, S690QL, and SAILHARD, the best result was a only 15mm crossbow, rectified in NPM's CPL. The flatness achieved met the international standard EN10029.

Keywords: Warpage, plate, quenching, heat treatment, crossbow.

MFR_054

Optimizing composition and process parameters for achieving High Ductility and formability in cold heading quality steel in SBM of RINL.

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Abstract

Cold Heading Quality (CHQ) steel is used for manufacturing high-performance fasteners and components through cold forming processes. Achieving optimal ductility and formability at cold working conditions in CHQ steel requires a balanced approach to alloy composition and control of manufacturing processes.

Special Bar Mill (SBM) in RINL has a unique feature of producing bars in straight form as well as in coil form for larger diameter sections (dia. 20mm and above). Most of the cold heading quality steel products are required in coil form only to achieve retarded cooling condition at the exit of rolling mill. Composition optimization involves adjusting carbon content to balance strength and ductility, incorporating alloying elements such as manganese and silicon to enhance mechanical properties, and selectively adding micro alloying elements like boron enhances through depth hardness for higher sections. Process parameter optimization focuses on controlling hot rolling parameters like mill speed, billet discharge temperature and PQS exit temperatures to achieve a uniform grain structure suitable for larger diameter sections. Implementing these strategies effectively requires intensive quality control and testing throughout the manufacturing process to verify and maintain the desired mechanical properties in CHQ steel for larger diameter sections. This work highlights the systematic approach necessary to optimize composition and process parameters, thereby achieving high ductility and formability in CHQ steel for larger diameter sections, crucial for meeting the requirements of industrial applications

Keywords: Cold Heading Quality steel, ductility, formability, process parameters

MFR_056

Optimization of micro-alloying and composition on the strength and toughness of 0.2%C-1.5Mn steel.

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Abstract

Micro-alloyed element (V and Nb) containing steels were prepared with varying nitrogen level along with Ni and Mo identify the strengthening and toughness contribution of all the alloying elements. The study was conducted in three different process routes keeping in mind the industrial processing routes suitable for plate and coil production. As rolled, normalized and coiling are the three-processing route. The As rolled structure showed that 0.15V+0.03Nb steel can provide the highest grain refinement and yield strength but toughness in as rolled steels are comparatively lower than other route of processing. In case of Normalized steel, the strength reduces significantly but the toughness increases three times at -50℃. The coiling at 600℃ after 1000℃ holding suggests that both the yield strength and the toughness can significantly increase specially in Vanadium and nitrogen containing steels. Characterization techniques such as Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Electron Back Scattered Diffraction (EBSD) and Transmission Electron Microscopy (TEM) have been used for further investigation. The interphase precipitation strengthening contributes highest in the coiling route during holding at 600℃. The increase of hardenability by Mo causes harder second phase formation which deteriorates the toughness values. Ni does not help in increasing the strength but may have an effect in toughness. The strengthening contribution was calculated for each steel and each route of processing. The processing microstructure property were correlated in light of grain size, precipitate formation and dissolution, second phase fraction, hardness and grain boundary data.

Keyword: Micro-alloyed steel, Vanadium, microstructure, Impact toughness, Yield strength.

MFR_091

Reducing Material Loss due to Clink Defect Formation in High Carbon 100Cr3 Grade Steel Bars

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Abstract

Clinks are thermal cracks caused by excessive high-temperature gradients within the material. The Blooming Mill (BLM) has faced significant challenges in producing high-quality bars and Round Corner Squares (RCS) due to material loss caused by clink formation in the High Carbon 100Cr3 grade hot rolled steel bars. Clink has led to a loss of approximately 60 metric tons (MT) of roller products per month, severely impacting techno-economics and delivery schedules. This study aims to identify and optimize critical parameters influencing clink formation, using hypothesis testing and Design of Experiments (DOE) methodologies, to improve product quality and eliminate material loss. The initial phase of the study involved identifying key parameters affecting clink formation. These parameters included furnace dwell time, furnace heating parameters, and the charging mode. Hypothesis testing was conducted to systematically analyze these factors and understand their impact on product quality. Subsequently, a DOE methodology was applied to optimize these parameters and determine the most effective combination to minimize clink formation. The 100Cr3 grade, typically rolled for Grinding Media Mill (GMM) from 250 mm x 250 mm input, required precise control of the heating process to ensure the integrity of the final product. Through the DOE approach, the optimized parameters were determined to be a dwell time of 4 hours, a Preheating Zone (PHZ) temperature of 850°C, a Heating Zone (HZ) temperature of 1050°C, and a Soaking Zone (SZ) temperature of 1180°C.

UT is a non-destructive testing method that provides precise detection of internal flaws, making it a reliable measure of the improvements achieved. The results of UT demonstrated a significant reduction in material loss due to clink formation, from 60 MT per month to 0 MT per month.The DOE approach was instrumental in identifying the critical factors and their optimal settings, leading to substantial improvements in the internal integrity of the bars. Extending the furnace dwell time and adjusting the temperatures in the heating zones effectively eliminated clink formation by reducing the high-temperature gradients within the material. By systematically analysing and optimizing the key parameters, BLM has successfully eliminated material loss due to clink formation, achieving a zero MT per month loss rate.The comprehensive measures undertaken to address clink formation in 100Cr3 grade material have proven highly effective.

Key words : Clink, JSGB100Cr3, Hypothesis testing, DOE, UT.

MFR_125

Effect of hot strip mill run out table cooling water quality on pitting corrosion of hot rolled low carbon steel

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Abstract

Pitting corrosion of hot rolled coils and plates is a significant problem as it contribute to rejections and reduce the productivity of hot strip mill. Higher concentration of chlorides in cooling water used for the control of temperature of hot rolled plates on run out table of hot strip mill has a significant effect on pitting corrosion. Chloride ions reduce the resistivity of water and promote the breakdown of protective film leading to the formation of corrosion pits. The severity of pitting tends to vary with the amount of chlorides in cooling water. Sodium tolytriazole (TTA-Na) when added to closed-loop cooling water system as a corrosion inhibitor, prevent pitting corrosion by the absorption and formation of a thin and uniform polymeric membrane on steel surface. Therefore, the effect of chloride concentration and the addition of sodium tolytriazole based inhibitor to cooling water on pitting corrosion of low carbon structural grade steel was investigated in this study.

Hot rolled strip cooling of low carbon steel on run out table of hot strip mill was simulated on Gleeble thermomechanical simulator using cooling water containing 60-650 ppm of chlorides with and without addition of sodium tolytriazole inhibitor. The samples then characterised using SEM and XRD for the thickness and composition of scale on sample surface. The thickness of scale was reduced from 24-32 µm to 13-17 µm and hematite in scale was decreased from 28% to 7.8% after inhibitor addition. Polarization resistance, corrosion rate and inhibitor efficiency was measured using electrochemical corrosion tests to evaluate the effect of chloride concentration and inhibitor addition on pitting corrosion. It was identified from this study that the severity of pitting increased at chloride concentration 200 ppm and above and therefore, recommended to add 100 ppm inhibitor to cooling water when chloride concentration exceed a critical value of 200 ppm to prevent pitting corrosion of low carbon steel.

Key words : Pitting corrosion, corrosion inhibitor, Sodium tolytriazole

MFR_103

Nitriding on AISI H-12 die towards improvement in product quality and tool life during hot extrusion of Incolloy 800 tube

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Abstract

Incoloy 800 is a nickel-chromium alloy used for steam generator tube due to its ability to maintain stable structure during prolonged exposure to high temperatures. Manufacturing of these tube required multi stage hot working and cold working. Hot extrusion is one of the deformation process in the manufacturing rout of these tube.

One of the major problem faced during extrusion of the above super alloy is wear out of die. This leads to low product quality and less tool life. The die material is AISI H-12 tool steel with hardness range of 43 to 47 HRc.

Increase in through hardness of H-12 by heat treatment to avoid wear out, leads to reduction in toughness. This has limitation of die cracking due to sever thermal shock during hot extrusion. Surface coating was required to increase the surface hardness without compromise in core toughness. In the present work, effect of gas nitriding of AISI H12 die on surface finish, dimensional stability and hardness was studied. The tool steel was heat treated with hardening at temperature 1040° C and two tempering cycle (temperature 610° C) to achieve hardness between 43 to 47 HRc. Gas nitriding was carried out on die after finish machining as per the required dimensional and geometrical (G&D) tolerance. Nitriding temperature was selected less than tempering temperature to avoid any die core softening. Surface finish before and after nitriding was analyzed. Concentricity of ID to OD and dimension change due to nitriding was measured. Analysis of case hardness and core hardness with distance from surface was carried out using micro hardness tester.

Surface hardness of 67 HRc or more and nitriding case depth of 0.4mm or more was achieved. There was no substantial reduction in core hardness. The concentricity and dimension after nitriding was achieved with in required tolerance limit.

Hot Extrusion Incoloy 800 was carried with nitrided die with extrusion temperature of 1100°C and extrusion speed of 80 mm/sec. Glass powder was used for lubrication during extrusion process. The tool life was increased by 3 times and there is improvement in product quality with respect to surface finish. There was intact of nitriding layer after multiple extrusion even the hot extrusion temperature of 1100° C. This may be as a result of low penetration of heat into nitriding layer due to high extrusion speed and thermal isolation of glass powder.

In future nitriding process can be tried on other cold working tool of different material to improve tool life

Key words :Gas nitriding, tool life, tool steel, G & D tolerance, surface finish
MFR_078

Technology Development of Ultra high thick pelton runner disc used in turbines of hydroelectric power plant

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Abstract

Pelton Turbine is a hydroelectric device that converts water's kinetic energy into mechanical power by employing high-speed jets of water striking spoon-shaped blades on a wheel generating rotational energy. The Forged pelton runner disc is considered as the "heart" of the Pelton turbine and thus the hydroelectric power plant.

Pelton runner disc forging is manufactured from a low carbon martensitic stainless steel grade. Generally, Thinner sections of this grade can be simply air cooled but for thicker sections (>300 mm) the industry adopts oil / polymer quenching to achieve the required cooling rates needed to achieve the necessary mechanical properties from the intended sampling location.

With the aim of achieving similar properties in section thicknesses upto 1000 mm, innovative approaches have been employed in all stages of manufacturing. Chemistry has been suitably finetuned to help during quality heat treatment. Study of cooling pattern in CCT diagram with each elemental addition requires simulation trials. Forging reduction on the entire cross section and temperature regime has been designed to get the required working on all three directions avoiding oversoaking / coarse grain structure.

Innovative air quenching methodology has been developed by performing large scale air quenching trials with modified heat treatment parameters. Modifications substitutes the use of oil / polymer / hot water quenchants for high thickness components. Modified tempering parameters have played a key role in achieving an optimum balance of strength and toughness in line with code and customer requirements.

Using this technology, L&T Special Steels Heavy Forgings has successfully achieved all quality requirements in forged pelton runners upto a heat treatment thickness of about 1000mm which is First time in India, embodying the "First time right" concept, global cost competitive and well appreciated by customer.

Key words : Martensitic Stainless Steel, Pelton Runner disc, Hydoelectric power plant, Heat treatment, air quenching technology, energy saving initiative, alternative to oil & polymer quenching, High thickness

MFR_115

Process capability improvement of Cold Rolled 590 Dual phase Steel for Automotive applications

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Abstract

The cold rolled high-strength dual-phase steel is widely used by automobile manufacturers in crash safety-critical parts. The Cold Rolled DP 590 grade is manufactured to meet various customer specifications, leading to a broad range of YS values that contribute to costly rework and internal rejections due to inconsistent mechanical properties. This study addresses the enhancement of the process capability index (Cpk) for yield strength (YS) in DP590 grade steel, a critical parameter influenced by wide specification limits and significant YS variability.

The primary objective is to increase the Cpk value from its current level of 1.35 to exceed 1.5, accompanied by a reduction in non-conformance incidents related to mechanical property variations. Regression analysis reveals significant correlations between YS and operational factors such as Skin Pass Mill (SPM) reduction percentage and strip speed in the continuous annealing line (CAL). Optimal SPM reduction percentages are found to enhance YS but may impact Total Elongation and surface roughness. Likewise, higher CAL speeds are observed to elevate YS by promoting finer grain sizes and increased martensite content, while ensuring that furnace temperatures remain within operational limits.

Implementation of strategic adjustments, particularly increasing SPM reduction percentage and CAL speed, has resulted in a noteworthy improvement in Cpk from 1.35 to 1.60. This improvement has been accompanied by substantial reductions in rework from 8% to 3% and internal rejections from 0.2% to 0.05%, highlighting the critical role of precise process control in aligning with customer specifications and enhancing both product quality and operational efficiency.

Key words : Process capability index, DP steel, SPM reduction and CAL speed

MFR_015

Improvement in impact energy at cryogenic temperatures of Grade - 304 in plate form product

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Abstract

In recent years, stainless steel producers and users have faced significant challenges due to the volatile and high prices of raw materials such as nickel, a critical component of the widely utilized austenitic (300-series) stainless steel grades. However, amidst these fluctuations, austenitic stainless steels continue to dominate many applications owing to their superior corrosion resistance and mechanical properties. The alloying elements in austenitic grades, predominantly nickel and chromium, contribute to their robust performance in diverse environments. Despite the cost pressures from nickel's price volatility, austenitic stainless steels remain indispensable in applications requiring high corrosion resistance, strength, and durability.

The Basic premise is to enhance the mechanical properties of materials, specifically targeting an impact strength of at least 60 Joules MPa at cryogenic temperatures (-196°C) and a yield strength of a minimum of 300 MPa at cryogenic temperatures (-196°C) for thicknesses ranging from 12 to 14 mm. These improvements are critical for applications in extreme environments, such as in the cryogenic storage where materials must maintain structural integrity under severe conditions. To achieve these objectives, optimization of annealing parameters were done. This has been done by comprehensive material characterization using methods such as tensile testing, Charpy impact testing, and microstructural analysis. The outcomes include the development of a material that meets the specified mechanical criteria, thereby extending the service life and reliability of components used in low-temperature environments at cryogenic temperatures. We have met demands of the customer in 304 with mechanical properties of yield strength >300 MPa and impact strength > 60 J at -196°C.

Keywords: Austenitic Stainless Steel, Charpy Impact testing, Tensile Testing, Annealing, Impact Strength, Yield Strength

MFR_093

Development of 55%Al Zn alloy coated steel of YS 550 grade using leaner chemistry

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Abstract

YS 550 grade of IS 15961 is recovery annealed product. Strength can be imparted to steel either by cold rolling or by using rich chemistry. Use of richer chemistry needs higher roll forces in cold rolling, higher temperatures in furnace and operating line at slower speeds. This was the process for 0.85-1.2mm thickness range material in TSM Khopoli.

We made efforts to use a leaner chemistry steel and use its strength attained through cold rolling. This yielded benefits in cold rolling process, operating furnace at lower temperature and at faster speed. Moreover, the properties achieved were also more favourable for the customer process. Leaner chemistry has also resulted in the ease of planning and saving on the ferro alloy in steel making.

Higher speed used has improved the surface substantially and enhanced the productivity. This in turn has also improved customer compliance.

This material is predominantly used for the manufacturing of solar panel structures.

Following table shows the specification of the Richer chemistry that was being used and the Leaner chemistry that we have substituted.

	C%	Mn%	Si%	S%	P%	Al%
Rich Chemistry	**0.035-0.07**	**0.15-0.60**	**0.04 Max**	**0.02 Max**	**0.025 Max**	**0.02-0.07**
Leaner chemistry	**0.06 Max**	**0.10-0.25**	**0.04 max**	**0.02 Max**	**0.025 Max**	**0.02-07**

Fig. 1

The paper talks about the methodology followed and the benefits derived out of using leaner chemistry.

Key words : Cold Rolling, Recovery Annealing, Strength etc.

MFR_096

Manufacturing of WASPALOY rings using rolled ring forging process

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Abstract

Waspaloy, is a nickel-based superalloy, is widely utilized in critical components of gas turbines, including blades, seal rings, and disks, operating at around 700°C. Its widespread application is driven by its exceptional properties, including high resistance to creep, fatigue, corrosion, and isothermal oxidation, as well as its high strength at elevated temperatures.

The manufacturing of Waspaloy rings through the rolled ring forging process presents significant challenges due to the difficulty in selecting optimal processing parameters. At low deformation temperatures, the material exhibits excessively high flow stresses, while high deformation temperatures lead to rapid grain growth.

The rolled ring forging process involves deformation of a heated waspaloy billet into a seamless ring by upsetting, piercing and ring rolling through radial and axial deformation. This method ensures uniform grain structure, which enhances the mechanical properties of the final product. The process typically includes heating the Waspaloy to its recrystallization temperature to facilitate deformation while maintaining the desired microstructure. Precise control of temperature, rolling speed, and deformation parameters is crucial to achieving the required dimensional tolerances and mechanical properties. Multiple ring rolling forming simulation and industrial manufacturing trials were conducted to verify the processing parameters to meet the mechanical and microstructure requirements.

This abstract provides an overview of the critical aspects of the Waspaloy ring rolling process, highlighting its importance in producing components that meet the stringent performance requirements of high-temperature applications.

MFR_134

Development of hot extrusion process of Advance Ni-based Superalloys for Indigenous Seamless Tube Manufacturing

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Abstract

Nuclear Fuel complex (NFC), Hyderabad has successfully pioneered the extrusion technology s in the area of seamless tube manufacturing of numerous materials such as Zirconium alloys, titanium alloys, special steel and Ni- based super alloys. These developments over the years led to supply of stringent quality tubular product for application in nuclear, defense and aerospace.

Under a National Mission for Collaborative Development of Advance Ultra Supercritical Technology, NFC has participated in development of tubular products for two major advanced superalloy grades such as Alloy-617 and Alloy 740H of potential application in boilers. Alloy 617 and Alloy 740H have been selected for long service life in extreme boiler operating conditions of temperature up to 700^{0}C and pressure up to 300 bar due to high temperature mechanical properties and hot corrosion resistance. The paper brings out the systematic study and methodology in development and manufacturing of tubular product for the two alloy grades on industrial scale while overcoming the significant challenges in optimization of hot extrusion parameters.

Alloy 617 being the solid solution strengthened nickel based super alloy has been envisaged for application in relatively high temperature zone of the boiler. Similarly, Alloy 740H is precipitation hardenable grade provide significant advantage over Alloy 617 for application. These advanced super alloys belongs to **"most difficult to extrude"** category due to high flow strength and inherent poor hot workability. This mainly due to high alloying content, microstructural characteristics and previous processing history. All the factor lead to restricted process domain of temperature, strain and strain rate and lead to major challenges in realizing defect free products especially by high strain rate deformation process such as hot extrusion.

A process flow sheet has been successfully established which includes hot expansion and hot extrusion was established successfully for first time to minimize the effect of microstructural variability and maximize the product yield for long length finished tubular product. Metallurgical characterization such as Optical, SEM/EDX and EBSD analysis were carried out at various stages of manufacturing.

The present paper covers the methodology of thermo-physical simulation using Gleeble uniaxial compression testing to closely predict the hot workability of the material under varying microstructural characteristics. Simulation was carried out considering industrial operating

conditions which consist of both intrinsic and extrinsic process variables. A significant milestone in the indigenous effort for manufacturing of tubular components for AUSC technology was achieved.

Defect free tubular blanks of Alloy 617 and alloy 740H were successfully extruded for cold working to realize finished tubular products of requisite mechanical and metallurgical properties

MPR_192

Minimization of Alligatoring Defect in Cr-Mn-N-Cu Austenitic Stainless Steels during Hot Rolling

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Abstract

The Cr-Mn-N-Cu austenitic stainless steel grades, part of the 200 series, are known for their moderate nickel, copper, and nitrogen content. These grades generally offer good corrosion resistance, handling atmospheric and mildly corrosive environments effectively. The addition of copper improves formability by lowering the work hardening rate, while nitrogen enhances strength and pitting resistance. Despite these advantages, a significant challenge in their production is the occurrence of alligatoring during hot rolling at the Steckel mill.

Alligatoring is a defect where the surface of the steel splits and forms a pattern resembling the scales of an alligator, resulting in a substantial decrease in yield due to the need to cut off affected portions of the coils and breakdowns at the mill. This work investigates the causes of alligatoring in Cr-Mn-N-Cu austenitic stainless steels during hot rolling. Various critical processing parameters were examined to understand the origins of this defect.

The investigation revealed that alligatoring is influenced by multiple factors rather than a single parameter. Key contributors include high superheat leading to uneven bonding, high secondary water temperature, inappropriate secondary water quantity, high nitrogen levels, and elevated tramp elements. Additionally, variations in rolling pressure, excessive roll gap settings, and environmental conditions such as humidity play a role in the formation of alligatoring. Effective control and monitoring of these parameters, along with proper material composition and equipment maintenance, are crucial to minimizing alligatoring and enhancing the quality of the rolled product.

ISM_201

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

NFM_035

Effect of alloying element and extrusion parameters on the formation of Peripheral coarse grain (PCG) in Aluminium 6061 alloy

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Abstract

Aluminium alloys (6000 series) are widely used for demanding structural applications due to their lightweight with good mechanical properties. Al 6061 is an obvious selection for Automotive and aerospace application due to its high conductivity, excellent extrudability and ease of fabrication made this alloy. Extrusion is one of the major metals forming processes widely used in the manufacturing industry. During extrusion of aluminium alloys, defect like formation of coarse grains at the surface, known as a Peripheral Coarse Grain (PCG) occurred which affect mechanical properties and aesthetics of the extruded material. PCG is a layer of recrystallized coarse grains that form in the outer band of an extruded section. PCG can be controlled by altering the extrusion parameters such as, temperature, strain rate, ram speed and post forming heat treatment operations. Along with the extrusion parameters, the addition of the alloying elements in aluminium increases its response to heat treatment due to formation of intermetallic compound. Those intermetallic compounds restrict the recrystallization of the grain by pinning the grain boundaries and decrease the PCG as well as increase the strength of the alloy. The objective of this work is to understand the metallurgical origins and mechanisms of the formation of the PCG and reduction of PCG layer by 50% by optimizing the alloy chemistry and extrusion parameters.

Keyword: Al 6061, PCG, Alloy chemistry, Extrusion.

Study on the modification of the mechanical properties of magnesium-2 at% aluminium alloy using the cyclic extrusion compression process

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Abstract

Cyclic extrusion compression (CEC) is a promising severe plastic deformation technique for producing ultrafine-grained materials with high angle grain boundaries. In the CEC technique, the billet is extruded first, followed by compression in each pass. The main advantage includes providing high hydrostatic pressure, which can be used to process difficult-to-form materials such as hexagonally close-packed (hcp) metals at room temperature. Magnesium and its alloys are well known for their difficulty in processing at low temperatures due to the limited number of slip systems.

The present study is aimed to understand the influence of CEC process on the processing of Mg-2 at% Al alloy at room temperature. The effect of CEC process on the grain refining mechanisms of Mg-2 at% Al alloy at different temperatures was carried out with an effective strain of 0.73 in each deformation pass. Microstructural studies and mechanical properties evaluation will be carried out to understand the underlying deformation mechanisms at different temperatures. Finite element analysis using ABAQUS 6.14 will also be carried out to understand the equivalent stress and strain distribution.

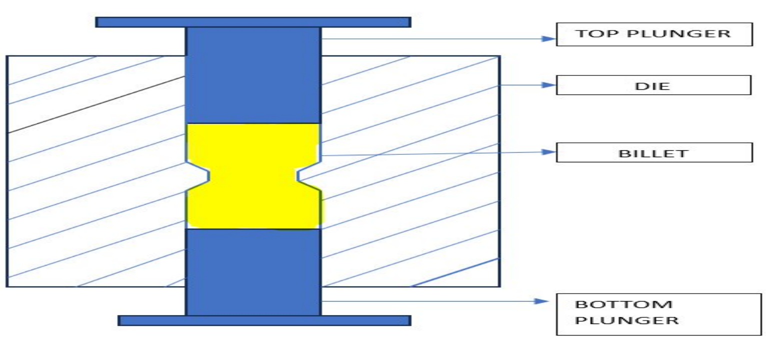

Fig.1. Schematic representation of the cyclic extrusion compression process.

Keywords: Cyclic extrusion compression; Magnesium; Grain refinement.

Reduction of streak shaped scale defects by improving the grain boundary strengthening in Ti-Nb stabilized ULC steel of Galvannealed product

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Abstract

Surface defects in galvannealed (GA) steel products significantly contribute to high rejection rates at both the manufacturing plant and customer levels. Among these, streak-shaped scale defects, similar to sliver defects from steelmaking, and appears randomly in titanium-niobium stabilized ultra-low carbon (ULC) steel coils. These defects, which become visible only after GA coating, manifest as pairs of parallel lines typically 1-2 mm wide and extending over 500 mm in length. Metallographic analysis reveals globular oxides dispersed along these lines, attributed to weak grain boundary regions that permit oxygen ingress from the wustite region, leading to internal oxidation. High temperatures, elevated oxygen presence, and prolonged residence times are key contributing factors. Lowering the temperature causes rolling issues, and residence time is dependent on mill conditions. To mitigate internal oxidation, enhancing grain boundary strength by adding surface-active elements is proposed. A plant trial was conducted with the addition of 10-15 ppm boron. Both trial and normal slabs were hot rolled under identical conditions. Results showed a significant reduction in defects per coil, from 8.5 to 1.7 in boron-added coils, demonstrating the efficacy of this approach in improving the quality of GA steel products.

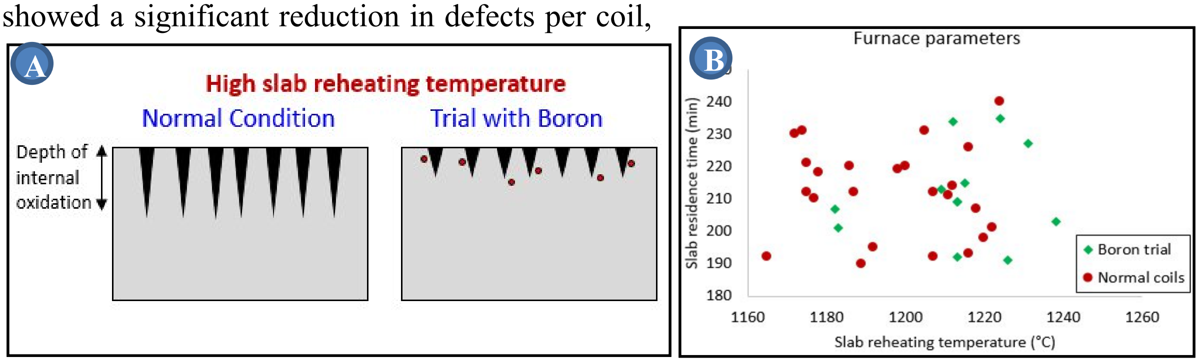

Fig. 1A: Internal oxidation phenomenon, 1B: Furnace parameters

Key words : Edge seam, Edger roll, Slab corner

Cutting-Edge Technologies to Produce Electrical Steel

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Abstract

Electrical steel (also called silicon steel) is a special steel tailored to produce specific magnetic properties, resulting in low power loss per cycle, low core loss, and high permeability, which is extremely sensitive to produce. Electrical steel is used in various applications, such as motors for electric vehicles, which is a booming market, as well as generators and transformers. NGO (Non-Grain Oriented) electrical steel is used for high frequency electric motors, while the high- energy efficient GO (Grain Oriented) electrical steel is intended for transformers and charging infrastructure.

Fives is as an international engineering group with extensive experience offering advanced technology for different applications. For the production of NGO and GO electrical steel, Fives provides process expertise, cold rolling mills and strip processing lines:

- Annealing & pickling line (APL)
- Cold rolling mill (CRM)
- Annealing & coating line (ACL)
- Decarburizing & coating line (DCL)
- Flattening & coating line (FCL)

Advanced technologies include:

- Thermal section for strip processing lines: a furnace with the best available technology for furnace atmosphere management, high H_2 atmosphere control, as well as smooth slow cooling and compact rapid jet coolers to achieve the required steel properties
- Induction heating technology for ultra-rapid heating
- Cold rolling: 20Hi cold rolling mills to achieve the desired thickness and flatness

This paper describes how advanced technologies used for production electrical steel lead to record performance:

- Strip temperature: up to 1,150 °C
- Rapid induction heating: 200 °C/s
- H_2 atmosphere: 0 to 95% dry or wet
- Cold rolling: 0.1mm rolling thickness on full width

METAL JOINING

Oral abstracts

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

MJN_011

Optimization and Standardization of FSW/FSP Techniques for Repairing High-Temperature Material Sub-Assemblies in Mining Sector Heavy Equipment

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Abstract

Friction Stir Welding (FSW) offers significant potential for repairing high-value components of Heavy Earth Moving Machinery (HEMMs) in the mining sector. The process has the potential to address the inherent limitations of conventional repair techniques. However, issues with process repeatability and lack of standards for FSW/FSP of steels and high-temperature materials limit its widespread adoption. This study aims to establish process repeatability through standardizing FSP for various engineering materials used in mining machinery. FSP was performed on EN-24 steel, IN-718, MS, SS, Ti, Al, Mg & Cu using optimized parameters, focusing on thermal conductivity, flow stress, ductility, and hardness. All experiments utilized the same FSW machine and WC tool, resulting in a standard operating procedure for FSW/FSP in crack repair and joining of different engineering materials in the mining sector. The study identified the contributions of thermal conductivity, flow stress, ductility, and hardness to be 35%, 25%, 20%, and 20%, respectively. For steels, thermal conductivity governs RPM selection; lower RPM (300-450) for low conductivity steels (<20W/m·K) and RPM based on tensile strength for higher conductivity steels. Titanium requires moderate RPM (800) due to its high hardness and low thermal conductivity. High thermal conductivity non-ferrous metals like Al, Mg, and Cu need higher RPM (1000 for Al and Mg, 800 for Cu due to its high thermal conductivity and ductility). Traverse speeds were optimized in combination with RPM to generate necessary heat for effective plasticization and flow of the material.

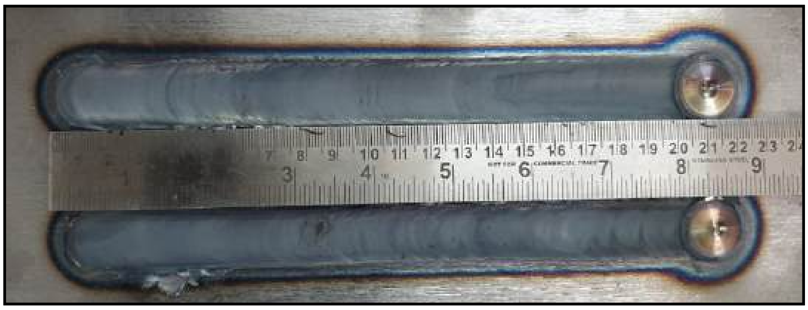

Fig. 1: Defect free EN-24 (AISI 4340) steel FSPed sample of total length 400 mm and depth of 4mm developed by using WC6%Co tool

MJN_005

Key words: FSW, FSP, Steel, Mining Machinery

References

1. Raj, S., Pankaj, P., & Biswas, P. (2022). Friction stir welding of Inconel-718 alloy using a tungsten carbide tool. Journal of Materials Engineering and Performance, 1-16.
2. Anshari, M. A. A., Imam, M., Yusufzai, M. Z. K., Chinthapenta, V., & Mishra, R. (2021). Stir zone anisotropic work hardening behavior in friction stir processed EN8 medium carbon steel. Materials Science and Engineering: A, 805, 140582.
3. Li, J., Shen, Y., Hou, W., & Qi, Y. (2020). Friction stir welding of Ti-6Al-4V alloy: Friction tool, microstructure, and mechanical properties. Journal of Manufacturing Processes, 58, 344-354.

A novel Self-reacting Tool Design to weld thick Aluminium Plates using Friction Stir Welding - Weld Characteristics and Performance Analysis

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Abstract

Welding of aluminium alloys is challenging especially in crucial applicatIons where the welding induced thermal damage should be minimal on microstructure and properties. Friction stir welding (FSW) is an effective solid-state welding technique that produce effective joints in Aluminium alloys with superior weld-efficiency. However, joining of thick plates using FSW is challenging. Present work is an attempt to develop FSW tool with novel design features to weld thick plates of AA2014 alloy. Results indicate that successful weld with refined microstructure and superior hardness in the weld zone is achieved using the designed tool. Due to the increased friction surface area in reactive tool design, the heat input required for welding is found to be much less as compared with the regular tool design, resulting in reduced tool speed requirement and higher traverse speed, increasing the productivity. Detailed microstructural evolution during welding and its correlation with the mechanical performance is presented.

MJN_006

Investigation of the Microstructure and Mechanical Properties of Cold Metal Transfer Welded SS304L

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Abstract

The recent innovation in the gas metal arc welding (GMAW) process, called Cold Metal Transfer (CMT) welding technique, has significantly reduced the heat input during the welding of thinner materials. The CMT welding technique is particularly well-suited for producing defect-free welds, especially when working with thin materials. Furthermore, CMT welding provides superior quality compared to conventional GMAW welding processes, as the microstructural characterization and mechanical properties of CMT welded joints have been demonstrated to be superior. SS304L is a strong and easy-to-fabricate material and finds extensive applications in automotive, medical, construction, Nuclear power plant and aerospace industries. However, conventional arc welding processes pose several challenges like Burn-through, distortions, splatter, and other flaws when welding thin SS304L sheets, due to high heat input. Therefore, present study investigates the microstructure and mechanical properties of Cold Metal Transfer Welded SS304L. The CMT welding process used ER 308L SS filler wire to weld SS304L sheets of 1.2 mm thickness. The CMT welding process resulted spatter-free welds due to low heat input and optimum penetration. The weld beads were found to be of excellent quality without any cracks in the welded SS304L sheet samples. The maximum micro-hardness value was achieved in the weld zone. Austenite was detected as main phase in both the base metal and the weld zone. The residual stresses were observed with compressive nature in the weld zone which attributes to the slightly higher corrosion rate in the welded zone as compared to the base metal of SS304L.

Keywords: Cold Metal transfer welding (CMT), SS304L, Hardness, Residual Stresses, Corrosion

MJN_110

Mechanical behaviour and microstructural evolution during the laser welding of Haynes 282 by integrating FEM and Phase field modelling

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Abstract

Advanced ultra-supercritical (AUSC) power plants are operated at a temperature higher than 700^0C and pressure exceeding 350MPa, which limits the use of many materials. Haynes 282 (HY282) is gamma prime-strengthened nickel-based superalloys specially used for AUSC components. Welding is an inevitable process in the construction of AUSC power plants. The weld thermal cycle will destroy the highly engineered microstructure of AUSC materials resulting in the degradation of its high-temperature properties. ICME framework was utilized to study the microstructure evolution during the joining HY282 using laser beam welding process. This study performed a macro scale FEM simulation of the joint using Simufact welding® software. The weld pool shape and temperature profile obtained from the FEM simulation are validated with experimental results. Microscopic dendritic growth in the weld pool was simulated by phase field simulation using Micress® software using the temperature gradient and cooling rate obtained from Simufact welding®. The simulated secondary dendritic arm spacing and microsegregation profiles match the experimental data.

Keywords: Multi-scale simulation, laser beam welding, Haynes 282, ICME

MJN_016

Study the effects of post-weld austempering on microstructure of a carbide free bainitic steel

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Abstract

This study examines the effects of post-weld austempering on the microstructure, texture, and mechanical characteristics of tungsten inert gas (TIG) weldments made from a carbide-free bainitic steel. The study investigates the microstructure changes that occur during post-weld austempering and how these changes influence the mechanical properties. Austempering is conducted at different temperatures and durations to examine the development of bainitic ferrite and retained austenite and enhance the toughness and strength of the weldment. Advanced characterization methods such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and electron back-scattered diffraction (EBSD) are used to analyze the evolution of texture and microstructural changes. The evaluation of mechanical behavior is conducted to identify relationships between heat treatment parameters and improvements in performance. The results indicate that by optimizing the austempering conditions, the mechanical characteristics of the weldment are much improved.

MJN_023

Study on explosive welded Aluminium to stainless steel joints in cylindrical configuration

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Abstract

Cryogenic stages of launch vehicle use Aluminium alloy (AA2219) as propellant storage system and Austenitic stainless steel (SS 321) as its feed lines. These two alloys are to be joined to create leak proof seals/adaptors. Solid state joining techniques like diffusion bonding, friction welding or explosive bonding can be used for joining two dissimilar metals having large difference in physical and metallurgical characteristics.

In this study, an attempt is made to realize lap joints of AA2219 and stainless steel through explosive bonding process. These joints are machined from explosive bonded AA2219 tubes with SS 321 rods in cylindrical configuration. The achieved joint provides higher interface area resulting in better leak tightness. Parameters such as stand-off distance, explosive height and explosive mixture were considered for process optimization. Mathematical calculations were used to generate weldability window for this material combination. Detailed characterization of the joint interface viz., light microscope, scanning electron microscope and energy dispersive spectroscopy is carried out. Machined hardware's from bonded rods were subjected to performance tests (Helium Leak test, LN2 shock test, Pressure test, Ultrasonic inspection) to demonstrate flight worthiness

DM_021

Enhancing Mechanical Properties of Submerged Arc Longitudinal Welded (SAWL) Pipe Grade for CCUS Applications through Varied Welding Consumables

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Abstract

The demand for Submerged Arc Longitudinal Welded (SAWL) pipes in Carbon Capture, Utilization, and Storage (CCUS) applications has surged, necessitating a comprehensive investigation into the influence of different welding consumables on the mechanical properties of these pipes. This study explores the effects of varied welding consumables on the structural integrity and performance of SAWL pipes, with a focus on optimizing mechanical properties for enhanced durability and reliability in CCUS environments

The research encompasses a systematic analysis of diverse welding consumables, including fluxes and wires, applied in the welding process of SAWL pipes. Experimental investigations involve the welding of pipes using different combinations of consumables, allowing for the evaluation of mechanical & metallography properties such as tensile strength, impact toughness, hardness and hydrogen-induced cracking. Through a series of mechanical & metallography tests, the study aims to identify the consumable combinations that yield superior mechanical properties, ensuring the SAWL pipes meet the stringent requirements of CCUS applications.

Furthermore, the study investigates the influence of welding parameters, such as heat input and travel speed, on the interaction between the consumables and the base material. This approach allows for a holistic understanding of the welding process and its impact on the resulting mechanical properties, providing valuable information for process optimization.

The findings of this research will contribute to the development of guidelines for selecting welding consumables tailored to CCUS applications. By identifying consumable combinations that enhance mechanical properties, the study aims to improve the structural reliability and longevity of SAWL pipes, thereby supporting the growing demand for robust and efficient CCUS infrastructure. Ultimately, the optimized welding consumables identified in this research will facilitate the construction of SAWL pipes that not only meet industry standards but also contribute to the sustainable and secure implementation of CCUS technologies in the global energy landscape.

Keywords: Submerged Arc Longitudinal Welded, Welding consumables, Mechanical properties, CCUS, Environment & sustainability.

MJN_047

Effect of welding speed on Microstructure of Laser beam welded Modified 9Cr-1Mo steel clad tube to end plug

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Abstract

The mod. 9Cr-1Mo (T91) clad tubes are welded with a bottom plug (P91) by using a Laser beam welding process for one end closure. Nd-YAG laser beam welding (LBW) process with a capacity of 500 w average power is used to carry out these welds. Though the LBW is a high quality welding process, to ensure its joint quality and to optimize its parameters, the effect of welding speed on a weld joint macrostructure and hardness is studied. The weld joints are qualified through various NDE techniques like visual, helium leak testing and radiography. T91 clad tube-end plug weld joints undergo post-weld heat treatment (PWHT) and second heat treatment as a need of the process of fuel pin fabrication. The PWHT temperature is 1033 K for one hour and cooled in the argon atmosphere. At a welding speed of 4 mm/s, the macrostructure studies reveal that the width of the weld metal is 1800 µm and the heat affected zone (HAZ) is just 200-240 µm towards the clad tube side and 100-120 µm towards the plug side. The penetration of 500 µm is achieved with the applied weld parameters and heat input. The highest hardness of 460 $HV_{0.2}$ is attained in the weld metal and reduced the same towards the base metal through HAZ. After the heat treatments, the hardness of the weld metal is reduced significantly and hence the viability of weld joint crack development is reduced.

Keywords: Laser beam welding, modified 9Cr-1Mo, P91, heat treatment, Heat Affected Zone

MJN_007

Optimizing Multi-Interlayered Joints in SS304HCu and Inconel 617 for Advance-Ultra-Super-Critical Power Plant Application

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Abstract

Advance-Ultra-Super-Critical (AUSC) power plants signify a vital advancement in "Clean Coal Technology," designed to achieve enhanced efficiency through high steam pressures and temperatures. These facilities present multiple benefits, including reduced investment costs for new projects, increased energy production with lower fuel consumption, decreased CO_2 emissions per MWh, and significant contributions to global climate change mitigation. The performance of AUSC plants hinges on the development of high-performance material joints. Efforts to develop indigenous materials like SS304HCu and Inconel 625 for high-pressure boiler components, such as superheaters, reheaters, piping, and headers, have commenced. However, fabricating and joining these materials poses considerable challenges. These components must withstand high heat loads (550-650ºC and 25-30 MPa), with short transient processes reaching up to 700°C and 35 MPa. Current joining methods employ T91 tube between SS304HCu and Inconel 625 which is a major concern towards safety and reliability due to extent of variation in physical and mechanical properties. In this context, the study focuses on developing multi-interlayered joints in SS304HCu and Inconel 625. The elemental effects on SS304HCu and Inconel 625 were meticulously analyzed, revealing intermetallic carbides (IMCs) and various secondary phases, most notably sigma phase formations. To mitigate these formations, the layer compositions and thicknesses were optimized. The Ni and Cr were found to be more suitable to SS304HCu and Inconel 617, respectively. However, Cr layer was separated from SS304HCu, and Cr was isolated from Fe to prevent sigma phase formation. A thick Ni-Cr layer was used between SS304HCu and Inconel 625 to achieve these separations. Elemental mapping, phase identification, and microtexture analysis were conducted using SEM-EDS-EBSD characterization techniques. The results indicated no intermetallic formation or penetration and mixing of interlayer elements—a unique aspect of this study. Post-annealing strain mapping across the joints showed uniform distribution, while nanoindentation tests revealed consistent micromechanical properties with minimal heat-affected and fusion zones. Furthermore, microscopic elemental variations were correlated with joint behavior, leading to the development of predictive models that provide valuable insights into the intricacy of the intermediate layer of SS304HCu-Ni-Cr-Inconel 617.

Keywords: Multi-interlayered joints, SS304HCu, Inconel 617, AUSC power plants.

MJN_012

Development of dissimilar metal SS321/Ti-5Al-2.5Sn alloy diffusion bonded joints from lab scale to industrial scale: interfacial microstructural evolution and its tensile response in temperature range of -196 oC to 500 oC

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Abstract

Dissimilar metal joint of SS321 and Ti-5Al-2.5Sn (α-Ti alloy) are produced by solid state diffusion bonding process performed at different temperatures (800-950°C) under 5, 10 MPa pressure for 30 min duration. The Gleeble Thermo-mechanical simulator (TMS) was used for producing DB joints on lab scale under vacuum at varying process parameter for the optimization of process parameters. The parameters optimized on smaller sample has been further used for producing DB joints on larger sample using vacuum hot press (VHP), to demonstrate the validity of optimisation from lab scale to industrial scale. The joint interface was metallurgically characterized through scanning electron microscopy (SEM) coupled with energy dispersive spectroscopy, EBSD analysis, Transmission electron microscopy (TEM), Scanning TEM, and Transmission Kikuchi Diffraction (TKD). Resultant interface microstructure, chemistry, and structural information at finer length scales was obtained. The observed 5 interface layers were comprising of intermetallic phases of σ phase, χ phase, $(Fe,Cr)_2Ti$, FeTi and β-Ti. The effect of change in heating process during diffusion bonding using TMS to VHP on growth kinetics of interface layers were investigated. The DB joint produced at 900 °C/10 MPa/30 min in VHP exhibited maximum shear strength and tensile strength of 261 ± 40 MPa and 253 ± 5 MPa respectively, and these values are approximately 50% and 43% of the respective shear and tensile strength of SS321. In comparison to the sample bonded in TMS, the VHP bonded samples showed slower growth of interphase layers particularly of layers 3 and 4, resulting in a shift in bonding temperature by +50 °C to obtain the maximum strength for the given bonding pressure and time. The joint strengths were evaluated at temperature of -196 °C, room temperature (RT) of ~25 °C and elevated temperature of 500 °C. It exhibited maximum tensile strength of 315 MPa, 253 MPa and 208 MPa respectively for the sample bonded at 900 °C. Zone of failure is found around interface layer 3 $(Fe,Cr)_2Ti$ + FeTi. Fracture surfaces of RT and -196 °C tested samples showed mixed

MJN_013

mode of featureless smooth and cleavage fracture, whereas 500 ºC tested sample has microvoid coalescence at interface with smoother fracture surface.

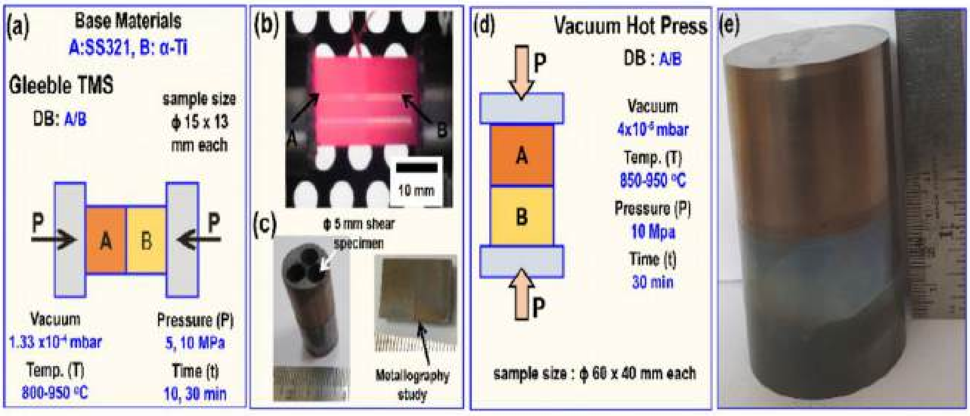

Fig. 1(a) schematic, (b, c) photograph of sample bonded in TMS; (d) schematic and (e) photograph of sample bonded in VHP of SS321/α-Ti alloy.

Key words: diffusion bonding, stainless steel, α-Ti alloy, vacuum hot press

An Experimental Study: Friction Stir Processing of Laser-Clad Copper on Commercially Pure Titanium

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Abstract

Titanium is widely utilized in aerospace, automobile engines, and seawater-exposed environments due to its high strength-to-weight ratio, fatigue strength, and corrosion resistance. However, it exhibits moderate thermal and electrical conductivity, and limited wear resistance. Copper, in contrast, offers excellent thermal and electrical conductivity, as well as certain antimicrobial properties. However, due to differing thermo-physical properties, low mutual solubility, and formation of brittle inter-metallic compounds, coating methods for copper on titanium often result in unsound coatings. Laser cladding, as a solution for surface coating, appears promising but remains underexplored.

This study employed Directed Energy Deposition (DED) to apply copper coatings on titanium substrates. Process parameters, namely laser power and scanning speed were varied to achieve different linear heat rates (15 to 120 J/mm), resulting in coatings of varying thicknesses. Optimization of process parameters based on coating adhesion, microstructure, and microchemistry yielded the best coatings at a linear heat rate of 30 J/mm. Friction Stir Processing (FSP), a non-conventional post manufacturing treatment, was attempted to improve adhesion and microstructure of the laser clad samples. The laser clad samples were characterized before and after FSP using optical microscopy and Scanning Electron Microscopy (SEM) along with Energy Dispersive X-ray Spectroscopy (EDS). Breakage of as-cast dendrites obtained from laser cladding, was observed along with one order grain refinement during FSP. Microhardness profiling was done on coatings with and without FSP, benchmarking the results against that of uncoated samples. Coating titanium substrate with copper was found to significantly increase the hardness up to VHN ~340 in laser clad samples against hardness VHN ~200 of Ti substrate. Also, hardness near the top surface was improved by 147% with an overall increase in coating hardness up to VHN ~420 by FSP.

Keywords: Laser cladding, Friction Stir Processing, Copper Coatings on Titanium, Grain Refinement, Microstructure.

MJN_022

Diffusion bonding of ZrB2-SiC-based ultra-high temperature ceramics with Ti-6Al-4V structural alloy

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Abstract

Joining ZrB_2-20 vol. % SiC (ZS) based ultra-high temperature ceramics (UHTC) to aerospace structural alloy Ti-6Al-4V (Ti64) is a major technological challenge to realize the composite as a thermal protection system for the space shuttle, hypersonic vehicles, etc. Significant differences in thermophysical properties such as melting temperature (~1500 °C), Young's modulus (~346 GPa), and hardness (~12 GPa) pose difficulty in fusion welding. Brazing leads to a thick interdiffusion zone with brittle intermetallic compounds such as Ti_5Si_3, TiC, etc. unable to relieve the residual thermal stress and the limited operational capability of the joint (1000 °C). Diffusion bonding conducted in a spark plasma sintering (SPS) unit can help to realize sound joint with better control over the reaction layer. In the current work, ZS is consolidated via SPS with multistage sintering (final temperature of 1800 °C) achieving a relative densification of 99.1 ± 0.1 %. The X-ray diffraction analysis revealed the formation of ZrC in trace amounts. The contacting surfaces were polished, yielding the surface roughness (R_a) of 507 ± 51 nm for ZS whereas 47 ± 6 nm for Ti64. The ZS pellets were joined with Ti64 alloy in an SPS unit with two different bonding temperatures of 800 °C and 1000 °C, bonding pressure of 30 MPa, and bonding time of 20 min. The scanning electron microscope (SEM) revealed uniform, planar, and void-free contact at the interface. Energy dispersive spectroscopy (EDS) of a specimen bonded at 800 °C revealed the formation of a Ti-Zr solid solution within Ti64, with no detectable reaction layer at the interface. Crack nucleation and propagation occurred at the interface on the ZS side. Conversely, a reaction layer with a thickness of 1-4 µm was observed for the specimen bonded at 1000 °C, indicative of a chemical reaction layer between Ti and ZS that resulted in a continuous joint layer. In situ synthesis of TiB whiskers was observed at the interface perpendicular to the ZS substrate. The detachment of boron atoms from the ZrB_2 lattice at the elevated temperature (> 800 °C), along with the diffusion in the (010) direction and the concurrent generation of vacancies at the growing tip of TiB, facilitated the nucleation of TiB at the ZS interface. The preferential growth orientation of TiB effectively mitigated thermal stress, as no cracking was observed at the bonded interface. TiB with a melting point exceeding 3000 °C, provides a robust framework for load transfer and ensures the joint's stability at operational temperature above 1000 °C.

Keywords: Diffusion bonding, whiskers, reaction layer, interface.

MJN_024

Effect of Welding Parameters on Laser Welded DP 980 steel

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Abstract

Welding of DP 980 steel is difficult on industrial scale due to soft Heat Affected Zone (HAZ). The present study investigates the effect of welding parameters on the laser welding process for DP 980 steel. The parameters considered for the experiment include welding current, welding speed, welding pressure, and lap length. Each parameter is varied at three different levels to assess its impact on the output parameters. The output parameters of interest are the temperature during welding and the thickness of the weld. The study aims to optimize the welding process by identifying the optimal combination of parameters that results in the desired weld quality. To design the experiment, the Taguchi method is employed. Furthermore, the analysis of variance (ANOVA) method is used to statistically evaluate the significance of each parameter and its interactions. ANOVA helps identify which parameters have the most significant impact on the welding process and which interactions play a crucial role. The findings from this study helped in optimization of laser welding processes for DP 980 steel, leading to improved weld quality and mechanical properties. It was found that welding speed is most significant parameters followed by current and pressure whereas least significant was lap length.

Key words : Laser Welding, Taguchi Method, ANOVA, DP 980 Steel

MJN_028

Development of novel Carbon modified filler for the gas tungsten arc welding of CP-Titanium

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Abstract

Titanium and its alloys are widely utilized in critical engineering applications due to their exceptional mechanical properties and corrosion resistance. The Gas tungsten arc welding (GTAW) process is widely used to join titanium and its alloys due to its exceptional weld quality and precision. This research focuses on the development of a novel carbon fillers having compositions (CP-Ti-x wt.% C, where x= 0.08, 0.2, 0.4) specifically tailored for GTAW welding of commercially pure (CP) Titanium. The primary objective is to enhance the mechanical properties and overall weld quality of titanium joints by incorporating these innovative fillers. The results demonstrate the potential of the novel carbon filler to enhance the mechanical properties and microstructural integrity of the GTAW welds in CP-Titanium. Microstructural analysis revealed refined prior-ß grains and equiaxed dendritic grains with nonlinear grain boundaries in the weld zone. The incorporation of carbon shows the formation of titanium carbides (TiC). The weldments prepared with modified filler exhibited a higher strength of 445±6 and hardness of 248±6 HV compared to autogenous welds due to TiC precipitation. These carbides act as strengthening agents and hinder dislocation movement, leading to increased strength and hardness. This formation of TiC phase in the weld zone promotes inoculation effect and growth restriction resulted in decreased grain size. The increase in hardness is attributed by grain refinement and the formation of TiC precipitates in the FZ.

Keywords: GTAW, Commercially pure Titanium, Grain refinement, TiC.

MJN_033

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 Properties; Microstructure

MJN_037

MINERAL PROCESSING

Oral abstracts

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Vanadium Recovery from Secondary Sources through Hydrometallurgy

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Abstract

The vanadium market is growing, driven by demand for high-strength steel in construction, automotive, and aerospace industries, as well as by renewable energy storage solutions like vanadium redox flow batteries (VRFB). VRFBs offer advantages like scalability, long cycle life, and high efficiency, supporting the transition to cleaner energy sources.

Vanadium, essential for steel alloys and energy storage technologies, is increasingly recovered from secondary sources due to limited natural deposits and substantial tailings from mining and industrial processes. Secondary sources of vanadium include slag from titaniferous magnetite ore (TMO) processing plant, vanadium sludge from alumina industries, spent catalysts from petroleum industries, pet coke gasification slag, and fly ash which is the by-product from coal combustion and steel making.

Hydrometallurgy is a prominent and effective technique for recovering vanadium from secondary sources due to its ability to handle complex feed materials and selectively extract valuable metals. Some of the advantages of hydrometallurgy for vanadium recovery are high selectivity, low energy consumption, flexibility and environmental benefits.

In summary, hydrometallurgy offers a versatile and efficient approach to recovering vanadium from secondary sources, contributing to the sustainable management of resources and supporting the growing demand for this valuable metal in various industries.

Hydromet Technology Solutions has done extensive work on vanadium recovery from secondary sources and has set up successful commercial plants. Figure-01 illustrates typical flowsheets used for processing various vanadium secondaries.

Keywords: Vanadium Pentoxide, Leaching, Roasting, Purification

MPR_089

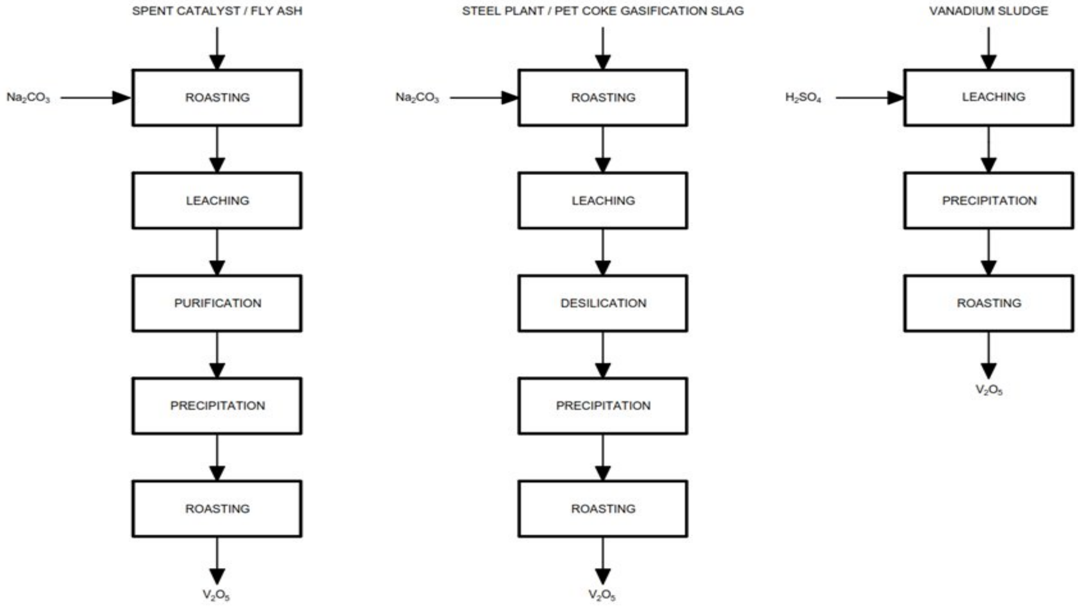

Figure 1: Typical Flowsheets for Processing Vanadium Secondaries

Recovery of lithium from a low-grade Indian Spodumene Sample

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Abstract

Lithium (Li) is called 'White gold' due to its high demand for rechargeable batteries. It is a soft and silvery-white metal. Lithium is primarily obtained from the spodumene in pegmatite deposits and lithium salts from underground brine deposits. Lithium, as a strategic metal, has been extensively used in lithium ion batteries (LIBs), ceramics, glass, greases, primary aluminum production, and polymers. Lithium can be recovered and used in the form of Lithium Carbonate and Lithium Hydroxide. India relies heavily on lithium imports to meet its domestic demand as it lacks significant lithium reserves. In India, lithium is present in the form of hard rocks, which needs proper exploration and research. Lithium-Caesium-Tantalum (LCT) is known to be India's granitic pegmatite deposit which is found in Bihar-Jharkhand, Bastar-Odisha, Karnataka, Rajasthan, Maharashtra, West Bengal, and Assam. India comes seventh and is expected to become the sixth-largest holder of lithium resources in the world, ahead of China after a large amount of lithium has been discovered in the Reasi district of J&K. Karnataka Pegmatite deposits appear to have more potential than Bihar-Jharkhand and Rajasthan. This work summarizes the Indian primary resources, reserves, beneficiation, and extraction techniques. Besides, experimental work carried out on Indian spodumene of Amareswar, Karnataka has been highlighted. Preliminary beneficiation and pyro and hydrometallurgical extraction work indicate that it is possible to recover over 95% of Li content from a feed grade of 0.7%.

Keywords: Low-grade lithium ore, Hard rock, Spodumene, Beneficiation, Pyro and Hydrometallurgical methods.

MPR_206

An Economical Process to maximise the recovery of Vanadium, Titanium and Magnetite values from Low-grade Vanadium-Titanomagnetite Ore

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Abstract

Vanadium titanomagnetite (VTM) ore generally contains valuable elements in complex form and it has an extremely high potential value and a valuable material for the metallurgical industry. The objective of the research work is to recover the titanium, vanadium and iron values from vanadium-titanium-magnetite (VTM) ore. The detail characterisation studies like microscopic analysis, XRD, SEM, EDX of each sample was carried out to understand the association of different minerals in the ore. the relevant information regarding association of different minerals. Size analysis of each sample was done to evaluate the liberation size. The beneficiation study of the Vanadium Titanium Magnetite (VTM) ore was carried. The beneficiation process included scrubbing, classification, grinding and magnetic separation. It has been observed that it should be ground to below 75 µm for liberation of mineral phases associated in the ore. In this product, TiO2 component mostly represents from ilmenite which is associated with magnetite phase. Both ilmenite and magnetite are in complex form. Some liberated magnetite is also available. According to chemical analysis free magnetite percentage is around 15%. It also shows that the vanadium pentoxide is associated with magnetite and its percentage is increased to 3.09%. The silica and alumina percentages are 2.55% and 1.39% respectively in LIMS concentrate. This concentrate contains valuable minerals magnetite, ilmenite and vanadium pentoxide which can be used for extraction of iron, titanium and vanadium. The WHIMS concentrates from beneficiation process shows that FeO percentage is high which indicates that either liberated ilmenite is reporting in this concentrate or associated with hematite phases. It does not contain more vanadium pentoxide. It may be considered as secondary concentrate. The constraints are high silica and high alumina in the concentrate which will report in the titanium oxide slag during extraction. The magnetic concentrate from LIMS and WHIMS are blended together and used for extraction of mineral values as silica and alumina are within in the limit. Therefore, in this particular ore the liberation increases once particle size goes down to below 75 µm. At the beginning ore is to be deslimed to classify 38 µm particles. This may be deslimed by hydrocyclone and underflow of hydrocyclone is subjected to LIMS followed by WHIMS. Then the coarse particles are to be ground to below 45 µm and subjected to LIMS and WHIMS. The LIMS concentrate is the super grade concentrate and WHIMS concentrate is sub-grade concentrate. WHIMS non-magnetic fraction is rejectable tailings. If concentrate 1 is considered as single product, the iron recovery is 25.71% whereas titanium dioxide recovery is 22.96% but vanadium pentoxide recovery is 90.54%. If concentrate 1 and concentrate 2 is blended and

MPR_310

considered as the final product, then iron recovery is 37.11% whereas titanium dioxide recovery is 36.48% but vanadium dioxide recovery is 92.27%. The concentrateThen, the pelletisation, induration, direct reduction and smelting of magnetic concentrate was carried out using laboratory scale setup. Magnetite concentrate was generated by physical beneficiation, which was used for pelletisation study. The induration study was carried out at the temperature at 1200 ℃ to achieve physical, chemical and metallurgical properties. The indurated pellet was used for DRI study at temperature at 1200 ℃ using coal as reductant. The reduced pellet was used for smelting reduction. It is possible to achieve iron metallic with high quality Fe content. The slag contains around 54-57% TiO_2 and 4.6-4.9% V_2O_5. The titanium and vanadium can be extracted using sulphuric acid leaching process. The main advantage of the beneficiation process flowsheet shown in Fig. 1 is maximising the recovery of vanadium pentoxide and process operating cost will be less. As impurities percentage in the concentrate 1 is less, the titanium oxide slag will be high quality. This concentrate can be directly sold in the international market. Otherwise, titanium slag with vanadium pentoxide can be sold in the international market for recovery of titanium and vanadium pentoxide.

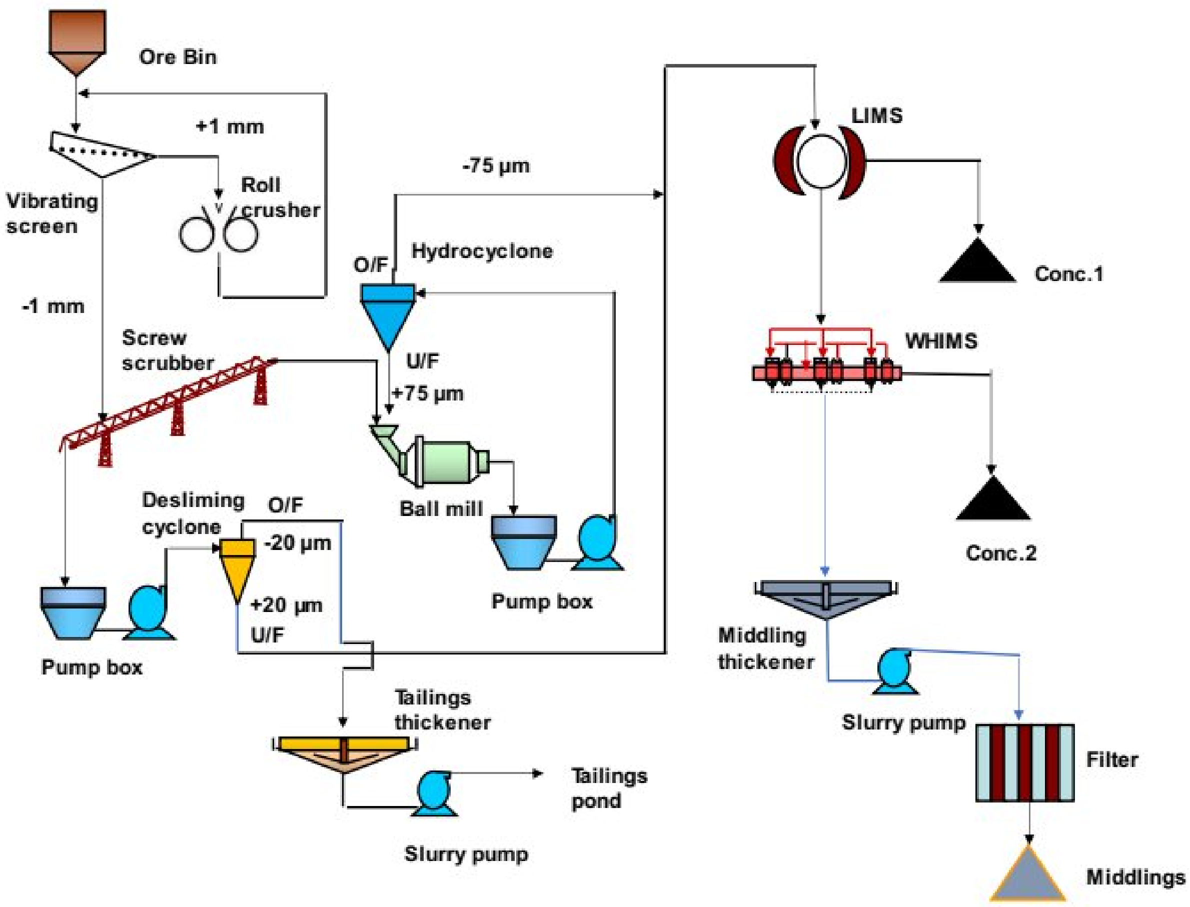

Fig. 1 Process flowsheet for beneficiation of VIM ore

Redox-controlled fed-batch bioleaching of Zn from ZnS concentrate by Leptospirillum ferriphilum dominated iron-oxidizing microbial culture

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Abstract

Bioleaching of ZnS has been studied widely in the past with low Zn recovery due to passivation layer formation causing barrier Zn leaching. Bioleaching operations in stirred tank reactors are carried out with aeration meeting O_2 and CO_2 requirements for microbial growth and ZnS oxidation. Aeration is one of the major operating costs; therefore, one way to reduce the oxygen demand could be restricting sulphide oxidation at the elemental sulphur level and not allowing further oxidation into sulphates. Therefore, a fixed volume fed-batch bioleaching of ZnS concentrate was conducted with 100% biogenic ferric ion solution densely populated with >95% Leptospirillum ferriphilum, and the redox value of the solution was 700 mV. The ZnS concentrate was fine ground material, with 80% passing 20 microns, composed of 52% Zn, 9.9% Fe, and 35% S. The addition of ZnS concentrate to the biogenic ferric solution was continued until the redox potential dropped from 700 mV to 600 mV. Depending on the redox profile, ZnS concentrate was added once/twice/thrice daily. Following each addition, the system was allowed to rest until the redox potential recovered to 700 mV, indicating the reoxidation of Fe^{2+} to Fe^{3+} by the microbial culture. This process was repeated until the redox potential no longer recovered to 700 mV, suggesting that no further bioleaching was possible. The cumulative ZnS addition determined the pulp density (PD); only 2% (w/v) PD was achieved in the first-stage of fed-batch bioleaching. Therefore, further enhancement of PD comparable to industrial operations was attempted with second-stage fed-batch bioleaching using the microbial culture from first-stage bioleaching after multiple time reactivation. The second stage, fed-batch bioleaching, was conducted with the reactivated microbial culture and successfully increased the PD to 7% (w/v). A similar reactivation procedure was then applied to the culture from the 7% PD experiment for conducting third-stage fed-batch bioleaching; interestingly, the PD approached 10% (w/v). The Zn content in bioleach liquor was analysed by Atomic Absorption Spectroscopy, and bioleach residue was analysed by X-ray diffraction and Scanning Electron Microscopy after the third stage of fed-batch bioleaching. The Zn recovery was 95%, 60%, and 70% for 2%, 7%, and 10% (w/v) PD, respectively. The leaching kinetics of Zn resulted in an Intermediate type of leaching, while the order of reaction was a first-order reaction with a promising Zn recovery for future technological advancement. This study highlights a promising method for processing sphalerite concentrates in the non-ferrous metal industry by controlling redox potential during bioleaching, which enhances zinc recovery while minimizing energy consumption and cost.

Keywords- Bioleaching, ZnS, Leptospirillum ferriphilum, leaching, pulp density, fed-batch

MPR_345

Effect of bauxite quality and operating conditions on chemical extraction in double digestion plants.

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Abstract

Bauxite contains different alumina bearing minerals such as gibbsite, boehmite and diaspore. The concentration of these minerals in bauxite decides technology for digestion viz. low temperature digestion or double digestion for economical extraction of alumina trihydrate from bauxite. For a given technology of digestion, the chemical extraction efficiency of alumina trihydrate from the alumina bearing minerals depend upon not only the minerology of bauxite and other impurities, but also upon the process parameters such as temperature, residence time, charging ratio and precipitation conditions.

In a typical double digestion refinery, where LT digestion is followed by HT digestion, the concentration of boehmite plays a very important role in overall chemical extraction of the refinery. The lower concentrations of boehmite (< 5%) are not economically feasible whereas the higher concentrations (> 10%) may lead to issues in achieving target extraction efficiencies. So, suitable blend of bauxite is essential to achieve required content of boehmite and higher extraction efficiencies.

The process parameters such as temperature of digestion, residence time and charging ratio affect the LT digestion and HT digestion extraction efficiencies. The process parameters vary from bauxite to bauxite due to mineralogical effect and concentrations of other impurities.

Different blends of bauxite with target MHA content ~8% were tested under varying conditions of digestion temperature, digestion time and charging A/C and the impact on chemical extraction efficiency was studied to arrive at the optimised conditions. Further the individual bauxites with varying MHA contents (~5 % to ~13%) were tested under the optimised conditions and the impact on chemical extraction efficiency was studied.

In this paper an attempt has been made to achieve higher extraction efficiency by blending different bauxites and optimising various process parameters.

Key Words: Bauxite, Digestio

MPR_369

Recovery of Rare Earth Elements from Lean Grade Uranium Ore Effluents

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Abstract

Rare Earth Elements (REE), a group of 17 elements, La-Lu along with Sc and Y have occupied a special and irreplaceable space in the modern-day technologies and renewable energy sector. REE's demand is expected to grow, due to world's focus on carbon neutral economy. The monopolistic nature of REE production and environmental challenges in the processing of the primary REE resources has led to increase in exploration of the waste streams for the recovery of REE in recent times. The occurrence of REE in the U ore samples is well known due to the similar ionic radii of the Ln^{+3} ions to U^{+4}. During the hydrometallurgical processing of uranium ores, these REEs are released into leach liquors along with other elements making it an attractive potential source of REE. Recovering these valuable elements helps in economising the U recovery from low grade ores. However, the complex solution chemistry of low-grade ores poses significant challenges for their selective extraction.

In this paper, we report studies carried out for the recovery of REE from lean grade leach liquor generated while processing a low-grade U (U_3O_8 – 230 ppm) ore sample. The leach liquor analysed about 120 mg/L of total REE along with 200 mg/L of U_3O_8. The REE recovery was attempted from the ion-exchange barren obtained after uranium extraction. Several process options viz direct precipitations, ion-exchange using strong cationic resin and solvent extraction using cationic extractant were tested for the recovery of REE. Among the tested methods, solvent extraction performed better using the D2EHPA solvent diluted in kerosene. McCabe Thiele diagram was generated under the optimised conditions of A/O ratio of 1 with extraction with 30% D2EHPA in kerosene. The stripping from the extract was carried out using 8 M HCl. The iron from the strip liquor was extracted using TBP (30% in kerosene) before REE precipitation as $REEF_3$ using NaF. Precipitation of REE as fluorides helped in the conservation of the HCl in the strip liquor. The process flow-sheet is depicted in Figure 1.

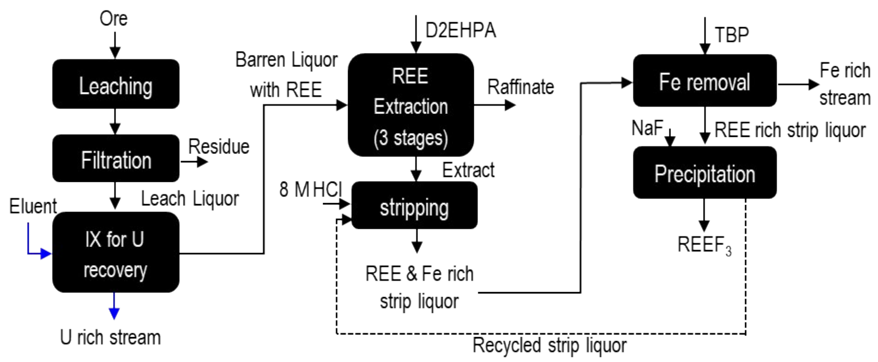

Figure 1: *Process flowsheet for the recovery of REE*

Keywords: Rare Earth Elements, Solvent Extraction, Di-(2-ethylhexyl) Phosphoric Acid, (D2EHPA)

MPR_356

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

MPR_363

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.

MSD_078

Enhancing Chromite Pellet Quality: Value-Added Utilization of SMS Dust for Improved Moisture Control and Strength

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Abstract

Industrial waste SMS bag dust with a high silica content was used to help with the consolidation process of chromite pellets in order to increase their consolidation moisture content, which was less than 9%, and their strength, which had a high Cr/Fe ratio of 2.50. The findings showed that adding more SMS dust considerably lowered the moisture content and quantity of green ball drops. Initially, the compressive strength increased with the addition of SMS dust but then decreased beyond a certain threshold. The quality of green balls improved noticeably when the SMS dust dosage was maintained between 1% to 2%. In particular, warmed and roasted pellets' moisture content decreased from 15% to 9% and their compressive strength increased from 131 N/P and 180 N/P, with the addition of 2% SMS dust. Furthermore, the preheating and roasting temperatures were lowered from 1100 °C and 1350 °C to 1075 °C and 1300 °C, respectively, which fell within the optimal operational temperature range for the grate-kiln process. The mechanism behind the SMS dust's role in strengthening pellet consolidation involved three main aspects: the formation of new minerals through solid-phase reactions between SMS dust and chromite, which facilitated mineral crystallization; the creation of a small amount of liquid phase during the roasting process, which aided ion diffusion; and the development of an intertwined structure between the liquid phase and chromite particles. These findings not only offer theoretical insights for producing high-quality chromite pellets suitable for submerged arc furnaces but also demonstrate the beneficial utilization of industrial waste, thereby presenting promising applications for the future.

Keywords: SMS dust; Chromite pellet; Moisture; Compressive strength; Industrial waste

MPR_188

Inorganic Carbon in Bauxite and its impact on Bayer Process

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Abstract

The Bayer process is known to be a hydrometallurgical extraction and refinement process of extraction of alumina from bauxite. Here Bauxite ore is initially ground and then digested in high concentration caustic solutions at an elevated temperature. Solids, usually oxides, quartz, and other resistant minerals, are separated out from the hot sodium aluminate slurry by physical means such as settling and filtration. The solids are counter current washed to recover the caustic solutions. Sodium aluminate liquor is cooled and precipitated. Aluminium tri-hydroxide is then separated from the spent caustic aluminate liquor, which is recycled back in the process circuit. During the constant recirculation of caustic liquor, different impurities can build up within the circuit and suppress alumina yield. Along with different other elemental impurities, the total carbon (TC) built up in the alumina plant is known to cause not only various plant operational problems, but also reduces liquor productivity and quality.

In this present study, different Indian & imported bauxites were characterized for carbon species like Total organic carbon (TOC) and total inorganic carbon (TIC). The impact of TOC and TIC was studied in one of the Bayer plants. The conversion rate was reviewed in details and its impact on increase in plant oxalate levels and decrease in plant causticity were also studied. It could be observed that the plant causticity(C/S) is a function of total inorganic carbon (TIC) in bauxite, which causes loss in precipitation productivity and soda salting in evaporators at higher concentration. Details investigation showed that, a C/S drop of 0.01, cause precipitation yields to fall by between 0.5 and 1.0 g/L. Impact of soda saluting on evaporation operation in terms of evaporation factor was also studied during this period.

Key words : TC,TOC, TIC, Bauxite, Bayer process.

MPR_347

78th Annual Technical Meeting
The Indian Institute of Metals

Chemical Tailoring of the Surface of Aluminum Trihydrate for the Application in Smart Polymers

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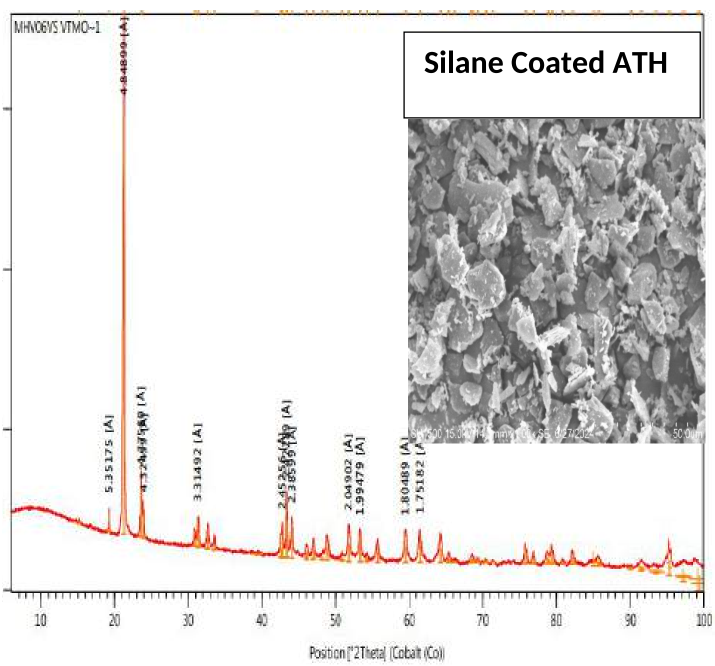
Abstract

The remarkable thermal stability and non-toxicity of aluminium trihydrate (ATH), a commonly used flame retardant, have drawn a lot of attention. Its use in some polymer matrices may be constrained, nevertheless, by its innate hydrophilicity and propensity to aggregate. Modifying the surface of ATH has become a viable approach to get around these restrictions. Surface modification is the process of changing the surface characteristics of the ATH particles to enhance their interaction with matrix materials. Through these changes, ATH's mechanical and thermal properties can be tailored, its dispersibility can be increased, and its adhesion to polymer matrices can be improved. The choice of modification technique depends on the intended application and desired properties.



This dissertation provides a thorough summary of the study on customizing aluminium trihydrate surface modification at Hindalco. The ATH surface was modified with Vinyl trimethoxy silane (VTMO), Stearic acid (STA) and Titanate Coupling Agent (TCA) with varying concentrations and at temperature of 60-70 °C in a Henschel mixer.

Several techniques namely Specific Surface Area analysis through BET method, determination of characteristic peaks using Fourier Transform Infrared Spectroscopy (FTIR)-Attenuated Total Reflection (ATR), Particle size distribution through Sedigraph, wettability and surface energy by contact angle meter, crystallinity through X-ray diffraction (XRD), surface morphology through Scanning Electron Microscopy (SEM) and elemental analysis through X-ray fluorescence spectroscopy (XRF) have been employed for this entire study. The modified ATH then incorporated into PVC matrixes around 40-60 phr for the synergistic improvement of flame retardancy as well as mechanical properties by performing UL 94, Tensile strength, Elongation at break and limiting oxygen index (LOI) which has a potential application in the cable industry. The secondary purpose was to replace the toxic and corrosive gas generated through halogen-based flame-retardant substance by low cost, and non-toxic gas emitted eco-friendly and sustainable ATH. The valuable ATH could be utilized in smart polymer applications like self-healing polymers, shape-memory polymers and thermoresponsive polymers considering its benefit in terms of flame retardancy, smoke suppression as well as mechanical properties.

MPR_349

REFLUX™ Flotation Cell full-scale trial in a copper concentrator scavenger and cleaning applications

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Abstract

REFLUX™ Flotation Cell (RFC™) is a novel technology that is transforming the hydrodynamics of flotation. RFC™ is designed based on a well-established REFLUX™ Classifier which is a hydraulic classification technology that separates based on specific gravity or particle size, but RFC™ separates particles based on flotation principles. RFC™ has been tested in many commodities such as coal, copper, molybdenum, iron ore, lead-zinc, gold tailings, potash, phosphate, limestone, graphite, etc. in both direct and reverse flotation. In this testwork, RFC™ has demonstrated improved flotation performance compared to incumbent open-tank flotation technologies by providing faster flotation kinetics and a shift in the grade-recovery curve.

For one of the industrial-scale demonstrations, RFC™ was installed at one of the copper concentrators owned by KGHM in Poland in early 2023. RFC100 Pilot unit as well as RFC850 Industrial Units were installed and slipstreams from scavenger feed and cleaner feed were tested for 10-12 months. The goal was to compare the test results amongst the existing performance of conventional flotation cells in the plant, standard bench-scale flotation, RFC100 pilot, and RFC850 industrial scale.

The results showed that the RFC850 industrial scale unit followed a 1:1 scale-up factor between the RFC100 pilot and RFC850 industrial scale units while providing the better separation efficiency than the conventional open tank flotation technologies. Additionally, RFC™ demonstrated up to 10 times faster flotation kinetics at industrial scale than the incumbent conventional flotation cells. As a result, RFC™ demonstrated faster flotation kinetics and its capability to reduce the flotation circuit size (CAPEX) in these applications by reducing the flotation cell size and the number of stages. This allows RFC™ to require less power, air, and wash water, helping in reducing the operating cost (OPEX). The results of the two test campaigns in scavenger and cleaner circuits will be discussed.

Key words: reflux flotation, RFC, flotation, upgrade ratio, fast flotation

NFM_076

Chromium (VI) Removal through Hollow Fiber Membran

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Abstract

The toxicological impact of hexavalent chromium on the environment has raised concerns about its treatment/removal from industrial discharge water. A process for the separation of chromium (VI) from industrial effluent through hollow fiber membranes has been developed and scaled up. The extraction process of Cr (IV) using hollow fiber membrane has been compared with the liquid-liquid solvent extraction technique. Prior to chromium extraction, the Fe content in the effluent was separated as ferric hydroxide following precipitation at pH -3.0. An extraction efficiency of 95% was achieved in the scaled-up hollow fiber membrane using Alamine 336 + TBP as the extractant at pH 4.0 and A/O ratio 1:1. The Cr (VI) content in the loaded extractant was stripped back to NaOH as the acceptor. The effect of parameters, such as pH, concentration of extractant and time on the extraction of Cr (IV) was evaluated. The extraction process was tested in bench-scale continuous mode at a flow rate of 800 mL/min through the hollow fiber membrane.

Key words: Chromium, Effluent, Extraction, Hollow Fiber Membrane, Solvent Extraction

NFM_021

Filteration and dewatering of nalco red mud

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Abstract

Red mud is a by-product of alumina extraction from bauxite ore. It contains high quantities of alkali, minerals, and metal ions, which are typically pumped as thick slurry to a residue disposal area. Dry cake disposal is the most preferred technique for the disposal of red mud, which reduces the environmental impact. Dry cake disposal also improves recoveries of caustic soda and alumina. In order to perform dry cake disposal economically, filtration, de-watering, and final cake washing become mandatory. Further drying, though adds to the cost may be the future norm for proper resources mobilization and further value addition.

Pressure filtration is one of the most used solid - liquid separation techniques for batch/semi-batch production & dewatering of difficult to filter suspensions like red mud slurry. The pressure filtration technology meets the requirement of high soda recovery, the high solids containing cake which can be no longer thixotropic and yields less volumetric mass (compact), and easily transported by conveyors or automated mobile stackers. Therefore, for bauxite red mud, pressure filtration can be the preferred technique over vacuum filtration and thickening.

This paper is an attempt to study the effect of various feed solids and filtration pressure on the final cake solids of NALCO, Damanjodi red mud. The traditional rotary drum vacuum filters can produce the final cake solids content up to 65 wt%, whereas, the results of pressure filtration tests produce the final cakes containing up to 76-78 wt% solids.

Red mud cake with high solids content provides several benefits such as long-term storage, future utilization for the recovery of valuable metals such as aluminium, iron, titanium, and rear earth elements.

Keywords: Red Mud, Bauxite residue, Red mud filtration, Dewatering, Drum filter, Pressure filter, Red Mud Utilisation, soda recovery, thickening. Solids-liquid separation.

MPR_395

Studies on Characterization of High Phosphorous Iron Or

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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

MPR_143

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

MPR_262

A clean approach for the production of metallurgical grade chromic oxide from low grade chromite ore tailings

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Abstract

Chromium is considered as strategically important and indispensable metal because of its huge application in many fields, such as steel production, chemical, textile and leather. In the recent years, the world annual demand for chromium is increasing rapidly due to continuous increase in steel production in developing countries. The growing demand for this metal leads to fast depletion of high grade ores. Therefore, it is important to develop a clean and economical process for the recovery of chromium from chromite ore tailing generated during beneficiation of ore. These tailings are discarded as waste leading to loss of chromite value and having adverse impact on environment. Therefore, the present article explores the possibility of extracting chromium from low grade chromite ore tailings containing 15.50% Cr_2O_3, 42.71% Fe_2O_3, 12.51% SiO_2 and 13.65% Al_2O_3 as major constituents with minimum dissolution of iron and silica. The present study proposed a new strategy to selectively recover chromium through liquid phase oxidation of chromite tailings in the sub molten KOH medium followed by water leaching and the liquor is crystallized to form potassium dichromate after purification. Potassium dichromate was reduced in presence of coke to produce metallurgical grade chromic oxide. Various process parameters such as KOH dosage, roasting temperature and time were studied and optimized. The chromic oxide obtained in this process was characterized through X-ray diffraction (XRD) and Scanning electron microscopy (SEM) followed by Energy-dispersive X-ray (EDX) to check it purity.

Keywords: Chromite ore, alkali roasting, leaching, crystallization, chromic oxide

NFM_005

Enhancing Iron Ore Quality Through Multi-Stage Dry Separation Technique

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Abstract

This study investigates the efficacy of multi-stage dry separation techniques for upgrading iron ore across various size fractions. The process employs a combination of Air Stratifier, Air Table, and Induced Roll Magnetic Separator to enhance Fe content and optimize yield. Iron ore in four different size fractions: -20mm to +10mm, -10mm to +6mm, -6mm to +3mm, and -1mm to +0.1mm are chosen as raw material size for dry beneficiation studies. For the -20mm to +10mm fraction (initial 60.5% Fe), the Air Stratifier produced a heavy fraction with 62% Fe at 48.65% yield. Subsequent processing of middling and light fractions on Air Table and Induced Roll Magnetic Separator resulted in overall heavy yields of 92.5% and 70% respectively, at ≥62% Fe. The -10mm to +6mm fraction (initial 59.7% Fe) achieved similar results, with the Air Stratifier producing a 41% yield at 62% Fe. Further processing led to overall heavy yields of 72% and 50%, maintaining ≥62% Fe. In the -6mm to +3mm range (initial 60% Fe), the Air Stratifier yielded 50-55% at 62.23% Fe. Additional processing of the light fraction resulted in a 67.7% heavy yield at ≥62% Fe. For the fine fraction (-1mm to +0.1mm with 59.17% Fe), which bypassed the Air Stratifier, direct processing through Air Table and Magnetic Separator achieved a 70% yield at 61.8% Fe.

The study acknowledges limitations in processing ultrafine material (<0.1mm) using dry techniques. This paper discusses the potential of combined dry separation techniques in significantly upgrading iron ore quality across various size fractions, offering promising implications for more efficient and environmentally friendly ore beneficiation processes. The results indicate that this multi-stage dry separation approach can effectively increase Fe content while maintaining high yields across different-size fractions. This method shows potential for improving iron ore beneficiation processes, potentially reducing water consumption and environmental impact compared to traditional wet processing methods.

Keywords: Dry Beneficiation, Fluidization, Iron Ore, Minimum Fluidization Velocity, Magnetic separation.

MPR_127

Impact of Flocculent Addition in Thickener on Tailings Concentration Process: A Study on Efficiency and Mechanism of Wettability Properties

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Abstract

The concentration of tailings is a vital aspect of mineral processing, as it directly impacts water usage, storage requirements, and environmental risk. It is a key factor in ensuring sustainable beneficiation, responsible mining practices, influencing everything from water recovery and reuse to tailings storage and environmental protection. The tailings concentration process is a critical step in mineral processing, and the addition of flocculants in thickeners can significantly impact the efficiency and mechanism of this process. This study investigates the impact of flocculent addition on the gravity and wettability properties of tailings concentration process. We found that the addition of flocculants in thickeners alters the surface properties of the tailings particles, leading to changes in the gravity and wettability properties.

A comprehensive experimental approach was employed, to test the impact of flocculants in flotation studies. Two sets of experiments were conducted: one using unfloculated tailings and the other using flocculated tailings with a polyacrylamide flocculant.Two sets of experiments were carried out at the same experimental conditions. The tailings constitutes Fe total in the range of 40-42%.
The results show that flocculation significantly improved flotation recovery and grade. The flocculated tailings yielded an average increase of 15.6% in recovery and 12.3% in grade compared to the unfloculated tailings. Additionally, flocculation reduced the amount of fine particles entering the flotation circuit, resulting in improved flotation kinetics and reduced reagent consumption. The study also explores the optimal dosage and type of flocculent required to achieve maximum efficiency. The findings suggest that flocculation can be a valuable tool for enhancing flotation performance and improving overall mineral processing efficiency.

Key words : Flocculent, iron ore tailings, wettability, Flotation kinetics.

MPR_265

Improvement of an Iron ore circuit by HPGR – a case study

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Abstract.

HPGRs (high pressure grinding rolls) have been developed within the last decades for energy efficient processing of a wide variety of ores. Especially existing processing plants for iron ore are working on the question of how the throughput of the existing plant can be increased. The optimization of those plants in regard to throughput finds its limits if no additional grinding equipment is installed which has the ability to reduce the transfer size to the ball mill further. From other applications the HPGR is known to do this job very efficiently at low energy consumption and low wear costs. This contribution will show the industrial results of eight HPGR that were commissioned in 2016 and 2017 in a magnetite processing plant. It will also address start up optimization work and material research to reach the present throughput increase of 12,5 %. As a consequence this technology came into focus of many major iron ore producers and thereby can be seen as a pioneer work for optimization of iron ore circuits.

DM_04

Utilization & beneficiation of low grade - high siliceous iron ore at ore beneficiation plant-2 for pelletisation at JSW Steel Limited

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Abstract

The expansion of steel production at JSW Steel Ltd, Vijayanagar has led to an increased demand for raw materials. Currently, the material received from the operating mines in the Sandur region exhibits a high degree of heterogeneity and complex mineralogical characteristics. As high-grade iron ore reserves deplete, the need to utilize low-grade, high-silica material becomes imperative. This shift is essential to meet the increasing demand for concentrates, as low-grade iron ores are more readily available during the mining process. Hence, these ores must be processed at a higher capacity to cater to the rising concentrate demand. Processing low-grade, highly siliceous iron ores presents challenges in the existing circuits of Ore Beneficiation Plant-2 (OBP-2). An innovative approach involves grinding the ore to 100% passing 150 microns, followed by beneficiation to upgrade the ore. This process includes the revival of High Gradient Magnetic Separation (HGMS), modifications in piping, and adjustments to spirals and cyclones.

Laboratory trials at OBP-2 for low-grade, high-siliceous ore have yielded encouraging results. The beneficiation process circuit involves grinding the low-grade iron ore in a closed loop with sizing cyclones, followed by desliming to remove fines of 8 microns. The desliming cyclone underflow is fed to gravity spirals for iron value recovery in concentrate. The tailings from the gravity spirals concentrate are further treated in the HGMS process to generate pellet concentrate. The concentrate and tailings slurry are fed to concentrate and tailing thickeners for densification and water recovery for reuse in the process. At the plant scale, the process flow circuit was implemented, and trial runs were conducted. Within one month, a feed rate of 5000 TPD was successfully achieved, enriching the product Fe content by 10 to 12 units with a 50 to 55% recovery by weight. This beneficiation approach for low-grade, high-siliceous ore offers an alternative route to meet the raw material requirements for agglomeration units.

Key words: Tons per day, Ore Beneficiation Plant -2, High Gradient Magnetic Separator

MPR_271

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

MPR_115

Advanced Iron ore beneficiation techniques developed at R&D Centre NMDC Ltd

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Abstract:

High grade iron ores are depleting day by day and leaving behind low and lean grade iron ore. Demand for iron ore is also increasing day by day, which necessitated increased volumes of primary ore to be mined. Conventional beneficiation technique requires huge amount of water and also challenges of managing tailings. Hence, scientists and researchers and experts in the domain knowledge explored waterless operation and techniques. Dry beneficiation techniques are very few and confidence on recovery and yield for this technique is limited.

Low grade ores require energy efficient solutions for liberating mineral, energy efficient water less comminution techniques followed by waterless beneficiation techniques which can compete with well-known and easy to operate wet beneficiation techniques of which total industry rely on. In this paper an innovative technique has been described in detail where waterless beneficiation technique being used in lab scale successfully which takes the advantage of density difference between gangue and ore present in the mineral. Process developed in R&D NMDC also suitable for coal washing in dry.

Optimizing water usage in industrial process of beneficiation has become an important part of the improvement. Water availability is a big challenge in beneficiation of ore; hence it is everyone's job to think or use process which does not take water as beneficiation media the consumption of water in the mineral industry can be in the order of 1.5 to 3.5 m^3 of water per metric ton of ore processed. A significant portion of metal mining production is concentrated in areas where water stress is already high.

Due to the decrease in ore grade larger tonnages are needed to be mined and which requires more water to produce the same amount of concentrate. The cost associated with Beneficiation process for water remains an obstacle to the economic viability of such resources. Moreover, increasing environmental and social challenges and risks related to water and tailing management acts as driver to finding solutions for reducing water in mining operations (Particularly Beneficiation). Metallic mineral processing operations are typically carried out in aqueous media where every possibility of risks such as failure of tailing dams, that's why non-aqueous processing (Dry Beneficiation) is now considered to be better option.

Key words: Beneficiation, Iron Ore, coal washing.

MPR_478

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

CEB-062

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.

Key words: Thickener, Pulp Density, Bed Mass, Rake Torque

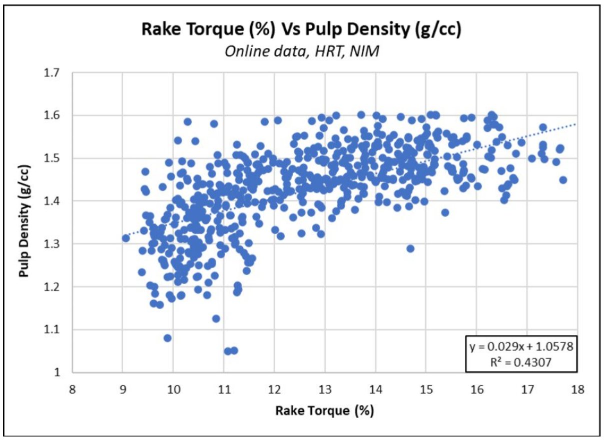

Figure 1: Effect of Rake Torque (%) and Pulp density (g/cc) for HRT

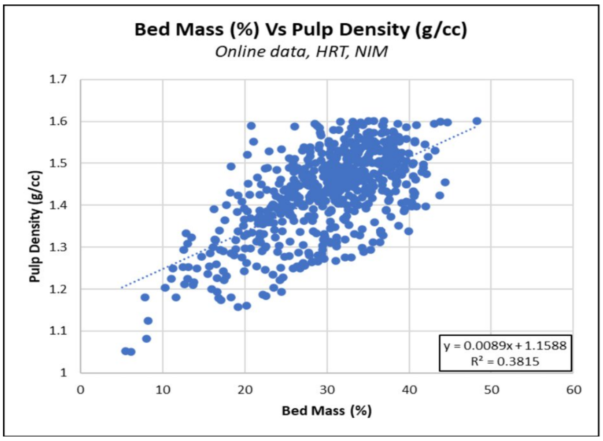

Figure 2: Effect on Bed Mass (%) and Pulp density (g/cc) for HRT

MPR_106

Hydrogen-based reduction roasting for enhancement of low-grade iron ore and preparation of dri-grade pellets

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Abstract

The rising concern about the depletion of high-grade iron ore and its decrement in future feedstock for the steel industry has forced researchers to consider the beneficiation of untouched, abundant low-grade iron ores. However, conventional mineral beneficiation techniques have difficulties enriching the assay value of low-grade ores beyond a particular value because of the complex mineralogical characteristics and liberation at the finer size, etc. The reduction roasting method would be a promising technique for upgrading low-grade ores. Therefore, the hydrogen-based reduction roasting of low iron ores (T. Fe – 58%) has been performed with varying temperatures (400-600 ◦C), time, particle size and reducing gas, etc., followed by its magnetic separation with various magnetic fields, up to 0.07 T. This method gives a higher yield of more than 85% and 92 % of iron has been recovered after the low-intensity magnetic separation. This technique was much better than the conventional techniques as the low-grade iron content increased to more than 65 % at low temperatures. Phase identification and elemental distribution of the concentrate and tailing have been performed through XRD and SEM-EDX techniques to improve the yield and recovery of the process. High-grade concentrate fines, Fe_3O_4, have been obtained from a low-intensity magnetic separator to prepare the DRI-grade pellets. The pelletisation of magnetite concentrates requires 30-40 % less energy than that of hematite ores during induration. Although energy is required for the reduction roasting process, there is a possibility of saving a significant amount of energy during the induration of pellets made from produced magnetite concentrate. The process may help reduce carbon footprint and facilitate efficient use of low-grade iron ore deposits.

Keywords: Low-grade iron ore, reduction roasting, magnetic separation, DRI-grade pellets.

MPR_098

CFD-DEM modelling for the controlled reduction of Hematite iron-ore to Magnetit

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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.

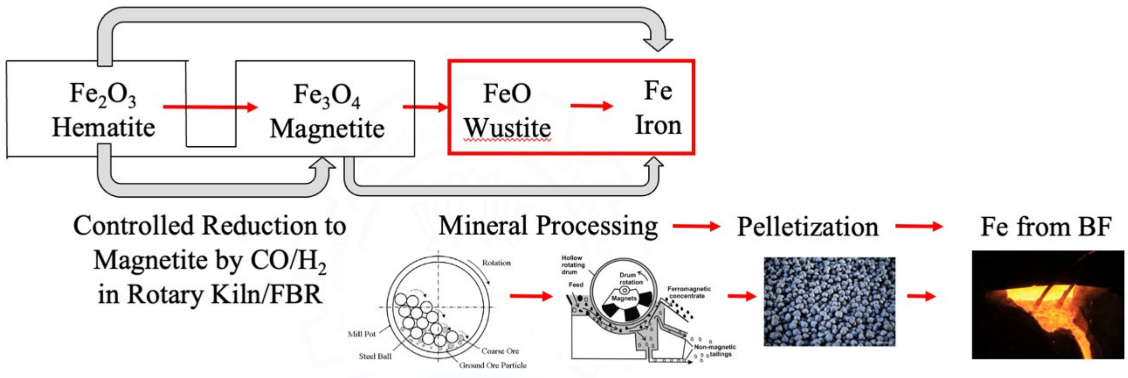

Fig. 1: Graphical representation of the controlled reduction of iron-ore to magnetite.

Keywords: Reduction-roasting; use of low-grade iron ore; fluidized bed reactor; enrichment to magnetite; reduction reaction modeling

MPR_254

Challenges in Producing Iron Ore Pellets from Goethite-Rich Concentrates

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Abstract

The production of iron ore pellets from concentrates containing high amounts of goethite poses significant challenges due to the mineral's distinct properties. A major issue is the high Loss on Ignition (LOI) in the range of 4 to 5%, which affects the thermal decomposition behavior, pellet strength, and energy consumption during firing. High goethite content directly impacts productivity and pellet strength, making it challenging to achieve a cold crushing strength (CCS) of more than 220 kg after firing. Additionally, goethite's inherent structural water content complicates the pelletization process, leading to increased porosity and reduced mechanical integrity of the final pellets. This paper investigates these primary obstacles in the pelletization process, focusing on the influence of high goethite content on reduction kinetics, mechanical properties, and overall pellet quality. Various strategies, including binder optimization, additive selection, and innovative processing techniques, are explored to enhance the efficiency and effectiveness of pellet production from goethite-rich concentrates. Advanced characterization techniques are employed to better understand the behavior of goethite during pelletization and firing. The research aims to provide comprehensive solutions to improve pellet performance in blast furnace operations, contributing to more sustainable and cost-effective iron making processes. Insights from this study are critical for industries aiming to utilize lower-grade iron ores efficiently.

Keywords : Thermal decomposition, Pellet strength, Energy consumption, Reduction kinetics, Goethite, Additive selection, Iron ore pellet quality

Process optimization for utilization of high-Alumina iron ore in pellet making

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Abstract

The demand for pellets in blast furnaces has recently increased because of their uniform shape and size, controlled chemistry, iron-enriched feed, high strength, and quality consistency. To meet this demand, low- and medium-grade iron ore fines with alumina (>3.5 wt%) must be used for pelletization because of the limited availability of high-grade ore. The alumina present in the ore has an adverse effect on the pellet properties because of its refractory nature. Therefore, a study was conducted to optimize the firing temperature and chemistry of the feed blend to produce pellets with good pellet properties. Firing temperature (1280 °C, 1300 °C, and 1320 °C), carbon (1 and 1.2%) in the form of coke fines, and MgO (0.60 and 0.80%) in the form of dolomite were used to optimize the pellet-making process for high-alumina iron ore fines. The best result was obtained for feed blend with 1.2% carbon and 0.80% MgO fired at 1300 °C to produce pellets of cold compressive strength more than 300 kg/pellet, reduction degradation index (−6.33 mm) near 7%, and porosity near 20%.

Key words : Pelletization, CCS, RDI, Alumina, Firing temperature, MgO, Carbon

MPR_331

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 CO2 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

MPR_278

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

MPR_446

Enhancing Fresh Feed Mill Capacity through Process Optimization: A Study on Feed Size Reduction and External Screening.

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Abstract

This study aimed to investigate the potential of process optimization to significantly increase the capacity of a 50 TPH fresh feed ball mill to 100 TPH. The core approach centered on modifying the ball mill's feed size and implementing an external screening process, all without altering the grinding media ratio or requiring substantial modifications to the existing equipment. By reducing the original feed size from -10 mm to -5 mm, the study sought to enhance grinding efficiency and thereby increase the mill's throughput.

To achieve this objective, a mobile screen was employed to pre-screen raw materials before they were fed into the ball mill. This screening process was strategically integrated into the operation, with the ball mill powered by a 625kW main motor. The results of this study were highly encouraging, as the mill's capacity was significantly increased, successfully reaching the targeted 100 TPH. Importantly, this capacity boost was achieved without overloading the motor, evidenced by the fact that the maximum average current draw only increased slightly from 220 kW to 240 kW. This indicates that the process optimization did not compromise the mill's operational stability.

The introduction of the mobile screening unit played a pivotal role in this success. The unit demonstrated impressive separation efficiency, effectively dividing the material into two fractions: approximately 45% of the material was classified into the -5 mm fraction, while the remaining 55% fell into the +5 mm fraction. This pre-screening not only increased the throughput of the fines ball mill but also ensured a more consistent and finer feed size, which is crucial for optimizing the milling process.

The improvements in feed size and the screening process led to a more efficient grinding operation, reduced energy consumption, and overall enhanced productivity. This modification proved to be a cost-effective and practical approach to increasing the fresh feed mill capacity. It offers valuable insights and a potential model for similar processing operations that seek to optimize their performance without significant capital expenditure.

The study underscores the potential of targeted process optimization in unlocking capacity bottlenecks, minimizing energy consumption, and improving overall efficiency in fresh feed milling operations. Such optimizations are particularly relevant in an industrial context where enhancing productivity while managing energy costs is crucial.

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Key findings of this study include:

• A successful increase in fresh feed mill capacity from 50 TPH to 100 TPH.
• Reduction of feed size from -10 mm to -5 mm without altering the grinding media ratio.
• Implementation of external screening using a mobile screen, which enhanced the separation process.
• A minimal increase in power draw, from 220 kW to 240 kW, indicating efficient energy use.
• Significant improvements in grinding efficiency, leading to reduced energy consumption and higher overall productivity.

The implementation of the mobile screening process has proven to be a highly effective strategy, successfully doubling our fine ball mill's fresh feed capacity. It is found that this advancement will significantly enhance our overall production efficiency, and remain committed to further optimizing our operations based on these promising results.

Keywords: Ball mill, Intermediate screening, Coarse grinding, Process optimization, Energy-efficient process.

Process optimization study for the reduction of pre-mixed lean-grade manganese/iron ore using hydrogen gas

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Abstract

The continuous depletion of high-grade manganese ore and the world annual demand for manganese ferroalloys has increased significantly due to soaring of the steel production. However, the conventional process uses carbon as a reducing agent for producing the ferromanganese, which is generating CO and CO_2 a major source of air contamination. In this study, dwindling high-grade ore and try to meet the demand of world ferroalloy have forced to the promotion of extraction from lean-grade ore. Therefore, lean-grade manganese/iron ore, which has used as a substitute of high-grade ores in the present study. Replacing carbon with hydrogen as a reductant offers a pathway to minimize the carbon emission. Application of hydrogen based reduction transformation of manganese oxide is proposed, where more than 90% phase transformation of manganese and iron at an optimum reduction temperature of 500-900˚C, a reduction time of 60 min, and hydrogen flowrate 0.5-1.5 lpm was observed. The maximum manganese existed predominantly in the form of manganosite. The present study explored the reduction thermodynamic and kinetic investigation of manganese and iron oxide, structural changes of the pyrolusite. The kinetics model for the reductive reaction will be identified. However, manganese oxide follows the reduction sequence of $\mathrm{MnO2} \rightarrow Mn2O3 \rightarrow Mn3O4 \rightarrow MnO$, thus the reduction of manganese oxides in each valence state proceeds simultaneously. The process parameter and kinetic study has been optimized for the above temperature. The reduced ore digestion with different parameter were determined by using ICP-OES. The phase transformation of reduced ore was examined by SEM, XRD and EPMA.

Keywords: Ferromanganese, Gas-Solid Reduction, Hydrogen gas, Manganese ore, Pyrolusite

MPR_483

Multi-Response Optimization of Coal Spiral Concentrator using Desirability Approach

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Abstract

Mineral processing problems require optimization of more than one response (Grade and Yield/Recovery) simultaneously. However, most of the literature published is on single response optimization, which focuses on only one response at a time. That is, either maximizing the product yield disregarding the ash content or minimizing the product ash content while compromising the yield. It is not possible to achieve global optimum value using this technique. To address this issue, multiple responses (product ash and yield) were optimized simultaneously using desirability function. In this study, a spiral concentrator was used to beneficiate intermediate size range (3 mm to 0.01 mm) prime coking coal fines. Washability studies were carried out to estimate the theoretical yield of clean coal. Box-Behnken design of experiments coupled with response surface methodology (RSM) was employed to establish the performance behaviour of the spiral concentrator. Variables considered were feed rate (lpm), feed pulp density (% solids by wt.) and splitter position. Experimental results were analysed with the help of a statistical software package (STATISTICA) and mathematical models were then developed. The main effects and interaction effects of the process variables of the spiral concentrator, on product ash content and clean coal yield, are presented and discussed in the Pareto and surface plots respectively. Desirability function was used to calculate the global optimum. An improvement of 5 units in the yield with marginal (0.6%) increase in the ash content is obtained using multiple response optimization compared to single response optimization.

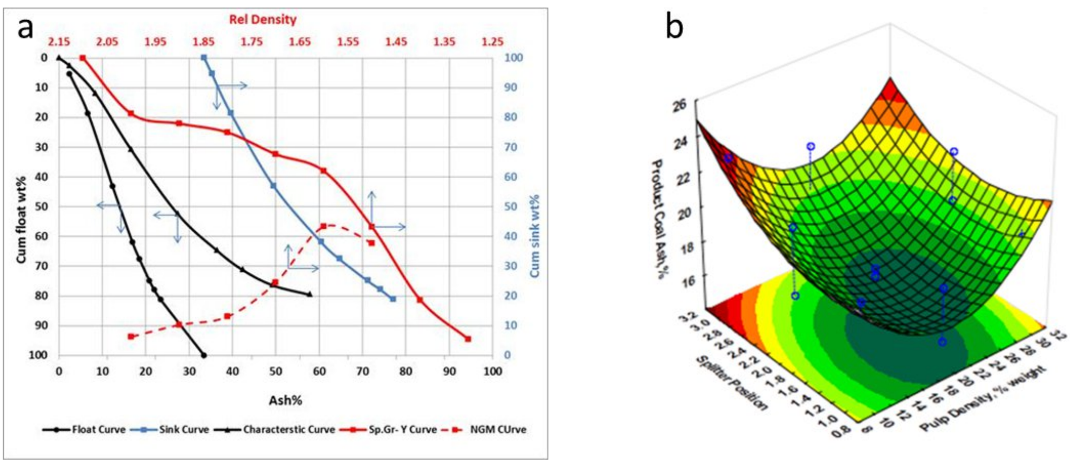

Fig. 1: a) coal washability curves of coal b) Response surface plot of clean coal

Key words: Spiral concentrator, Box-Behnken design, Multiple response optimization; Ep.

MPR_157

Novel Dual Beneficiation Method to Enrich the Carbon Content and End-Value of Coal Washery Tailings

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Abstract

Coal is one of the key elements which is rich in carbon content. Carbon finds its applications in many areas like materials, metallurgy, and power generation. To enhance the potential application of coal in metallurgical grade, it should meet some requirements in its composition. The coal goes through several beneficiation processes and the required quality coal is being used for metallurgical purposes and lot of coal is being rejected as low grade which is used in kilns and fluidized beds. The rejects and coal tailings are rich in carbon content which has generally good calorific value and coking coal presence. To utilize this carbon content, further upgradation of carbon content by adopting some beneficiation techniques is required. In this work, we aim to improve the carbon content in coal tailings by adopting the physicochemical beneficiation techniques requiring less and environmentally sustainable reagents for the process, involving the feasibility of large-scale up-gradation. The two physicochemical techniques adopted for the research work are froth-flotation and oil agglomeration methods. The reagents used are fatty acid-based reagents, diesel, and kerosene. The coal tailings are rich in fixed carbon content of 40.27 wt.% and ash content of 37.19 wt.%. However, the carbon content can be increased up to 50-60 wt.%. The fatty acid reagent in the froth flotation method reduces the ash content to 19.94 wt.% with a concentrate yield of 52.09 wt.%. However, the oil agglomeration method reduces the ash content to 25.63 wt.% with a concentrate yield of 66.00 wt.% with diesel as a reagent. The combination of these two methods of froth flotation followed by oil agglomeration with fatty acid reagent reduced the ash content to 11.07 wt.% with an overall concentrate yield of 75.97 wt.%.

Key words: Beneficiation; Carbon enrichment; Coal tailings; Froth flotation; Oil agglomeration

MPR_220

Lab scale study and Pilot scale process to remove soluble Tar material from Coal Water

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Abstract

At Tata Steel Jamshedpur New By-product plant, the coal water temperature and coal water flow rate vary frequently due to the deposition of tar material inside the heat exchangers and pipelines. Coal water which comes from battery liquor, contains soluble tar material which gets deposited on the surface of heat exchanger & pipelines while cooling, and results in fouling of heat exchanger. The inefficient convection due to continuous fouling affects the performance of heat exchangers and scrubbers. This leads to frequent shut-down for maintenance and disturbs the downstream processes as well. To remove soluble tar from coal water, a novel polymeric chemical coagulant (RT-08) was synthesized in-house. The lab scale experiments demonstrate the capability of the in-house coagulant in separating the tar material. Further, a commercial cationic polymer flocculant was employed which settled down the separated suspended tar. The post treatment results indicate the successful reduction in tar along with significant decrease in cyanide and TSS percentage in the treated coal water. The dosing of coagulant and the flocculant were optimized at lab scale with respect to the tar recovered. The encouraging result has inspired to perform a pilot study (at New By-product plant, Tata Steel Jamshedpur) to treat coal water in an integrated process using in-house developed polymeric coagulant and commercial cationic polymer flocculant. The pilot scale study showed tar recovery of nearly ~ 0.7kg/m^3, ~ 70% cyanide reduction, and a drop in TSS from ~ 60 ppm to <10 ppm without affecting the TDS and pH of water.

Fig. 1: Tar deposition in heat exchangers tubes.

Key words : Coal Tar, Deposition , Heat Exchanger, Excess Liquor

MPR_259

Automatic control of oil water emulsion system for improving coal flowability at Coal handling Plant, DSP

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Abstract

The flowability of coal in the coal handling plant of DSP becomes a concern during the monsoon season, as it causes jamming in silos, chutes, screens, and transfer points. This leads to operational problems and production drops. To overcome this issue, the addition of a proper oil-water emulsion to the coal charge during the rainy season is desirable. Adding oil to moist coal also improves the bulk density of the coal charge. Currently, there is a manual facility for the oil-water emulsion addition system, which requires instrumentation and automation for controlled and optimal utilization of oil in the emulsion, reducing manual intervention. The primary aim of the new oil-water emulsion system is to improve the bulk density and flowability of the coal charge, leading to better coal charge into ovens and improved coke quality.

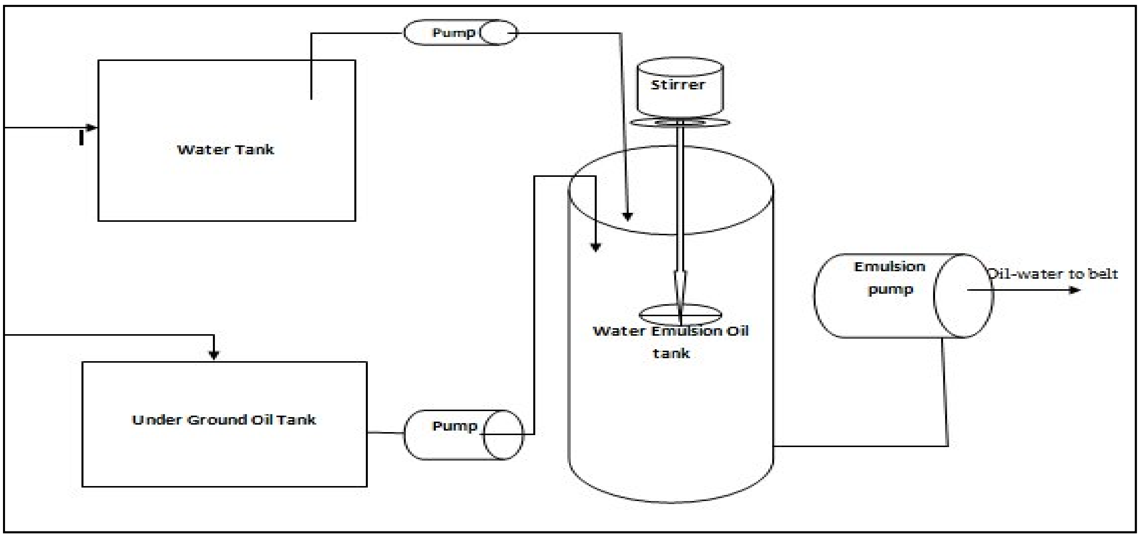

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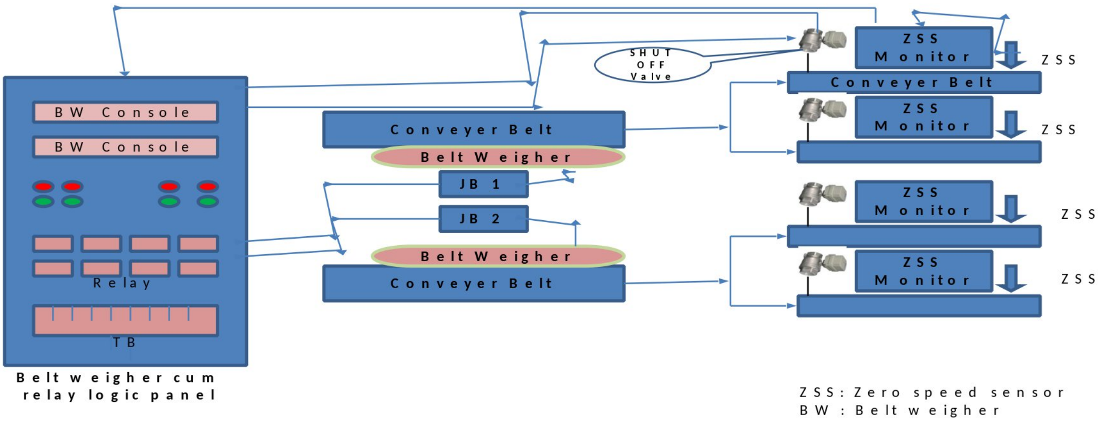
Fig 1: Layout of Oil emulsion system



Keywords: Belt weigher, Shut off Valve, Manual Flow meter, ZSS, Relay logic panel

Fig 2: Schematic diagram

Advanced Flotation Methods for Carbonaceous Particles in Blast Furnace Dust: A Study on Collector Dosage and Classification Effects

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Abstract

The increase in steel production has led to a substantial rise in the generation of solid wastes, which must be reprocessed and utilized in a sustainable manner. These wastes are complex metallurgical residues, which are prone to contaminate water, soil and atmosphere if not properly disposed of. The blast furnace off-gas dust is a major contributor in this regard. The BF dust exhibits a fine particle size distribution, contains various constituents such as hematite, calcite, dolomite, sylvite, quartz, and zinc as well as considerable amounts of carbonaceous particles in both amorphous and graphitized forms. Direct recycling of BF dust is challenging due to the presence of alkali metals (primarily potassium) and zinc, which eventually increases the alkali and zinc load in the system. Additionally, the inconsistent carbon content in the dust affects the agglomeration process by making it difficult to maintain a consistent fuel rate. Consequently, it is crucial to separate alkali metals, zinc and carbonaceous particles prior to recirculating it in the mainstream process. In view of this, a process flowsheet has been developed to separate these constituents, which would make the recirculation of BF dust more effective. However, the present work is focussed only on the flotation separation of carbonaceous particles from BF dust by offering an optimized flotation process through a comprehensive approach including detailed characterization and subsequent experimental work.

In the present study, the efficacy of froth flotation was examined using diesel oil as the collector and methyl isobutyl carbinol (MIBC) as the frother, applied to both direct feed and hydrocyclone-classified feed to improve carbon recovery. Direct flotation with a collector dosage of 1000 g/t proved ineffective due to interference from ultrafine particles, necessitating a higher collector dosage. However, the hydrocyclone-classified fraction achieved an impressive 84.4% carbon recovery and 66% Fixed Carbon (FC) grade with a reduced collector dosage of 500 g/t. Kinetic studies indicated that the flotation process follows a first-order rate equation, with the classified feed demonstrating a higher rate constant (0.0384 s^{-1}) compared to the direct feed (0.0225 s^{-1}). Petrographic analysis of the flotation product showed an increase in vitrinite content from 18% to 40%, while calorimetric analysis revealed a significant rise in calorific value from 2287.9 Cal/g to 5340.8 Cal/g. Based on these findings, a classification-flotation processing flowsheet proposed, which aims to recover 67.5% of carbon values at a FC grade of 66%.

Key words: BF dust, flotation, hydrocyclone, flotation kinetics, rate constant

MPR_344

Statistical Optimization of Lab Scale Flotation Cell Parameters for Coal Beneficiation

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Abstract

Flotation cells are used to treats around 20% of the feed material coming to Tata Steel washeries. The feed size for the flotation circuits are usually 0.5mm and lower. The optimization of flotation cell operations is critical in mineral processing to enhance yield and reduce ash content, thereby improving overall efficiency and profitability. This study focuses on a statistical approach to optimize the flotation cell parameters to maximize yield and minimize ash content in coal flotation processes.

Flotation, a complex physio-chemical process, involves the separation of hydrophobic materials from hydrophilic ones through the use of air bubbles. Although, the technique have been around for more than a century, the control of the cells are still something that is not fully developed. Even though many OEM's have developed different methodology to control the flotation cells, there is still a gap between the lab scale and actual flotation performance. The current investigation aims to identify key operational factors and their interactions that significantly influence flotation performance by employing advanced statistical techniques, including Design of Experiments (DOE) and Response Surface Methodology (RSM).

In case of Coal flotation usually, the clean coal is recovered from the top and ash particles are recovered form tailings. The efficiency of this process is influenced by various parameters such as air flow rate, pulp density, reagent dosage and impeller speed. Traditionally, these parameters are optimized through trial-and-error methods, which are time-consuming and often suboptimal. The approach of One Variable at a Time (OVAT) can result in local maxima as interaction between the variables are not fully captured. In contrast, a statistical approach allows for a more systematic and efficient optimization process, providing a deeper understanding of the underlying interactions between variables. Considering the number of variables and also the variations to be studied, a central composite design framework under the fractional factorial design was utilized to develop predictive models for yield and ash content. The number of experiments in the test is 24. With the optimized model, both the linear and quadratic effects, as well as the interactions between variables could be explored. Regression equations developed with the model could be used for describing the relationship between the independent variables and the responses (yield and ash content). The statistical significance of the model and also the individual variables and their interactions will also be analyzed during the model development. Validation tests need to be done for the model to ensure robustness

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and viability to be used in actual operations. The developed models provide a powerful tool for predicting flotation performance under various operating conditions. This can intern result in optimizing the key parameters and significantly enhancing the flotation process, leading to improved resource utilization and cost savings.

Key words: Coal, Flotation, RSM, DOE, Optimization

Enhancing Flaky Graphite Recovery from Low-Grade Ore through Ultrasonic-Assisted Flotation

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Abstract

This study investigates the feasibility of using low-frequency ultrasound to enhance the flotation of flaky graphite from low-grade ore. The research provides a fundamental understanding of the ultrasonic-assisted graphite flotation process and compares it with conventional flotation methods. Flotation experiments were conducted in three stages: rougher, cleaner, and re-cleaner, under both conventional and ultrasonic-assisted conditions. The results showed that ultrasonic-assisted flotation significantly outperformed conventional flotation, leading to higher yields, increased fixed carbon content, and improved recovery rates in the flotation concentrate products. The study also delves into the ultrasonic mechanisms responsible for breaking graphite-impurity locked particles and reducing particle size. Both the raw graphite (RG) and the final flotation concentrate products from conventional and ultrasonic-assisted processes were characterized using techniques such as stereomicroscopy, X-ray diffraction and field emission scanning electron microscopy.

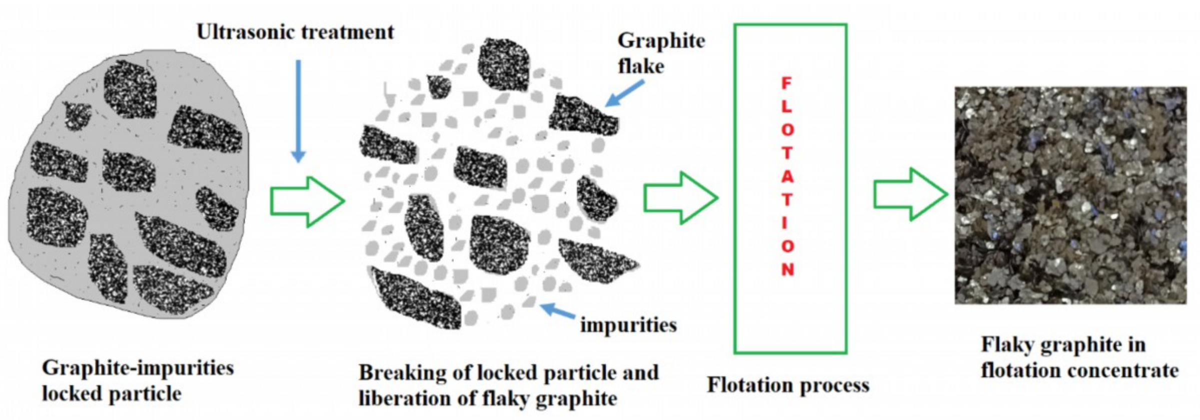

Fig. 1: Schematic representation of cavitation effect on graphite flotation

Keywords: Flaky graphite; ultrasound; flotation; cavitation

MPR_388

Dry Beneficiation of Indian coal for ash reduction using a pneumatic separator

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Abstract

The geological occurrence notably shifts the characteristics of the coal from easy to difficult. Indian coal often has higher ash content, is difficult to wash due to its drift origin and offers significant challenges to the end-users. The majority of industrial technologies utilized today for beneficiation of coal are based on wet processes. During wet processing moisture is introduced in the range of 6% to 15%, depending upon the size of coal which is as detrimental as ash content to the heating value of coal. Present work showcases the dry beneficiation mechanism of Indian origin coal using a pneumatically controlled deck separator in which the coal particles get separated from the heavier mineral particles as a result of horizontal and vertical stratification. The responses of dry processing of coal samples (near gravity material = 26-29%) studied under varied process variables were found to be dependent on the washability characteristics and the operating parameters used for achieving the desired product. The probable error (Ep) values are found to be higher during experimental trials attributing to higher cut density. Study shows the enormous potential of utilizing a pneumatic deck separator for dry processing of Indian coal to achieve a clean coal with around 12-14% absolute ash reduction as compared to feed in one pass. Heating value of clean coal improved significantly during dry processing.

Keywords: dry beneficiation, stratification, washability, probable error, clean coal, heat value

MPR_466

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.

MPR_40

NON FERROUS METALS

Oral Abstracts

Development of a novel low-cost Al alloy from primary route with better functionality than ADC12

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Abstract

In the automotive industries, ADC12 or A380 is widely used. Si is one of the most important alloying elements in ADC12 and generally kept in the range of 7-12 wt.% to facilitate strengthening, castability and dimensional stability of the part. In the present study a low-cost Al alloy was developed from primary route with better functional properties compared with regular ADC12. This study investigates the role of macro- and micro-alloying additions on the performance of cast Al alloy. This development comprised of three major phases: (i) macro alloying (ii) fine tuning of the composition and (iii) final casting of the proposed alloy. The microstructural and mechanical properties were evaluated after each phase before proceeding to the subsequent phase. Unlike the ADC12, the addition of Sr in trace amount modified the eutectic Si in the newly developed alloy. As a result, significantly better hardness of 98 HV, tensile strength of 257 MPa, and ductility 10% were achieved in this as-cast alloy. As the amount of major alloying elements in the new alloy is significantly less than the ADC12 which leads to superior corrosion resistance and at the same time makes it significantly cheaper in cost.

Keywords: Micro-alloying, casting, microstructure modification, tensile strength, corrosion

NFM_073

Development and Characterization of Stir Cast A356 Aluminium Alloy Matrix Composites Reinforced with Multi-Walled Carbon Nanotubes (MWCNTs)

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Abstract

This study investigates the microstructure and mechanical properties of T6 heat treated Ex-situ A356-MWCNT composite, cast at 650°C with and without mechanical stirring. Computational fluid dynamics (CFD) modelling is employed to optimize the melt pouring temperature of 650°C, while the optimum stirring speed and time is found to be 600 rpm and 30 minutes, respectively based on experimentation. The CFD model findings indicate that reducing the melt pouring temperature decreases micro-porosity, free surface defect concentration, and entrained air volume fraction of the solidified composite. Whereas microstructural examination using optical microscopy (OM), X-ray Diffractometer (XRD), and FESEM reveals the impact of mechanical stirring on dendrite to rosette transformation of primary aluminium (α-Al) grains. Results indicate that the combined influence of mechanical stirring as well as MWCNT addition leads to the transformation of composite microstructure in terms of dendrite size reduction from 132 µm to 73 µm and a reduction in secondary dendritic arm spacing from 11.1 µm to 4.7 µm. The addition of MWCNTs within the melt facilitates higher nucleation of primary α-Al dendrites as well as increases their volume fraction from 55% to 71%. The success has been achieved in terms of noticeable improvement in mechanical properties of the composite due to MWCNT addition, which is evident from the enhancement in Yield strength (YS), Ultimate tensile strength (UTS), and percentage elongation to fracture values of the as cast A356 alloy without stirring i.e., 88±5 MPa, 126±2 MPa, and 0.91±0.15, respectively to 117±8 MPa, 173±4 MPa, and 1.25±0.06, in case of. After T6 heat treatment, these values are further enhanced to 228±7 Mpa (YS), 247±6 Mpa (UTS), and 2.5±0.07 (percentage elongation).

The study demonstrates the potential of MWCNTs as reinforcement and mechanical stirring as a potential liquid metallurgy route to develop the A356-MWCNT composite for structural applications where higher strength to weight ratio is in demand. The optimized process parameters and the use of T6 heat treatment contributes to the significant enhancement of material properties, making A356-MWCNTs composites suitable for aerospace, automotive, and defense applications among others.

Key words: MWCNTs, Ex-situ composite, Stir casting, Microstructure, Tensile properties.

MSD_079

"Aluminium Hot forming: - Opportunities and Challenges in Automotive light weighting

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Abstract

In today's Automotive world, there is NO need to advocate "Light weighting". Government policies for carbon footprint reduction combined with high safety standards are driving OEMs to adopt advanced manufacturing technologies.
Steel hot forming is selected as most preferred way to reduce weight as it is easy to adopt and commercially known. It had many advantages compare to conventional cold stamping of standard and high tensile steel. The process consists of heating blank to nearly 1000 ◦C and quenching it in tool to for martensitic structure. Higher strength up to 2000 MPa can be achieved by this process. There are many examples where part weight is reduced by 15 to 20 % by this method.
But Steel hot forming has limitation as specific density of steel is still high. Thus, there is limitation to its weight reduction capability. For further reduction, OEMs have started exploring Aluminium hot forming. This process, like steel hot forming improves hardness of the part by series of heating and cooling cycles.
Aluminium has been used in car for a while but mainly into cold forming and specifically to A and B class panels. Some efforts are made to produce Aluminium die cast parts for chassis. The main advantage was to have jointless parts, but the big disadvantage was "wall thickness" limitation of die casting process. Also, commercial viability is also a big question for large die casting parts.
Now hot form aluminium is used for Body-in-White which are strength driven applications. Aluminium hot forming is slowly making its way in mass production with many developments in process optimization. But in India, it has many challenges. "Raw material availability", "New Technology", "Tooling Know how" are some of the challenges in adopting this technology in larger scale.
A case study will explain the advantages of Aluminium Hot forming, specifically the HFQ® process.

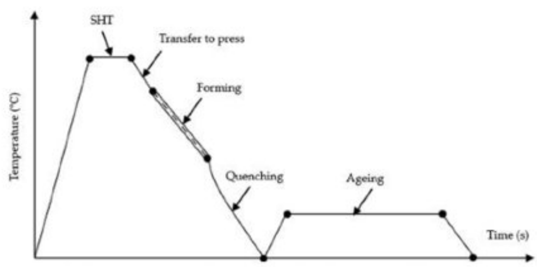

Fig. 1: Temperature vs time plot for the HFQ process steps

Development of AlSi3 Sow ingot for Steel Industries

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Abstract

Corrosion in metals is one of the biggest losses to Industry and Nations. To prevent the same, Galvanization is one of the scientific methods to increase life of Steel products. Thus, Galvanized steel sheets requirement is continuously increasing in the market. For manufacturing the same, Aluminium 53-57%, Silicon – 1.4-1.8% and Zinc – 40-46% molten melt is required with which Steel sheets are coated to prevent corrosion. This coating mix is produced by metallic mix of AlSi3 and Zinc in 1.4:1 ratio. All AlSi3 grade Aluminium was being imported due to stringent Chemistry and lower Fe%. Around 3 years ago, production of AlSi3 started from one of the primary producers of Aluminium in India. To bring more stability in Supplies there was a need for more suppliers in Country as Import was still significant.

Hindalco, (being pioneer in supplying one of the purest Aluminium in the World) took the responsibility to develop this product to curb imports and bolster Government's vision of "Make In India". Team conducted detailed study about technical requirements of the product and domestic market size. It revealed that additional facilities would be required to bridge demand-supply gap and preferred product was T ingot with weight range of around 1380-1420 kg. Hindalco decided to venture into this product development, but technology supplier stated that commissioning of new T ingot manufacturing equipment will take 1.5 to 2 years. Considering the urgent need in Industry, Aditya Aluminium plant team took the challenge to design product having same chemistry with existing product lines and to take trials with customers as per their need. Team brainstormed internally by understanding the end application and came up with an idea of producing AlSi3 Sow ingot with weight range of 450 – 470 kg. Major challenge was the alloying element addition as there is no holding furnace for mixing the alloys. Alloying addition and homogenization Process was then internally developed by Aditya Aluminium Cast House Team and trails were taken. Many challenges like maintaining right chemistry, weight and surface finish were overcome and then successful launch of the product was done. Customer was requested to charge 3 sow ingots instead of single T ingot during their process to maintain the right ratio with existing supplies of Zinc. Customer suggested some more modifications which can replace T ingot requirement and the same were further incorporated in future supplies. Customer appreciated the innovation and zeal of Hindalco team to develop a new product in 3 months' time. Currently, Aditya Aluminium is consistently supplying 8 KTPA to both Domestic and International customers.

Keywords: AlSi3, Sow Ingot, Galvanized steel, Aditya Aluminium

NFM_036

Effect of Borides of AlB master alloy in the reduction of tramp elements to make conductor grade aluminum alloy

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Abstract

Aluminium is being used as an economical alternative to copper for power transmission. But, the presence of impurities in the form of transition metals such as Ti, V, Zr and Cr specially worsen the electrical conductivity of smelter grade aluminium alloy. These transition metallic impurities such as titanium, zirconium, vanadium and chromium are removed from molten aluminium with the addition of Al-B master alloys, called boron treatment. Al-B master alloys contain borides in the form of AlB12 and AlB2 phases that helps in the reduction of tramp elements by Boron treatment. These borides react with the transition elements, become heavy and settle at the bottom of the furnace during holding of molten aluminium alloy. After holding the furnace for certain time the pure Al metal is decanted from the top. This AlB treated Al alloy is further used or making conductor grade cables.
The conductivity of EC grade or Alloy grade Aluminum is measured in % IACS (International Annealed Copper Standard) which reaches up to 63% after addition of 0.2% AlB master alloy per tone of the melt within 30-40 min of holding time.

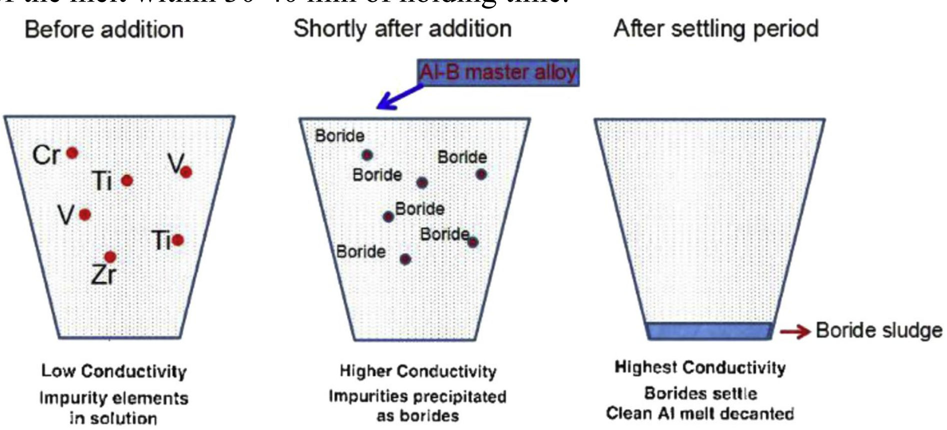

Figure 1: Schematic representation of the reduction of tramps after addition of AlB Master Alloy

Keywords :AlB, Conductor cables, transition elements, AlB12, IACS

NFM_012

Designing new aluminium alloys for high temperature applications

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Abstract

Aluminium alloys that can sustain temperatures in excess of 400 ^{O}C may replace few titanium alloys that are used at such service temperatures. Towards this pursuit a good amount of effort has been put forth by research and academic fraternity. Present aluminium alloys offer many positive attributes like low density, high specific stiffness, good castability, ease of machining, recyclability and great formability. However, their applications at high temperatures (> 400 ^{O}C) is still very limited. Most commonly used aluminium alloys for high-temperature automotive applications use 2000, 5000, and 7000 group of alloys which loses its strength at high temperatures owing to multiple factors. Recent research has demonstrated that adding rare earth elements can improve mechanical characteristics at both ambient and high temperatures. Al-Ce based alloys have shown great promise for such applications. Several other approaches to develop high temperature aluminium will be discussed in the presentation.

Key words: aluminium alloys, casting, high temperature, rare earth elements

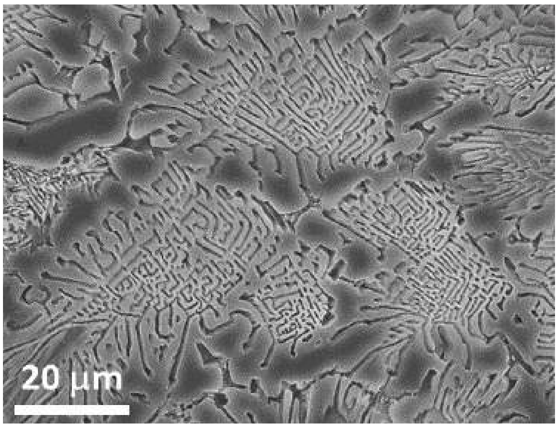

Fig. 1: Microstructure of near eutectic Al-Ce alloy

NFM_063

Development of heat treatment cycle for defect free crimping of C63200 aluminium bronze

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Abstract

Aluminium bronze C62300 is a copper base alloy consisting of 2-4% Fe and 8.5 to 10% of Al and has an α+ β structure. This alloy is used for critical applications like control component which control the liquid rocket engines and stages. C62300 has high wear and corrosion resistance, and moderate strength. It is a medium-duty wrought-strengthened product suited for environments involving wear and fatigue, especially where high ductility is required for cold working or "swaging". Microstructure of this alloy is very sensitive for manufacturing process like forging, extrusion, and heat treatment. Selection of the process parameters is critical to achieve uniform microstructure.

During crimping of C62300 valve, cracks were observed near crimped portion. Detailed metallurgical analysis was performed on the failed part. Hardness was measured on raw material, crimped and uncrimped parts. Hardness of the uncrimped machined parts showed 20HV higher hardness than that of the raw material. Various combinations of heat treatments were performed on machined part to soften the material for ease of crimping. Annealing at 650°C-1hr followed by air cooling showed 20HV reduction in hardness and this cycle was chosen for softening. Crimping on annealed valve yielded defect free component. Tensile tests on annealed samples were performed to assess the margin of safety available for usage. Microstructure of annealed parts was captured using optical microscope and scanning electron microscope. Stereo and scanning electron microscopic (SEM) images of cracked valve is shown in Figure 1a & 1b. Optical microstructure of annealed samples revealed uniform distribution of α, β, k (intermetallics) phases. This work describes efforts made to understand the reason for failure and establish suitable softening treatment for defect free crimping of C63200 aluminium bronze alloy.

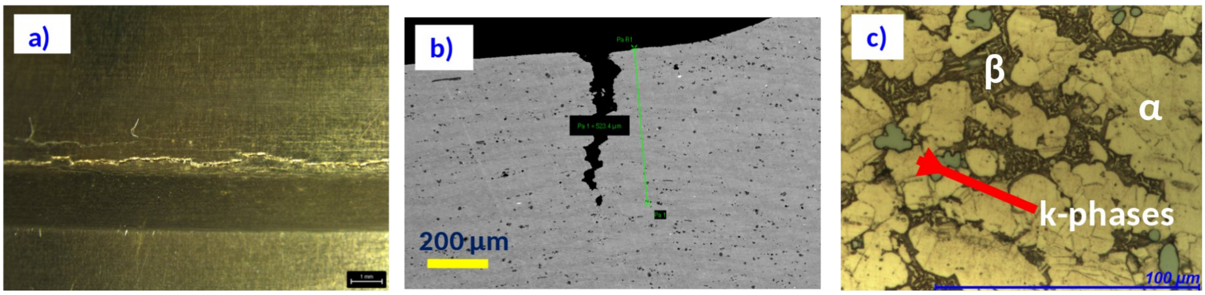

Fig. 1: a) Stereomicroscopic images of cracked valve b) SEM micrograph showing cross section of the crack and c) optical micrograph of annealed C62300 showing presence of k (kappa), α, β phases

Key words: C63200, annealing, crimping, and k phase

NFM_067

Development & Stabilization of AA5052 Aluminium alloy Closure Stock for Industrial Use

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Abstract

Development of AA5052 closure stock has been driven by the need in packaging applications especially for cosmetic containers which are majorly imported. This study focuses on the optimization of Critical Input Variables like evaluation of alloy composition, processing techniques like investigation of samples at different gauges during multi-pass hot rolling with particular interest in microstructure to establish the optimum Hot rolling gauge. Similarly, lab trial was done at different temperatures to optimize the Inter annealed temperature. Key processes included reduction in cold rolling to achieve desired thickness, mechanical properties and earing percentage value to meet agreed Quality Assurance Plan. The developed AA5052 closure stock exhibits superior durability, making it highly effective for diverse packaging needs. These advancements offer substantial benefits in packaging efficiency and product protection, contributing to the overall quality and reliability of closure products.

Currently, Hindalco is engaged with Indian manufacturers for commercial production of AA5052 Closure Stock to indigenize this product.

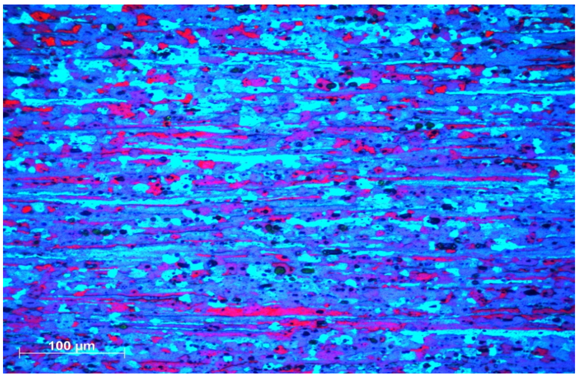

Fig. 1: Grain Size at 200X magnification

Fig. 2: Cosmetic containers

Keywords: AA5052, Earing, Packaging

MPR_382

Insights into Magnesium Alloys Significance

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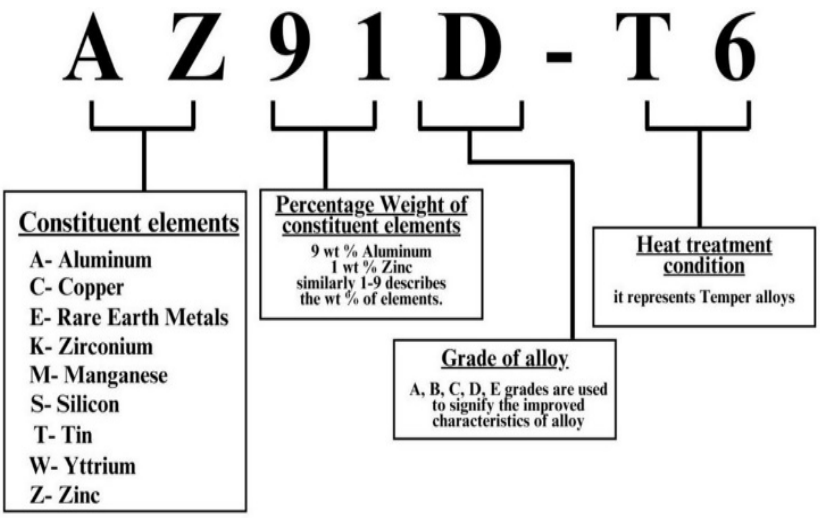
Abstract

Metal alloys are essential materials used in various commercial applications, including automobiles, aeronautics, electronics, and medical devices. Their versatility and durability make them invaluable in industries that require high performance and reliability. In applications such as aero engineering and automobiles, components are designed to operate on critical principles of withstanding high loads while remaining lightweight. Magnesium alloys are known for their lightweight properties, making them commercially popular for such applications. Mg alloys are categorized into different series, each incorporating different metals. This review article focused on and discussed the thermal and electrical behavior of Mg alloys. Moreover, significant fabrication processes to produce these alloys are also stated and concluded with influencing parameters that provide insights into improving Mg alloys.



Keywords: Magnesium, alloys, ceramic reinforcement, properties

NFM_075

The future scope of magnesium-rare earth based alloys for light structural sectors

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Abstract

Magnesium, the lightest and most abundantly available structural material, has been studied for its potential when alloyed with new materials. The addition of different metals affects properties such as dimensional stability, stiffness, specific strength and damping capacity. Rare Earth (RE) elements have been considered alloying elements to enhance light metal alloys' strength, conductivity and corrosion resistance. However, the high cost and complexity of using pure RE metals in the melting process present a significant barrier to commercializing these processes. Statistical reports indicate that 90% of structural components are manufactured using gravity die casting. The use of RE master alloys is a promising solution for fabricating light metals in the coming decades. Current research is primarily focused on utilizing rare earth (RE) metal alloy processing to improve the properties of these alloys.

A master alloy is a pre-alloyed concentrate or mixture of alloying elements. It is added to a melt to adjust composition, control structure and change solidification behaviour. Using a master alloy instead of a pure metal can be more economical and technical. Master alloys dissolve more quickly at lower temperatures, saving valuable energy and production time. Depending on its application, a master alloy can also be referred to as a "hardener", "grain refiner" or "modifier".

The majority of rare earth elements are attractive alloy components for magnesium-based alloys. In particular, cerium, yttrium, neodymium and gadolinium have been chosen for this study. The addition of these elements can enhance the high-temperature strength, ductility, machinability, adaptability, electrical conductivity, castability, surface appearance and creep resistance of the alloys. Moreover, these elements are utilized to modify and refine the grains of the alloy.

The current study focuses on processing rare-earth-based master alloys, assessing the feasibility of developing alloys using master alloys, understanding the different forms of binary precipitates, and establishing the correlation between the structure and properties of various rare earth elements (cerium, yttrium, neodymium, and gadolinium) in the development of magnesium-based alloys for future structural applications.

Keywords : Magnesium, Mg-RE alloys, Master alloys, Rare Earth; Alloy Development

NFM_054

Magnetron sputtered Ti-Zr-Mo alloy thin film Coatings for Surface modification of Ti-6Al-4V

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Abstract

Ti-6Al-4V alloy is the most renowned biomedical implant owing to its excellent combination of mechanical properties and physiochemical stability. However, the long-term success of this biomedical implant material is hindered by low wear resistance and excessive leakage of toxic Al and V ions in the human body over a prolonged period. This study explores the application of a Ti-Zr-Mo alloy coating on Ti-6Al-4V, aiming to mitigate these issues by enhancing the wear resistance and biocompatibility of the alloy. The Ti-6Al-4V alloy was coated with biomedical Ti-Zr-Mo alloy film using DC/RF magnetron sputtering in multilayer mode. Post-deposition, the as-deposited (AD) films underwent annealing treatment at 350°C for 2 hours followed by 700°C for 15 minutes to facilitate interlayer diffusion and alloy formation. Phase analysis by grazing incidence X-ray diffraction (GI-XRD) confirms the alloy formation after annealing with the evolution of α′, α″ and β phases, while the AD film shows pure Ti peaks. The annealing treatment promotes the formation of TiZr solid solution phases, indicating successful alloy formation. The AFM results reveal that surface roughness decreases with an increase in annealing temperature, attributing to higher ad-atom mobility at high temperatures. The nanoscratch test results demonstrate a lower friction coefficient (0.25) in both AD and annealed films compared to the substrate (0.35). Furthermore, the annealed film samples exhibit enhanced wear resistance compared to AD film and substrate. The electrochemical studies performed in simulated body fluid (SBF) indicates that the annealed film presents superior corrosion resistance compared to uncoated and AD film coated on Ti6Al4V samples. Biocompatibility assessed using an MTT assay with L929 cells, where the annealed film exhibited higher cell density indicating enhanced biocompatibility over time. The SEM analysis of the MTT assay samples corroborated these findings. Additionally, osseointegration studies, conducted by immersing the samples in SBF solution for 2, 7, and 14 days revealed that hydroxyapatite (HAp) formation was most prominent on the annealed thin film, followed by the substrate, and least on the AD film. The spherical apatitic morphology of the HAp particles, confirmed through SEM, suggests favourable conditions for bone integration.

The above results comprehensively indicate that Ti-Zr-Mo alloy thin film coatings significantly improve the wear resistance, corrosion resistance, and biocompatibility of Ti-6Al-4V implants. The enhanced properties of the annealed Ti-Zr-Mo alloy thin film coatings could play a crucial role in extending the longevity and clinical performance of orthopaedic implants.

Key words : Implant Material, Magnetron Sputtering, Corrosion Resistance, Wear Resistance, Biocompatibility.

BSF_044

Optimizing Electrical and Mechanical Properties of A356 Alloy with High Fe and Cr, Mo & V Addition

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Abstract

Aluminium alloys that offer both good electrical conductivity and high strength are highly desirable for producing various cast components in power transmission applications. However, these two properties are often contradictory, making it challenging to achieve an optimal balance. This study focuses on developing an A356-based alloy with 1 wt% iron (Fe) and additional alloying elements, including chromium (Cr), molybdenum (Mo), and vanadium (V). The addition of iron is intended to enhance the recyclability of the alloy, while Cr, Mo, and V are introduced to suppress the formation of β-phase intermetallic particles, which are known to degrade mechanical properties, and to promote the formation of α-phase intermetallic particles, which have a positive impact on strength and ductility. Fe-bearing phases, β-phase is usually present in a plate-like or needle-like morphology and α-phase is present in the polygonal or blocky shape and their effect on mechanical properties is linked to their morphology.

Given that the alloy is intended for casting applications, its fluidity was characterized to ensure that the improved mechanical and electrical properties do not come at the cost of casting performance. The new alloy demonstrated significant improvements over the standard A356 alloy, including enhanced tensile strength, hardness, and wear resistance, while maintaining ductility and ensuring good electrical conductivity. This improvement is primarily achieved by alloy additions that influence invariant reactions responsible for the formation of β-phase intermetallic particles and stabilize the desired α-phase, based on the criteria for substitutional solid solution. Microstructural characterization further revealed that Mo, Cr, and V preferentially substitute Fe within intermetallic particles, effectively stabilizing the α-phase. These elements were added incrementally to determine the optimal composition that balances mechanical and electrical properties. The results indicate that a carefully optimized combination of Cr, Mo, and V additions to an Fe-rich A356 alloy can achieve the enhanced balance of properties, offering a promising approach for high-performance, recyclable aluminium alloys in power transmission applications.

Keywords: electrical conductivity, strength, intermetallic particles, morphology, cast aluminium alloy

NFM_059

"A Comparative Analysis of Copper Smelting Technologies:Flash Smelting vs. Bath Smelting"

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Abstract

This paper presents a comprehensive comparison of two prominent copper smelting technologies: flash smelting (Outotec: Metso) and bath smelting (Mitsubishi). The analysis encompasses several critical factors, including process efficiency, environmental impact, operational costs, trouble shooting and technological advancements.

Flash Smelting Furnace (FSF), introduced in the mid-20th century, utilizes fine, powdered concentrates, which are injected into a preheated - high-temperature reaction shaft (a part of FSF) with oxygen-enriched air. The process is highly efficient due to the rapid oxidation reactions that occur in the gas phase, leading to higher metal recovery rates and reduced fuel consumption. Flash smelting is lauded for its lower energy requirements compared to traditional smelting methods, resulting in decreased greenhouse gas emissions. Furthermore, it exhibits superior capability in capturing sulfur dioxide (SO_2), a major pollutant in copper smelting, thus reducing the environmental footprint. However, flash smelting requires concentrates with specific particle size and chemical composition, necessitating stringent control over raw material quality.

Bath smelting (Mitsubishi Smelting Technology), on the other hand, involves the melting of copper concentrates in a liquid slag bath within a furnace. This method is distinguished by its robustness and flexibility, as it can process a wider variety of feed materials, including lower-grade ores and recycled materials. The inherent flexibility of bath smelting allows for more effective handling of impurities, which can be advantageous in processing complex concentrates. However, the energy consumption in bath smelting tends to be higher than in flash smelting due to the continuous need to maintain the molten bath at high temperatures. Additionally, controlling emissions, particularly SO_2, can be more challenging in bath smelting, although modern technologies have incorporated advanced gas handling systems to mitigate this issue.

The operational costs for both technologies vary based on specific plant configurations and raw material characteristics. Flash smelting typically incurs lower operational costs due to its higher energy efficiency and reduced fuel consumption. In contrast, bath smelting's cost-effectiveness is bolstered by its ability to process diverse and lower-cost feed materials, offsetting some of the higher energy expenditures.

Technological advancements in both methods have continually aimed to improve efficiency, reduce emissions, and enhance metal recovery. Innovations in automation and process control

have further optimized operational performance, ensuring consistent product quality and environmental compliance.

In conclusion, the choice between flash smelting and bath smelting depends on several factors, including the nature of the feed material, environmental regulations, and economic considerations. Flash smelting stands out for its energy efficiency and lower emissions, making it a preferred choice for high-quality concentrates in regions with stringent environmental standards. Conversely, bath smelting offers greater flexibility and resilience in processing varied and complex concentrates, making it suitable for operations focused on maximizing resource utilization and cost-effective production. Future developments in both technologies are expected to further enhance their respective strengths, contributing to more sustainable and efficient copper production.

Key words: Copper smelting, Flash smelting, Bath smelting, Process efficiency, Emissions, Energy

Development of High-Magnesium AA5182 Aluminium Alloy for Lightweight EV Battery Enclosures

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Abstract

The demand for electric vehicles (EVs) is rapidly increasing in India, prompting automobile manufacturers to seek lightweight EV batteries for their vehicles. However, suppliers for such specialized components are currently only available in the global market. In response, the Hirakud FRP(a unit of Hindalco Industries Limited), in partnership with the Hindalco Innovation Centre, Taloja, has developed a high-magnesium 5182 aluminium alloy specifically for EV battery enclosures. Mahindra & Mahindra was the inaugural customer for this development, requiring the material in gauges of 1.2 mm, 1.5 mm, 2 mm, and 3 mm for various components of the EV batteries, including top and bottom cover plates and reinforcements. To meet these requirements, a comprehensive formability study was undertaken to optimize mechanical properties, microstructure, and surface characteristics. Challenges in achieving the desired mechanical properties were addressed through a compositional study, adjustments to the alloy composition, introduction of intermediate annealing, and fine-tuning of finishing line parameters such as stretch levelling and elongation. Based on the application requirement for top cover of a battery enclosure with high forming features, to enhance the formability of the top cover plate, oiling processes were adapted based on global suppliers' practices.

The successful development of the AA5182 alloy demonstrates Hirakud FRP's commitment to advancing automotive material technology and reinforces its role as a trusted partner in driving Atmanirbhar Bharat forward. By overcoming significant challenges related to mechanical properties, formability, and finishing processes, the project emphasizes the importance of innovation and adaptability in meeting the evolving needs of the electric vehicle market. This achievement not only establishes Hirakud FRP as a key contributor to sustainable transportation but also sets a new standard for future advancements in battery enclosure materials.

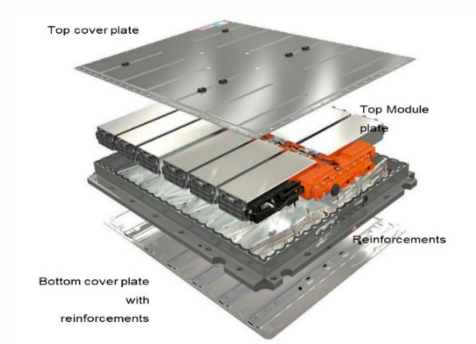

Figure 1: Picture showing different parts of an EV Battery

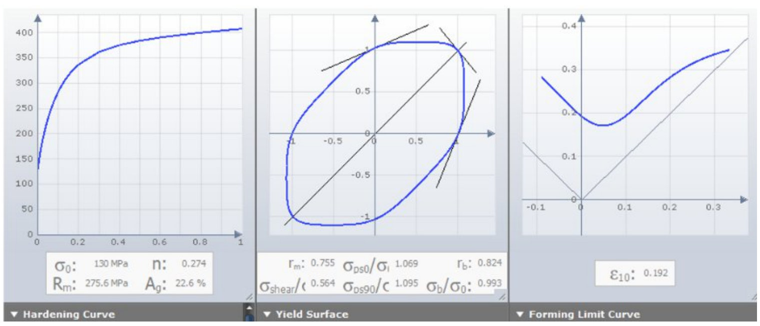

Figure 2: Formability test results for AA5182 material

Key words: EV Battery Enclosure, Compositional study, Formability,
NFM_055

Challenges in Development of Alloy 740H Grade Boiler Tubes for AUSC application

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Abstract

Seamless tubes of nickel based precipitation hardening superalloy 740H was first time manufactured by Nuclear Fuel Complex indigenously for Advanced Ultra Super Critical Boiler (AUSC). The applications demands an alloy that can sustain exposure at extreme conditions of very high pressure of around 35MPa and high temperature of 750ºC over a very long course of time of more than 10000 hr. Establishing the manufacturing for such novel alloy with a limited data available in literature was a challenging job.

The alloy has been processed through a series of thermo-mechanical processes consisting of hot extrusion followed by cold pilgering along with intermediate solution annealing passes. The finished tubes of 52mm OD x 9.6mm WT were finally solution treated and aged at suitable temperature and time to achieve the requisite mechanical and metallurgical properties.

Forged and machined billets underwent Deep Hole Drilled (DHD) for getting billets ready for extrusion. The material was difficult to process due to presence of higher percentage of cobalt. Process parameters were set based on limited literature available (fig a showing process map) and initial hot extrusion trails were taken. Crucial parameters such as preheating temperature, strain rate and strain were established and blanks with acceptable quality were extruded (Fig b) shows extruded blanks.

After extrusion, further cold work by pilgering was established. Heat treatments trials at various temperature time cycles were carried out to optimize the solution annealing and thermal aging parameters for achieving the finished tubular products for AUSC application. Metallurgical characterization and Mechanical & Non Destructive Testing were carried out at various stages to ascertain tubes produced meeting the stringent requirement.

a

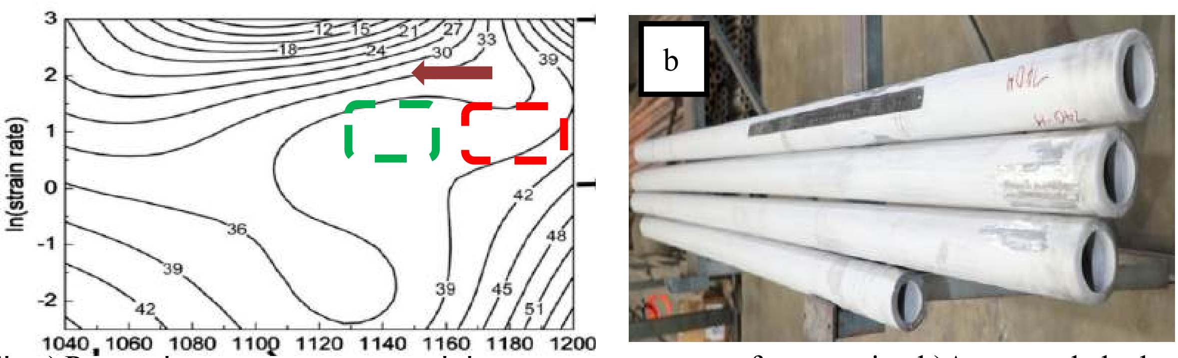

Fig a) Processing map –green area giving temperature range for extrusion b)As- extruded tubes

NFM_065

Key words: Hot extrusion, Cold working, Solution Annealing, Thermal aging, Super Alloy 740H

References:

[1] Wang, Jue, Jianxin Dong, Maicang Zhang, and Xishan Xie. "Hot working characteristics of nickel-base superalloy 740H during compression" , Materials Science and Engineering
[2] Kim, Dong-Min, Chiwon Kim, Cheol-Hyeok Yang, Ji-Un Park, Hi-Won Jeong, Kwang-Hyuk Yim, and Hyun-Uk Hong. "Heat treatment design of Inconel 740H superalloy for microstructure stability and enhanced creep properties", Journal of Alloys and Compounds

Investigation of the hot deformation behaviour and processing map of AM50 Magnesium Alloy

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Abstract

Magnesium-based materials are attracting the interest of manufacturers for their potential applications in the aerospace, automotive, electronics, and sports industries due to their outstanding characteristics such as specific mechanical properties, good castability, excellent machinability, and better recyclability. Among various commercial magnesium alloys, especially AM-series magnesium alloys are the most widely used ones due to their adequate strength, good castability, and better corrosion resistance. However, these alloys still have substantial limitations, such as relatively poor formability at room temperature. This is because of the hexagonal close packing (HCP) crystal structure, which contains a limited number of slip systems at room temperature, which limits the applications of these alloys in various industries. High-temperature deformation of magnesium alloys often improves workability by activating the extra slip systems. This work aims to examine the hot deformation behaviour of AM50 Mg alloys by the analysis of the constitutive equation, hot processing maps, and microstructure evolution. A processing map based on the dynamic materials model (DMM) has been developed to determine the safe processing zone by performing a hot tensile test at temperatures ranging from room temperature to 450°C and strain rate varies from 0.001 s^{-1} to 1 s^{-1}. Scanning Electron Microscopy (SEM) was employed to analyse the microstructural behaviour, while Energy Dispersive X-ray (EDX) spectroscopy was used to confirm the sample composition. Additionally, fractographic analysis via SEM provided insights into the fracture mechanisms of the alloy under different deformation conditions. The results indicate a significant correlation between the constitutive model and processing map for focusing on the microstructure and mechanical performance, highlighting the potential of AM50 alloy for applications requiring enhanced strength and durability.

NFM_077

Selective recovery of rare earth elements from coal fly ash in the light of diagnostic leaching

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Abstract

Critical and strategic elements like rare earths which are called the vitamins of modern day technology, have drawn researchers' attention throughout the world towards harvest of alternate sources like coal fly ash when there is a dearth of *easily exploitable primary sources in a country like India. On the other hand, with varied soil characteristics, petrified rocks in the form of coal are bound to display different modes of occurrence for the rare-earth elements* even within few kilometres of their existence. The sequential leaching of one typical coal fly ash sample from Kota, revealed that the major source of rare earth in that matrix (36.65% of the total REEs) is silica based phases which are Quartz and Mullite. However, the iron bearing phases like hematite also play as the host for substantial quantity of REEs (20.81% of the total REEs). For these kind of samples, one needs to break open the total matrix of coal fly ash to recover the total REEs at one shot which will call for strong and harsh treatment which will pose challenge to the environment. Thus the diagnose of sequential leaching says the treatment of coal fly ash to recover the entire REEs may call for a two-step process that will first attack the iron phase followed by leaching the silicate phases, thereby converting considerable amount of REEs from the parental host bonds to extractable forms. With this aim, coal fly ash samples from different power plants of India have been collected and studied for their rare earth content and recovery by hydrometallurgical route. These samples were dissolved in nitric acid by (1) acid-digestion method and (2) by fusion with NaOH + $NaNO_3$ mixture at 600°C followed by successive hydrothermal treatment of the fused mass. The analysis of major and trace elements were done by ICP-AES. All the samples showed similar kind of element distribution pattern with total rare earth content found in the range of 300 to 500 mg/kg and major elements as silicon, aluminum, iron, calcium and magnesium. Considering the low concentration of REE in the leach liquor generated by the above method, ion exchange method was adopted towards recovery. Preliminary tests with different types of resins were tried to find the most suitable one among them. Separation of total rare earths from bulk matrix elements were carried out by using TEHDGA (N,N,N',N'-tetrakis-2-ethylhexyldiglycolamide) impregnated XAD-7 resin. Quantitative separation of rare earth was obtained with no uptake of major elements. The loading capacity of the impregnated resin was evaluated from the experimental data that was comparable to the loading capacity obtained from the Thomas model. The adsorption of rare earth metal ions followed Langmuir adsorption isotherm suggesting mono-layer type of adsorption and indicated uniform distribution of the active sites all over the resin substrate.

NFM_060

Elution of loaded rare earths was achieved with 0.01 M nitric acid and all the rare earth metal showed similar elution behavior. The most noteworthy property of the resin is its high stability and recyclability. Thus, employing a diagnostic leaching (sequential leaching) before laying final recovery process will pave the effective route in terms of selective recovery of the valuable rare earths from coal fly ash.

A sustainable technology for melt processing of Aluminium alloys

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Abstract

Worldwide consumption of aluminium products is expected to accelerate, driven by growth and industrialization in China, India, Russia, and Brazil. in this context, the aluminium industry is making continuous improvements in the environmental efficiency of producing aluminium through primary and secondary processes. A large difference in energy requirements for production of primary aluminium (113 GJ/t) vis-à-vis secondary aluminium (13.6 GJ/t) has prompted recycling of aluminium alloys. Most of the countries are now setting goals so that in another 20-30 years complete recycling of the metals can be achieved.

During recycling of scrap one of the issues with recycling by remelting route is the build-up of oxides. It has been suggested that the oxides some of which have very low lattice misfit with primary ✔ Al can act as the potent nuclei for grain refining. The lattice misfit of aluminium with commonly found oxides like MgO, Al_2O_3 and $MgAl_2O_4$ in the recycled scrap is 3.1%, 3.38% and 1.41% which is comparable with the traditionally used grain refiner TiB_2 which has a lattice misfit of 4.22%. Hence the oxides can act as the potent nuclei for grain refining. The oxides formed during the service of a material get agglomerated during the remelting and unless these are removed or broken and uniformly distributed in the melt, recycling will not be effective. This problem is addressed using the melt conditioning treatment. This not only solves the problem of oxide build up but also eliminates the need for the addition of grain refiners. In the present work an inclined slope technology, patented by IIT Bhubaneswar, that provides low cost effective and continuous output has been designed and used. To add additional energy the slope was provided with vibration input. Grain refinement was obtained on casting A356 alloy through slope treatment.

There was almost 35-40% reduction in the grain size of the ingots cast through melt conditioning through vibration. The hardness was increased by almost 11-12 % through inclined slope and vibration application. Further in the alloy A356 the Si needles also showed refinement and morphology change due to the melt conditioning thus further enhancing the control of the mechanical properties of the cast ingots. Low energy consumption downstream processing of aluminum alloys such as twin roll casting can be integrated with the melt conditioning to make it still greener. The paper discusses the details of processing, microstructure development and possible underlying mechanism in the light of nucleation theories.

Key words: Sustainability, aluminum alloys, melt conditioning, characterization

NFM_008

Mineralogic and thermodynamic explanation behind ferrite formation during industrial zinc sulfide roasting

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Abstract

Considerable efforts towards efficient roasting of zinc-sulfide (ZnS) to oxides have been made by academia and industries over years owing to its importance in the overall Zn extraction process. While works have been primarily optimizing roaster input chemistry, process parameter control and optimization via automation is also not uncommon. Despite such, a common issue faced while ZnS roasting is formation of ferrites. They being complex Zn-Fe based oxide traps valuable metals that remains as wastes after final processing stages. Hence, in present work, experimental and simulation studies have been conducted essentially to underscore rationale behind ferrites formation as per present industry's adopted process perspective. To begin with, as-collected concentrate(ZnS) and calcines(ZnO) from distinct roaster input/output locations, have been chemically evaluated in terms of metal as well as mineral content. Additionally, characterization study of the aforementioned samples has been done on FESEM and XRD to explain mineralogic disparities. The outcome of such analysis indicates that ferrite formation is predominantly due to unavoidable presence of Iron (Fe) in Zn concentrate and that has its distribution primarily in association with mineral sphalerite. Moreover, sulfides of Fe i.e., pyrite and pyrrhotite have their mineral p80 of 50µ, i.e., coarse and thus ferrites are mostly common in bed calcines. While talking in terms of process condition, roaster bed calcines preferentially favors the ferrite formation as also seen in past investigations. To affirm such explanation to inevitable presence of ferrites in roaster bed, thermodynamic simulation study in FactSage have been carried out. There, as per roaster's process condition (material flow and temperature) Zn based ferrites along with zincites are the stable phases. Finally, analysis to curb such formation during roasting have also been proposed.

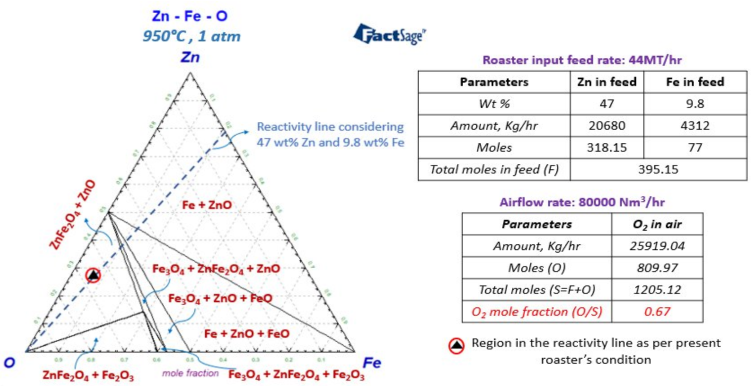

Fig. 1: Stable phases present inside roaster as per Zn-Fe-O ternary phase diagram at 950°C

Key words : Zinc sulfide, non-ferrous, fluidized bed roasting, ferrites

NFM_009

Processing of Polymetallic Nodules through Gaseous reduction-smelting for extracting Cu, Ni, Co, and Mn

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Abstract

The limited availability of land-based resources for critical metals nickel (Ni), cobalt (Co) and copper (Cu) in India has prompted research and development efforts to extract these valuable metals from seabed mineral polymetallic nodules (PMN). In PMN, the valuable metals, Cu, Ni, and Co, are found as integral components within the iron and manganese oxide matrices. Therefore, disintegrating the iron and manganese oxide lattice structure is crucial for the efficient recovery of these metals. PMN primarily consists of Mn and Fe with ~2-3% by weight of Cu, Ni and Co hence when hydrometallurgical processes based on acid or ammonia leaching are employed to just extract these three metals it results in the generation of large amounts of residue.

Traditionally, recovery processes have focused on extracting Cu, Ni, and Co from PMN, but incorporating Mn into the recovery process could enhance the overall economic viability and minimise watse generation. To this end, CSIR-IMMT, Bhubaneswar have developed a four-metal extraction process. This process employs a gaseous reduction-smelting route to recover Cu, Ni, Co, and Mn from PMN. Initially, the nodules are pelletized after which the pellets undergo gaseous reduction using compressed natural gas (CNG) as the reducing agent. The reduced pellets are then melted to produce an alloy containing Cu, Ni, Co and a significant amount of Fe along with a slag comprising Mn, Fe, and silicon (Si) oxides.

The gaseous reduction parameters as temperature, amount of gas and pellet size have been optimized to maximize the recovery of Cu, Ni, Co and some Fe in the alloy while retaining Mn in the slag. This process enriches the slag with Mn, resulting in a higher Mn/Fe ratio (>7) in slag compared to a low Mn/Fe ratio (<3) in original PMN. The alloy phase, which constitutes about 6-8% of the feed material, can be further processed through hydrometallurgical methods for the recovery of individual metals. This approach significantly reduces the solution volume compared to direct acid or ammonia leaching processes.

The slag is further smelted with coke as the reducing agent and dolomite as the flux, to recover Mn in the form of standard-grade silicomanganese. Various parameters, such as the amounts of coke and flux and the holding time, are optimized to produce the desired grade of silicomanganese and enhance Mn recovery. This process presents an attractive approach due to its efficient recovery of Mn as well from polymetallic nodules in a utilizable form.

Keywords: Polymetallic nodules, Gaseous reduction, Mn-rich slag, Smelting, Silicomanganese
NFM_066

Production of silica powder from silt and purification of silica sand

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Abstract

Sandstone is a sedimentary rock mostly composed of quartz or Feldspar framework grains. It is cemented through different cementing reagents. Due to presence quartz/ Feldspar and cemented strongly sandstones are highly resistant to wear and tear and chemical attack. The uses of Sandstone enlist as Natural Pavement, exterior and interior decorations in daily life. But in Research and Development Sandstone are a rich source of silica and quartz. After sand separation from sandstone the cementing material that is left over is the Silt which are also having significant silica and alumina values. After the sand separation the residual silt is kind of a waste. Along with enrichment of Silica and alumina values, silica powder can also be produced from Silt. For the second resource, silica sands impurities like iron can be removed to make it less than 100 ppm to make a suitable for glass making.

Fig. 1: Silica Powder from Silt and Pure Silica Sand

Key words :Silt, Sandstone, Silica Powder, High pure silica sand, Glass making

NFM_040

Development of a Flowsheet for the Recovery of High-Purity Manganese Compound from Manganese Residues Generated in Zinc Hydro Smelter

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Abstract

In this study, we developed a comprehensive flowsheet designed for the treatment of manganese-containing waste to produce a high-purity manganese product. The process involves leaching the waste material in a reducing atmosphere by purging SO2 gas, which facilitates the solubilise manganese into the solution at pH <2.0. the leachate is neutralized by adding fresh Mn residue to raise the solution pH ~4.0, which helps to precipitate the iron impurity (Fe).

After neutralization stage, the manganese-rich solution undergoes purification step to remove the process impurities and enhance the purity of manganese sulphate solution. In the final step, manganese gets precipitated from the manganese solution to form a magnesium compound of exceptional purity and containing 71% manganese (Mn).

During the leaching process, the remaining insoluble residue is rich in lead (Pb) and silver (Ag), which is a high value-added material and recyclable through pyro smelter for metal recovery. The overall approach aims to develop an environmentally sustainable process to eliminate the waste disposal by converting manganese residues into resource products.

Key words: Manganese waste residues, Leaching, Reducing Atmosphere, Waste elimination

NFM_040

Extraction of Rare earths from Magnets as high purity oxides and Metals: Selective recovery and scale up studies

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Abstract

Among critical metals listed by Ministry of Mines, Rare Earth Elements (REEs) are essential for advancement in renewable and greener technologies, required for carbon neutral economy. Among REEs, light REEs (specifically Nd, La, Ce, Sm) are in huge demand for permanent magnets, which are intensively required in traction motors of EVs, wind turbines, hard disks, MRI machines and missile guided system. Recycling of such magnets to recover REEs from end-of-life products is of great interest to Indian economy to meet circular economy and SDG goals. Typically, such permanent magnets (NdFeB and SmCo) contain appreciable of rare earths, which is reportedly highest among the secondary resources, making it attractive and economical. The challenges in recycling lies with the development of selective and scalable process. Not only the process should be selective and scalable, but it also emphasize on the recovery of other metals as valuable product to offset the loss of values. At CSIR-NML, pyro and hydrometallurgical process were developed to selectively recover Nd-Pr-Dy-Ce(>99.5% purity)oxide from NdFeB and Sm oxide (>99.6%) oxide from SmCo magnets. The present work provide a comprehensive overview of processes developed and challenges associated with Industrial adaptation.

Keywords: NdFeB, SmCo, pyrometallurgy, hydrometallurgy

NFM_062

Operating aluminium smelter with power interruptions: Some Experiences/ Challenges

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Abstract

The electrochemical process of aluminium smelting is a power guzzler operation and requires around 13kWh/kg of aluminium produced. Due to a variety of reasons, ranging from raw material supply of power plants, technical faults, power demand, various legislations, the power to smelters could be modulated from time to time. The power interruptions of varying durations affect the operation of aluminium electrolytic pots. A stable power to the pot maintains a steady heat balance in the pots. The disturbance in heat balance due to power fluctuations disturbs the mass, chemical, magnetic, and electric balances in the pot, that affects the performance of the pots. Smelters have learnt from the experiences and modified their operational procedures for various types of power interruptions. The behaviour of the pots, in terms of temperature, bath chemistry, noise variations after current down and during/ after ramping up is analysed, so that the operations could be more planned and stable. Some experiences/ challenges of operating the 340kA prebake aluminium electrolysis line around the target process parameters during such critical periods is highlighted in the paper.

DM_066

POWDER METALLURGY

Oral Abstracts

Process parameter optimization of aluminum alloy Al2139 using laser bed powder fusion (LPBF) technique

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Abstract

Due to the superior mechanical qualities, high-strength aluminum alloys, particularly those that are age-hardenable, such as the 2xxx series, 6xxx series, and 7xxx series, are widely employed as structural materials in the transportation and aerospace sectors. Processing of these high-strength aluminium alloys using laser bed powder fusion (LPBF) additive manufacturing has several challenges due to the hot crack susceptibility during the manufacturing. In the current work, a systematic study has been conducted on optimizing the process parameters for Al2139 aluminium alloy using the LPBF technique. The effect of the major processing parameters such as scan speed, laser power, and hatch spacing on the powder melting and densification behavior was investigated. Furthermore, the laser energy density was established to measure the combined influence of the aforementioned main factors to regulate the LPBF process. A parameter densification map was established to select optimized processing parameters for LPBF processing of Al2139 alloy.

Keywords: Selective laser melting, aluminium alloys, process parameters, Al2139, density.

PMA_017

Effect of High-Temperature Substrate Plate During Powder Bed Fusion Laser Beam Melting of Titanium (Ti-6Al-4V) Alloy

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Abstract

Powder Bed Fusion Laser Beam Melting (PBF-LB/M) has shown significant potential in the fabrication of complex geometries and high-performance components, particularly in the aerospace and biomedical sectors. Ti-6Al-4V is one of the most commonly used materials in PBF-LB/M due to its excellent mechanical properties, corrosion resistance, and biocompatibility. For Ti-6Al-4V, studies indicate that the PBF-LB/M process parameters, including laser power, scan speed, hatch spacing, and layer thickness, are critical in determining the additively manufactured (AM) parts' final microstructure and mechanical behavior. In addition to these parameters, substrate plate heating is another factor that can influence the properties of the AM-built test coupon. The microstructure of Ti-6Al-4V manufactured by PBF-LB/M typically consists of a fine martensitic α' phase due to the rapid cooling rates. This microstructure can be varied by changing the AM build substrate plate temperature, as this will change the thermal gradients and, thereby, the cooling rates. In the present work, Ti-6Al-4V alloy powder was used to fabricate test coupons by the PBF-LB/M process-based SLM 280 AM system attached with the high-temperature preheating (up to 550 ℃) module. The process parameters were optimized to achieve samples with no porosity or other defects. Different substrate plate heating temperatures ranging from 100℃ to 500℃ are chosen for the fabrication of test coupons. The effect of substrate plate temperature is investigated for variations in achieved microstructure and phases using scanning electron microscopy (FE-SEM), electron backscattered diffraction (EBSD), and X-ray diffraction (XRD). The hardness and dissolved oxygen content variation were measured for different chosen conditions. In addition to achieving nearly dense defect-free PBF-LB/M fabricated coupons, this work reveals the effect of different substrate plate heating temperatures on phase evolution and microstructural features.

PMA_024

Powder Bed Fusion Laser Beam Melting (PBF-LB/M) of High Speed (AISI M2) Tool Steel

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Abstract

A high-speed steel (HSS) – AISI M2 tool steel is widely used in cutting tools, molds, and rollers due to its high hardness and wear resistance. However, M2 HSS alloy has problems due to the severe hot cracks and solid-state cracks during the powder bed fusion laser beam melting (PBF-LB/M) process, and it does not meet the mechanical requirements for any industrial applications. This constitutes a need for detailed investigation to understand the M2 melting and solidification during the PBF-LB/M process with respect to the processing window, scan strategy, sample design, and effect of substrate plate pre-heating. This work used AISI M2 tool steel powder in the PBF-LB/M-based SLM280 system to generate the required test coupons. The study elaborates on the challenges observed during the PBF-LB/M processing of M2 tool steel for various approaches and demonstrates the successfully achieved M2 tool steel builds in different shapes without any cracks and porosity. Investigated as-built and post-build heat treatment for microstructure, carbide precipitates, hardness, and compression strength properties achieved. The processibility of M2 tool steel by PBF-LB/M will be demonstrated with the manufactured prototype of the conformal M2 drill-bit.

PMA_026

Additive manufacturing of NiTi shape memory alloy through laser powder bed fusion technique: Influence of powder characteristics and process parameters

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Abstract

NiTi shape memory alloys (SMAs) find application within diverse engineering sectors such as aerospace, biomedical, sensors and actuators etc., primarily due to their exceptional superelasticity (SE) and shape memory effect (SME) properties. NiTi SMA characteristics are well demonstrated to be altered through compositions, microstructures, processing routes etc., Typically, NiTi SMAs are produced through powder metallurgy or casting routes. However, these methods have certain drawbacks, such as the inability to create complex structures or components and the formation of undesired impurities like TiC and Ti_4Ni_2O. These impurities may cause secondary phases to develop, which deteriorate SMAs phase transition characteristics. To efficiently overcome these issues NiTi SMAs have been attempted, in recent decade, to be produced involving additive manufacturing (AM) technology. The possibility to print complicated geometries and a high buy-to-fly ratio are the two highly appealing features of laser powder bed fusion (LPBF), which make them to be a most effective AM technique amongst many.

In the present study, the characteristics of plasma atomized NiTi SMA powders of different types (pre-alloyed and blended) and the respective printed parts produced through the LPBF technique have been investigated. It is observed that the pre-alloyed powder exhibits a more spherical shape with fewer satellite particles compared to the blended powders, as shown in Fig. 1, which eventually affect the powder flowability during printing. It is further found that the pre-alloyed powder exhibits a SME due to the presence of the NiTi phase, as confirmed from the differential scanning calorimeter and X-ray diffraction results. On the other hand, the blended powder does not show any SME. The transformation temperatures (TTs) of the pre-alloyed powders during the heating- and cooling-cycle, respectively, are: A_f = -27.31 °C, A_s = 7.25 °C, R_f = 7.25 °C, R_s = -6.11 °C and M_f = -57.32 °C, M_s = -14.99 °C, R_s = 9.79 °C, R_f = 16.15 °C. The optimization of printing process parameter for NiTi SMAs was done successfully by varying laser power from 160 to 240 W and scanning speed from 830 to 1330 mm/sec. While other process parameters such as hatch spacing 70 µm, layer thickness of 40 µm and scanning strategy stripe with 67° rotation, remained constant. Post characterization of printed parts confirm SME and the presence of required NiTi (B19 and B2) phases. Our findings provide valuable insights for considering AM technology to successfully produce NiTi SMA, using pre-alloyed and blended NiTi powder, with varied metallurgical, functional and mechanical properties.

PMA_028

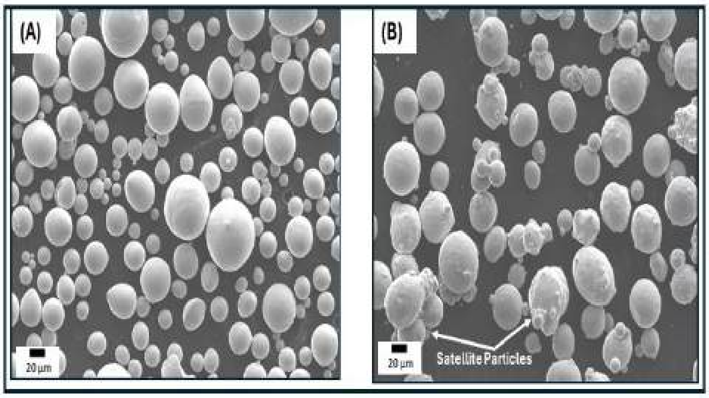

Figure 1: SEM images highlighting (A) pre-alloyed and (B) blended NiTi SMA powder morphologies.

Keywords: Shape memory alloys (SMAs), Nickel titanium (NiTi), additive manufacturing (AM), laser powder bed fusion (LPBF).

Analytical estimation of melt pool profile and temperature field in part scale laser powder bed fusion

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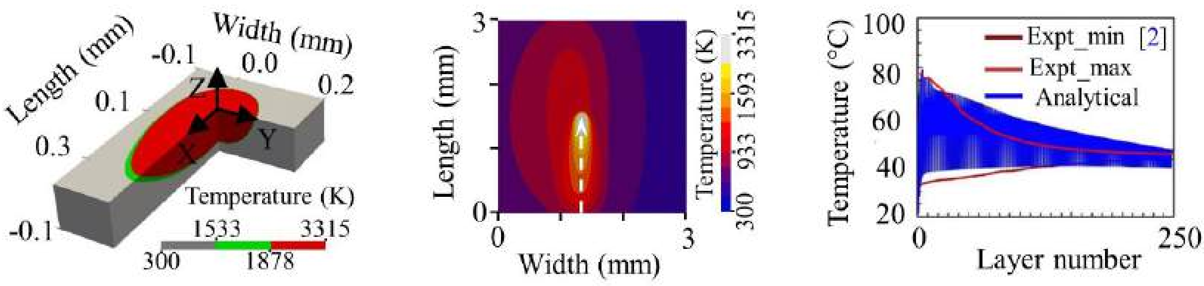
Abstract

A three-dimensional analytical heat transfer model is presented for a rapid calculation of the temperature field, melt pool dimensions and thermal cycles in part-scale laser powder bed fusion (LPBF). The model is able to consider track-by-track layer-by-layer deposition of powder alloys with diverse scanning strategies. In contrast to the reported numerical models, which are usually capable of simulating only a few track and layers due to their immense computational demand, the proposed analytical model can simulate the deposition of tens and hundreds of tracks and layers quickly and fairly reliably. The analytically computed results of melt pool dimensions, thermal cycles and cooling rates are tested rigorously with numerically computed and experimentally measured results from independent literature.

Fig. 1(a) shows a three-dimensional melt pool enclosed by liquids isotherms and Fig. 1(b) shows the computed temperature field for single layer LPBF of Ti6Al4V powder alloy. Fig. 1(c) shows the analytically calculated thermal cycles for a 250-layer LPBF of 14-7 SS powder [2] and the corresponding measured minimum and maximum temperature loci. A fair agreement between the computed and measured peak temperature values is revealed in Fig. 1(c). The analytically computed thermal cycles can further be extracted to estimate important metallurgical variables, such as temperature gradient and solidification cooling rates, which can help assess the quality of build structure and its mechanical property. The analytical model can compute the temperature field for a build volume of 10^4 mm^3 in less than an hour on a notebook computer, enabling track-by-track and layer-by-layer simulations for any part-scale LPBF.



(a) (b) (c)

Fig. 1: Analytically computed (a) melt pool along 17th track, and (b) temperature field for a single layer LPBF of Ti6Al4V powder alloy; (c) Comparison of analytically computed part-

scale thermal cycles with the corresponding measured minimum and maximum measured temperature loci for 250 layers LPBF deposition of 17-4 SS alloy [2]

Keywords: LPBF, Analytical model, Melt pool dimensions, Thermal cycles, Part-scale

References

1. Zagade P, Gautham BP, De A, et al. Analytical estimation of fusion zone dimensions and cooling rates in part scale laser powder bed fusion. *Addit Manuf* 2021; 46: 12.
2. Schnell N, Schoeler M, Witt G, et al. Experimental and numerical thermal analysis of the laser powder bed fusion process using in situ temperature measurements of geometric primitives. *Mater Des* 2021; 209: 109946.

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

PMA_066

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.

PMA_058

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°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

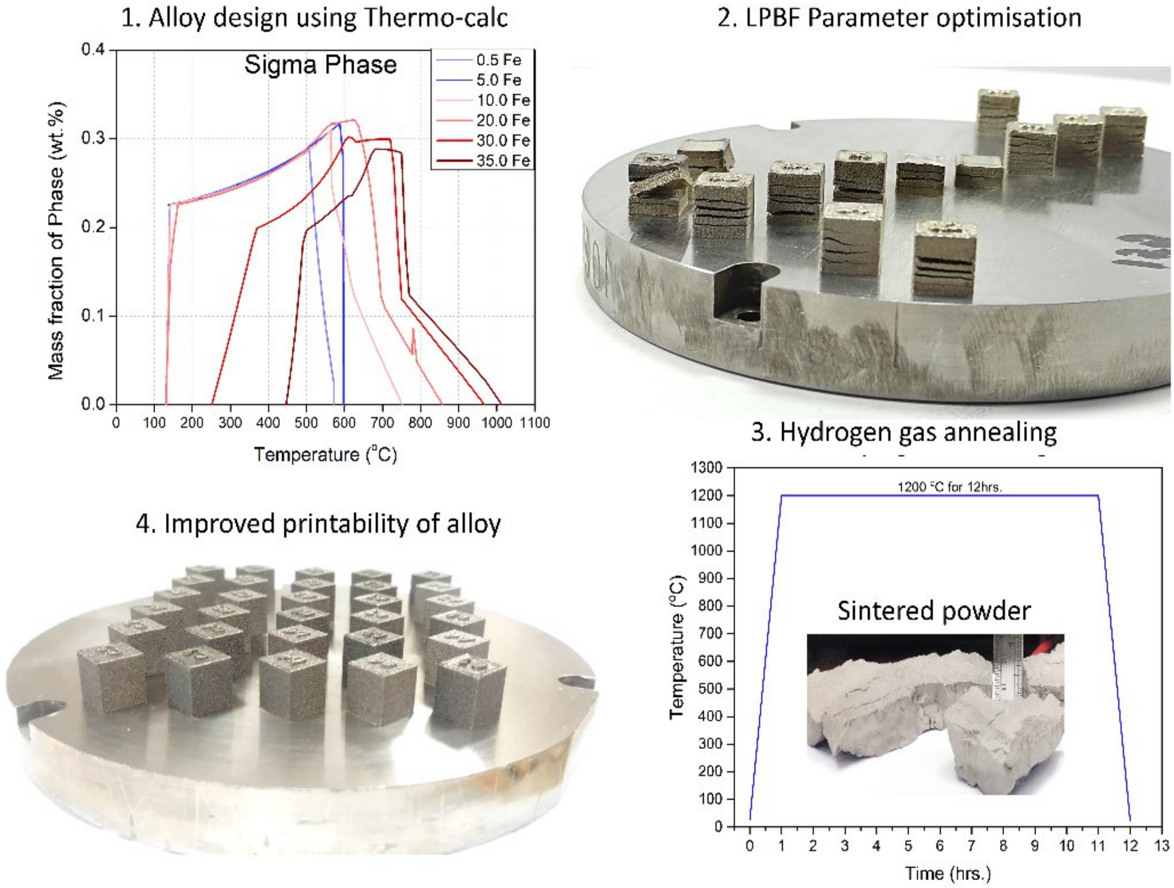

Figure 1 Graphical Abstract

PMA_066

Additive Manufacturing of SS316L - IN718 Bi-Metallic Structure: Interfacial Microstructure, and Mechanical Properties Insights

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Abstract

Joining of austenitic stainless steel (SS316L), and nickel-based superalloy (IN718) is technologically essential for various applications such as nuclear, power, and gas turbine industries. Considering challenges arising from conventional welding processes, additive manufacturing (AM) of bi-metallic structures with the combination of SS316L and IN718 was successfully demonstrated using the laser powder bed fusion (PBF-LB/M) process. The AM-built bi-metallic structure has been systematically investigated for the microstructure, mechanical properties, and interface bonding mechanism at different length scales. The bi-metallic interface shows a gradient microstructure containing equiaxed grains, twin boundaries, and columnar and cellular structures. Furthermore, a compositional gradient across the bi-metallic interface with significant intermixing of iron (Fe) and nickel (Ni) elements was evidenced, possibly resulting from the in-situ heat treatment. Adopting a stripe scan strategy with a 67° rotation suppresses epitaxial grain growth in the additively manufactured SS316L part. Higher hardness and tensile strength across the bi-metallic interface have been observed compared to either side of the alloys of the bi-metallic structure. The development of stronger bi-metallic-associated underlying mechanisms was critically discussed.

Keywords: Additive Manufacturing, Bi-metallic structure, Stainless steel (SS316L), Inconel 718, Interface, Gradient microstructure and composition.

PMA_094

Numerical investigation on the role of powder particle geometry on the bead formation in the LASER-based Powder Bed Fusion process

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Abstract

Laser powder bed fusion (LPBF) is a versatile manufacturing technique for manufacturing complex components in strategic applications such as space and defense. In this process, traditionally spherical particles are used. Production of spherical particles through Gas Atomization is costly and energy-intensive. A greener way of generating stock powders for LPBF could be through circular manufacturing by recycling machining chips to powders. This process is established in our earlier works[1]. One major drawback of the powders generated in this manner is their irregular morphology. The printing dynamics in LPBF will significantly vary when powders of different morphology other than spherical are used. Physics-based numerical simulations could help us get deeper insights without extensive experimentation.

In this study, the effect of particle morphology on the melt pool properties during the LPBF technique is studied using numerical simulations. LPBF technique is simulated using an open-source discrete element method (DEM) framework, Ligghts ®, and 3D computational multiphysics software, AM PravaH™, developed by Paanduv Applications. Specifically, the non-spherical particle shape is captured using superquadric curves, and the LPBF process simulation is performed using AM PravaH's macroscale melt pool dynamics module. Simulations for single-track, single-layer, and multilayer LPBF processes were performed with standard spherical particles and non-spherical particles. Different properties of the molten pool and spreading layer such as Marangoni convection, porosity, depth of solidified layer, and melt flow dynamics were analyzed in detail and compared with the standard spherical powders. With the optimized parameters, experiments are conducted to estimate the reliability of the numerical results.

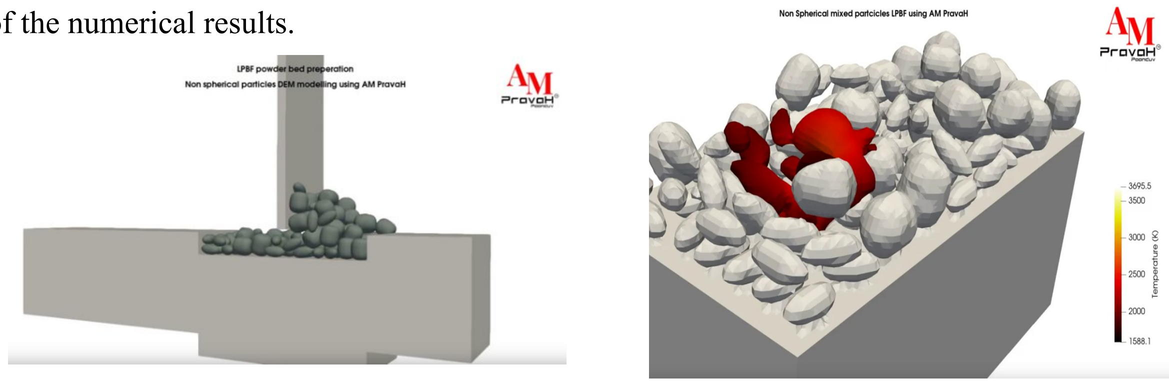

Fig. 1: Simulation of powder spreading and LASER interaction

Keywords: Laser powder bed fusion, melt-pool dynamics, process simulation

[1] Patel, M.S., Besekar, A., Annamalai, S. *et al.* Role of Nickel Particulate Reinforcement on Microstructure and Mechanical Performance of AZ31 Magnesium Composite. *Trans Indian Inst Met* (2024).

Effect of Thermal Processing on the Flow Characteristics of Equi-Atomic AlCoCrFeNi High-entropy Alloys synthesized through mechanical alloying for Additive Manufacturing

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Abstract

The effectiveness of additive manufacturing (AM) is highly dependent on the flow characteristics of metal powders, namely their sphericity, circularity, and roundness. This research examines the influence of thermal processing on the flow characteristics of equi-atomic AlCoCrFeNi high-entropy alloys (HEAs) powders, produced by mechanical alloying. The study investigates thermal treatments such as annealing in inert environment to improve the flowability in terms of circularity and roundness of powder by altering particle shape and lowering the thickness of surface oxides. In addition, subjecting the material to heat treatment cycles in an inert atmosphere at temperatures ranging from 300°C to 700°C for a duration of 1-hour results in a progressive rise in circularity as the temperature increases up to 700°C. However, the roundness of the material is mostly unaffected by these temperature variations. Upon further increasing the temperatures up to 1200 °C, may cause a decrease in particle size, leading to a gradual decrease in circularity. Increasing the duration of heat treatment at elevated temperatures often reduces the roundness and circularity, with a more noticeable impact at higher temperatures. The study also determines that the temperature range of 650°C to 975°C is necessary for the production of sigma phase, which is a transition from the cubic phase to a tetragonal closed-packed structure. The diffusionless martensitic transition increases the yield strength of the material as well as decreases the depth of deformation during ball milling, which encourages the development of spherical particles.

The objective of optimising these thermal processing settings is to enhance the flow dynamics in terms of high powder sphericity, purity, and a narrow size distribution, of the powder during additive manufacturing (AM). It heavily impacts on the density of coating layers, precision in forming, and uniformity of microstructure, resulting in improved packing density and reduced porosity in the final produced components.

Keywords: Additive manufacturing, high-entropy alloys, mechanical alloying, thermal processing, powder flowability.

PMA_037

Development of Additive Manufactured Nitinol alloy using Pre-Alloyed Powder

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Abstract

Nitinol, an equi-atomic alloy consisting of Nickel and Titanium, is the most prevalent Shape Memory Alloy (SMA) due to its unique ability to recover its original shape after deformation through shape memory and super-elasticity effects. These exceptional properties have led to Nitinol's extensive applications in space technology, particularly in payload separation systems. Additive Manufacturing (AM) offers a cost-effective and precise method for producing near-net shape components, and this study focuses on processing Nitinol using the Powder-Directed Energy Deposition (P-DED) technique. This method involves pre-alloyed Nitinol powders with an atomic composition of 50% Nickel and 50% Titanium. The key process parameters such as laser power, powder feed rate, and laser scan speed were investigated to optimize the manufacturing process. Preliminary experiments were carried out and each experiment was evaluated on a scale from one to ten based on the porosity levels in the microstructure, with samples exhibiting lower porosity receiving higher grades. An Analysis of Variance (ANOVA) was performed to determine the influence of process parameters on the deposit density. The results highlighted that the powder feed rate is a critical factor in achieving a dense deposit. Additionally, increasing the laser power, powder feed rate, and laser scan speed was found to reduce porosity in the material. Consequently, samples produced with optimized parameters attained a density of approximately 99%. However, when building multi-layered square deposits, residual stresses led to delamination from the base plate. To address this, the substrate was preheated to minimize the temperature gradient between the base plate and the printed deposit, thereby reducing residual stresses. This approach allowed for the deposition of a few more layers but did not entirely eliminate the delamination issue. However by systematically varying the base plate material, preheating temperature, and scanning strategy, the delamination issues were largely resolved. Using these optimized process parameters, samples measuring 30 x 30 x 20 mm were successfully printed with a density exceeding 99%. The printed samples were subsequently separated from the substrate using Wire Electrical Discharge Machining (EDM) and characterized to estimate transformation temperatures. The effects of different heat treatments on the transformation temperatures of the deposits were also explored.

Key words : Nitinol, Additive Manufacturing, Shape Memory Allo

PMA_089

Analytical Journey of Particle from Powder to Part

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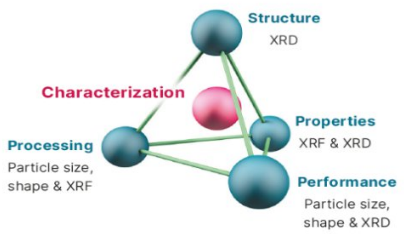
Abstract

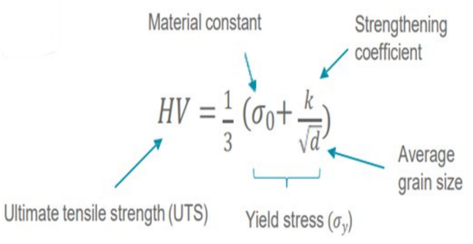
Powder metallurgy (PM) covers a wide range of ways in which materials or components are made from powders, chiefly metal and ceramic. PM processes can reduce or eliminate the need for subtractive processes in manufacturing, lowering material losses and reducing the cost of the final product. Several other PM processes have been developed over the last fifty years viz;

Powder forging; Hot/Cold Isotactic Pressing
Metal Injection Molding;
Electric current assisted Sintering
Additive Manufacturing



Properties of metal powders critical to product performance:

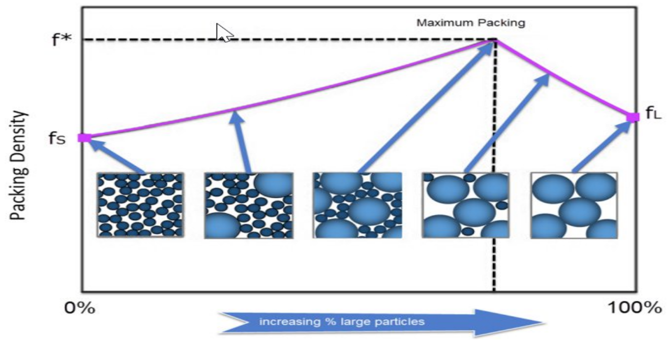
- Flowability
- Particle morphology
- Packing density



An Orthogonal Characterization of these properties of the powder and the part helps understand the journey of the particles from powder state to their final part.

A desire to achieve a high density part with a smooth finish is directly related to the powder packing density. Figure 1 shows how both particle size and particle size distribution are influential. Maximum packing density is achieved with a distribution that includes both coarse and fine particles, with finer particles increasing density by filling the interstices left by larger ones.

PMA_092



Case Study is presented wherein the journey of metal particles is traced from its powder form to final part using **Cold Isotactic Processing**

Figure 1: Packing density reaches a maximum when the particle size distribution includes both fine and coarse particles.

Key words : XRD, XRF, Particle Size, Particle Shape

Study of Magnetic Properties of Core-shell based Fe-Fe_3O_4 PM processed Soft Magnetic Composites

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Abstract

Ferrite based soft magnetic composites (SMCs) having high magnetization and good permeability with low eddy-current loss operating under moderate to high AC frequencies is essential for motors, transformers, inductors and in power electronics. Different processes have been attempted to obtain SMCs, with core-shell powders gaining prominence. This work focuses on a novel PM method of obtaining core-shell composite powder of Fe-Fe_3O_4 using controlled low-temperature oxidation to obtain ferrites (Fe_3O_4) as electrically insulating layer around Fe-powder. The aim is to tune the phase-percentages of ferromagnetic-core and ferrimagnetic-shell with time-temperature controlled-diffusion of oxygen to considerably reduce delamination at interface of Fe-Fe_3O_4. The synthesis involves oxidation of Fe-powder at 400°C-600°C for 5-15 minutes. Samples are then cooled under inert atmosphere (N_2) and consolidated in SPS. A thorough investigation of core-shell powders was done using Micro-X-ray diffraction, Field Emission Scanning Electron Microscopy, Electron Back Scattered Diffraction and Saturation magnetization (Ms) was measured using Physical Property Measurement System (PPMs) & B-H Loop tracer. The process resulted in higher Ms values (209-136 emu/g) compared to those reported in literature in such powders with shell thickness ranging from 0.4-14.3 µm. The core-shell based powders were consolidated and heat treated to obtain cylindrical compacts. The B-H loop hysteresis measurements were carried out at frequency range of 1 Hz to 1500 Hz. The saturation magnetization was highest found to be 1.8 T, coercivity 7 Oe@1 T with a maximum permeability 'µ' of 2471. The total losses were 42 W/kg. The total loss was found to be 12 W/kg @ 1200 Hz for core-shell powders processed at 600 °C/ 5 min, which can be compared with Fe-Si for 400 Hz application range. The loss separation was done and the Hysteresis loss was found to be constant with increase in eddy current loss as expected with increase in frequency. The detailed results and microstructure would be presented with data co-relation vis-à-vis shell thickness.

Fig. 1: FESEM morphology of Fe-Fe3O4 core-shell powder processed at 500 °C for 5 min of Oxidation

Key words : Soft-magnetic-composites, Fe-ferrite, core-shell, hysteresis-loop
PMA_096

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

PMA_012

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 :

1. N.K. Mukhopadhyay, D. Mukherjee, S. Bera, I. Manna, R. Manna, Synthesis and characterization of nano-structured Cu-Zn γ-brass alloy, Materials Science and Engineering A. 485 (2008) 673–680. https://doi.org/10.1016/j.msea.2007.10.039
2. N. K. Mukhopadhyay, D. Mukherjee, S. Dutta, R. Manna, D.H. Kim, I.Manna, Synthesis and characterization of nanocrystalline and amorphous $(Al_4Cu_9)_{94.5}Cr_{5.5}$-brass alloy by rapid solidification and mechanical milling. Journal of Alloys and Compounds 457 (2008) 177–184.doi:10.1016/j.jallcom.2007.03.043.

PMA_020

Single-step synthesis of antimony doped tin oxide nanocrystalline powders using flame spray pyrolysis

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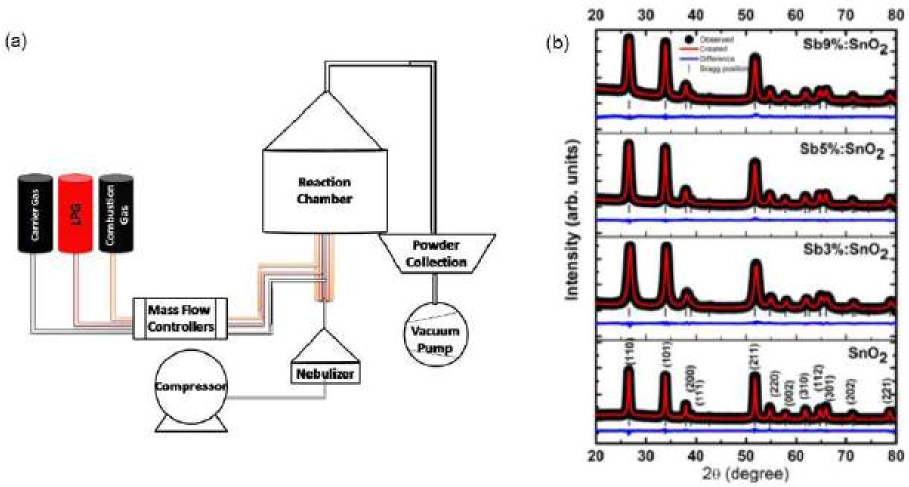
Abstract

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

RCC_024

Microstructural evolution and phase analysis of SS410-Al2O3-SiC multilayered functionally graded composite fabricated through laser cladding

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Abstract

In the present study, a functionally graded metal-ceramic composite structure comprising SS410, Al_2O_3, and SiC particles with varying composition, structure and properties in a single deposit was successfully fabricated using direct energy deposition (DED). The composition varied from 90% SS410 with 10% (xAl_2O_3 + ySiC) to 10% SS410 with 90% (xAl_2O_3 + ySiC), where x=70% and y=30% in a five-layered FGM design. The microstructure, phase evolution and mechanical properties of the components with different composition gradients were characterized by microscopy, energy dispersive spectroscopy, wavelength dispersive spectroscopy, X-ray diffraction and micro hardness. The investigation revealed that complex phases such as $C_{0.12}Fe_{0.79}Si_{0.09}$, M_7C_3, Fe_3C, and Fe_3Si formed as a result of the interaction between SiC and SS410 during the cladding process. Microstructural analysis showed a transition from columnar dendrites at the bottom zone of the cladding to a typical cellular structure and carbide particle agglomerates in the middle zone, with finer grains at the top zone. This gradation in microstructure correlated with an increase in microhardness ranging from 299 HV at the bottom to 966 HV at the top. This enhancement in hardness is primarily attributed to solid solution strengthening from C and Si originating from the decomposition of SiC and the precipitation of intermetallic phases.

Keywords: armour material, functionally graded materials, direct energy deposition, $C_{0.12}Fe_{0.79}Si_{0.09}$, graphite.

PMA_013

Effect of strain rate on the mechanical properties of addiitvely manufactured titanium alloys

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Abstract

The effect of strain rate on the mechanical properties of additively manufactured Ti2448 alloy (Ti, 24wt.%Nb, 4 wt.% Zr, 8 wt.% Sn) is undertaken. Invsetigation of the samples are undertaken using tensile testing, hardness measurements, X-ray diffraction, electron back scattering diffraction (EBSD) methods. The samples are processed by laser powder bed fusion (LPBF) using a prealloyed powder. X-ray diffraction shows the formation of predominant β phase along with the minor fraction of orthorhombic α″ phase. In the grip section, the hardness values are simialr along the sample length, with minor variations. The gauge section of the tensile samples exhibited lower hardness values, due to microstructural differences between the gauge and grip sections. EBSD inverse pole figure maps showed the presence of typical melt pools having a fish scale structure formed the LPBF processing. A minor fraction of orthorhombic α″ phase was detected during EBSD investigation. EBSD analysis revealed a polycrystalline structure with high-angle grain boundaries. The samples are tested at on an univerisal testing machine at four strain rates (0.0001 s^{-1}, 0.001 s^{-1}, 0.01 s^{-1}, and 0.1 s^{-1}). Upon tensile test, the ultimate tensile strength remained relatively constant at around 744 MPa, with a slight decrease at the highest strain rate. Yield strength varied significantly, decreasing at lower strain rates and increasing at higher strain rates, peaking at 316 MPa. The fracture strain decreased with increasing strain rates, indicating reduced ductility at higher strain rates. Tensile tests indicated strain rate sensitivity, with varying yield strength and fracture points at different strain rates.

Keywords: Laser powder bed fusion, Titanium alloy, Mechanical properties, Electron back scattering diffraction.

PMA_038

The effect of WAAM process parameters on heat transfer, crystallographic texture, mechanical properties and surface texture of Al4043 alloy

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Abstract

In recent years, wire arc additive manufacturing (WAAM) has gained lot of prominence due to cost effectiveness, higher rate of deposition and the ease of building complex parts. In this study, an effort has been made to understand the effect of process parameters such as voltage (V) and gas flow rates (GFR) on the quality of the as deposited Al4043 alloy. Heat input was estimated using inverse analysis. A multi scale investigation involving grain morphology, crystallographic texture and the evolution of residual stress was carried out. Higher voltages (16-19.5V) with lower forward traversal speeds lead to higher value of peak heat flux 993.10±218.76 kW/m^2-1320.44±89.86 kW/m^2. At lower voltages (13-14V), the peak heat flux was found to be 729.99±18.92 kW/m^2 and % porosity was lower (5-6%). The crystallographic texture showed a {100} orientation of planes, due to large thermal gradient which promotes grain growth in the heat flow direction. The UTS was found to be 78 MPa for 13.5V specimen against 26.3 MPa obtained for 19.5V fabricated sample. % Porosity was inversely proportional to gas flow rate. Torch angles (TA) above 10° resulted in asymmetric deposition of droplets indicating a poor wettability. The improvement in the wettability was observed for TA between 5 and 10°. For voltages (+14V), GFR (10-13 l/min) and TA (+5°), better surface topographical characteristics were obtained in the as deposited Al4043. Key words: WAAM, Voltage, Torch Angle, Peak Heat Flux and UTS;

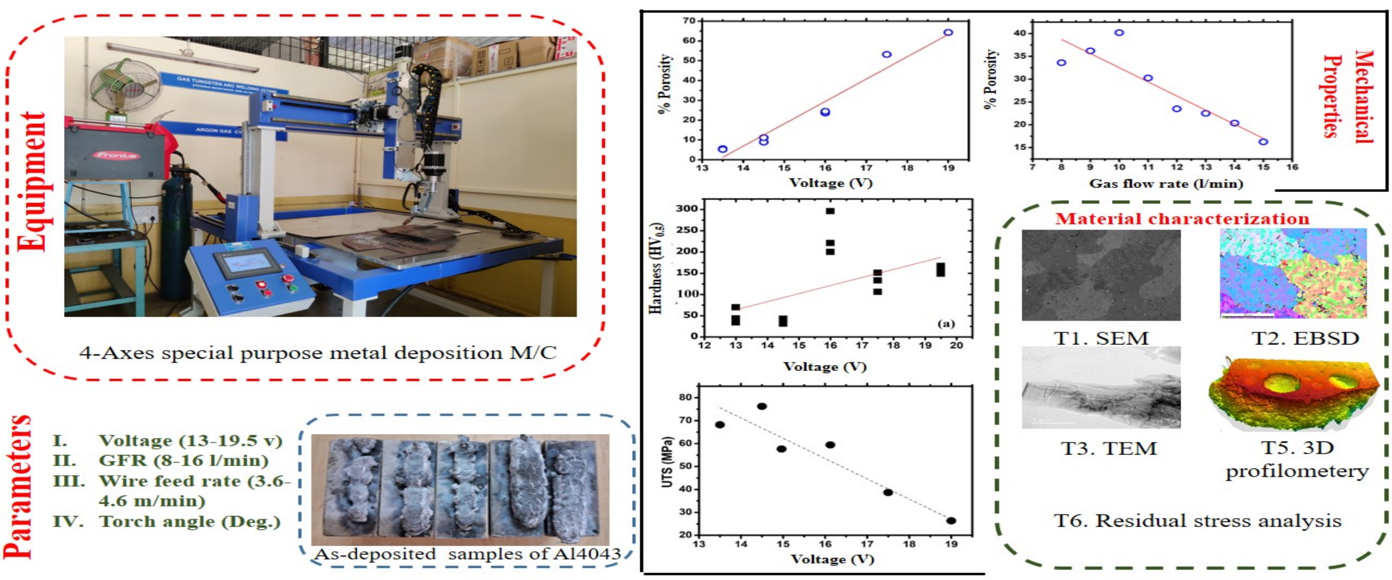

Fig.1: Highlights of the experimental investigation

PMA_040

Structure Property Process Parameter Correlation of Laser Surface Cladding of Rockit® 401 Powder on Al 1100 Substrate with Layering

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Abstract

Layer-wise laser surface cladding (LSC) of Rockit® on Al 1100 substrate was carried out by direct energy deposition (DED) method using a 6-kW continuous wave fiber-coupled diode laser. Owing to the difference in thermal conductivity and reflectivity between ferrous alloys and Al, dissimilar material cladding of the former on Al has several challenges like, uncontrolled melting, delamination, brittleness, along with the scope of precipitation of brittle Fe-aluminide compounds. Detailed parametric optimization produced homogeneous and consistent clads with no delamination or marked brittleness. The average surface roughness of the as-fabricated LSC samples was observed to be 7 – 11 µm. X-ray diffraction analysis revealed that all clad layers consisted of retained austenite, ferrite, martensite, and $Cr_{0.7}Fe_{0.3}$ and similar solid solution phases, without signature of formation of Fe-aluminides. The microstructure of the clad zones mostly comprised directionally solidified dendrites with multi-phase eutectic aggregate in the inter-dendritic regions, with an average microhardness in the range of 450–500 $HV_{0.1}$. MicroCT study revealed that the percentage of void distribution decreased consistently with increase in vertical layers. Distinct signature of the preferred orientation of the matrix grains had been noted by orientation imaging and texture analysis. Mechanical properties on the surface in terms of hardness, wear resistance, elastic modulus/stiffness, and flexural strength under tension consistently improved as the number of vertically clad layers was increased. This improvement is attributed to a lower level of Al dissolved from the substrate, and a higher volume fraction of eutectic aggregate comprising hard solid solution and interstitial compounds, characteristic of a pure Rockit® clad. Thus, under selected parameters it development of Rockit® clad on Al 1100 substrate was successful with improved properties and without any cracking or delamination.

PMA_049

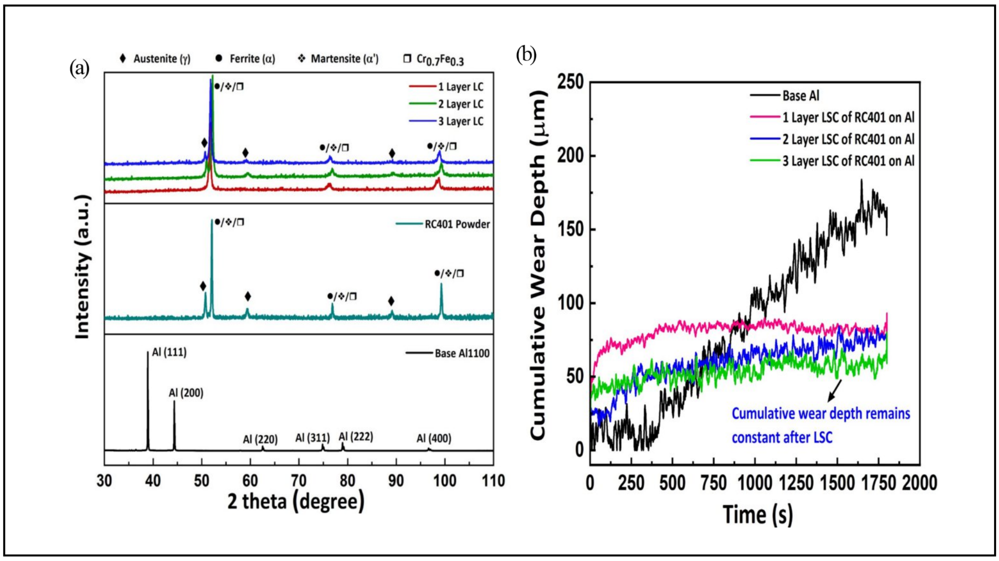

Fig. 1: (a) X-Ray diffractograms and (b) variation in cumulative wear depth for layered LSC of RC401 on Al 1100 Substrate

Key words : Laser cladding, Rockit 401, Aluminum, Fretting wear resistance

Effect of Novel β-eutectoid Alloying for Improved Mechanical and Tribological Properties of Titanium via Laser Material Deposition.

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Abstract

Implementation of laser-based additive manufacturing (AM) methods for making Titanium (Ti) alloy parts gained considerable industrial acceptance over conventional manufacturing routes. Though the laser-AM of the (α+β) type Ti-6Al-4V (Ti64) alloy and most of the α-phase dominant Ti-alloys, result in remarkably improved mechanical strength, owing to the rapid solidification process involved during the layer-wise deposition, anisotropy in mechanical behavior (due to the growth of prior-columnar β-grains) and a considerably reduced ductility limit certain practical applicability. In contrast, the β-phase dominant Titanium alloys possess inherent ductility and superior fatigue resistance, and the issue of microstructural anisotropy can be successfully addressed by β-alloying. Such a β-phase dominant Ti-Fe-Co system was reported in literature via conventional manufacturing routes, showing a good combination of strength and ductility. However, studies on such alloy systems via laser-AM processing are limited due to the complexity of multi-material systems (as β-phase strengthening involves alloying) in such a complex and non-equilibrium solidification process. Considering Ti64 alloy as the base material, this study investigates the Ti64-Fe-Co systems at two extreme alloying conditions via a laser-material-deposition method. This preliminary investigation aims to study the phase evolution (possible intermetallic phases) and microstructural features as an effect of β-phase strengthening with the potential β-phase stabilizing elements Fe and Co at hypo-eutectoid (low-alloying) and hyper-eutectic (high alloying) compositions. The resulting XRD analysis shows improved β-phase stability with alloying, where the β-Ti phase evolved as a major phase along with the Ti (Fe, Co) phase with an increase in alloy concentration. The resulting backscattered SEM-microstructural features show two distinct regions with the equiaxed dendritic and the matrix region depicting a reversal of high concentrations of Fe and Co upon changing the composition, as evident from the EDS analysis. An improved hardness of twice that of the commercial Ti64 alloy was achieved even at the lower alloying condition, and a further improvement in hardness at higher alloying conditions shows the strengthening effect of the Ti(Fe,Co) phase. The formation of $AlTi_3$ and Ti_2Co intermetallic phases formed at higher cooling rates during laser-material deposition also contributes to the strengthening effect. The laser-deposited novel Ti-alloys also show improved elastic modulus compared to the commercial Ti64, where identical load-vs-displacement behavior for both alloying conditions indicates the strengthening effect with an increase in alloy concentration without deteriorating the elongation properties. One of the most common issues of poor tribological properties of most Ti-alloys (including Ti64), has also been successfully addressed via this in-

situ alloy development work, showing up to 45% improvement in the wear resistance compared to commercial Ti64. A considerable reduction in the specific wear rates with minimized surface deformations for the laser-deposited alloys shows the reduced tendency of abrasive wear, as analyzed from the resulting wear surface morphologies. These findings offer valuable insights for developing metastable β-Titanium alloys with improved strength and tribological properties through laser-based additive manufacturing, aiming for potential applications in aerospace and automobile industries.

Keywords: β-phase strengthening, in-situ alloying, phase evolution, hardness and modulus, wear characteristics.

PMA_060

Structure – property correlation in additively manufactured near-alpha Titanium alloy

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Abstract

In this study, we investigate the effect of post processing heat-treatment on an additively manufactured near-alpha Ti-6Al-2Sn-4Zr-2Mo alloy. In as-printed condition fine martensitic lath structure is formed because of high cooling rates in the laser directed energy deposition method. As printed results in high yield strength but very low ductility. Post processing three heat-treatments were designed, first stress relieving treatment at 650°C, second cyclic heat-treatment below beta transus, third Isothermal holding at 930°C. Post-heat treatment microstructure results in the formation of equilibrium alpha and beta phases. Stress-relieved and equilibrium microstructure results in significant improvement in the ductility at the expense of yield strength. Cyclic heat-treatment results in the formation of globular alpha and increased lath thickness. This study shows that with the design of suitable heat-treatment mechanical properties comparable to wrought counterparts are achieved.

Keywords: Near-alpha alloy, DED, Heat-treatment, Microstructure, Mechanical Properties

PMA_063

Microstructure and Mechanical Properties of Laser Directed Energy Deposited Inconel 718/Boron Carbide Metal Matrix Composite

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Abstract

Inconel 718 (IN718), a nickel-based superalloy known for its high strength and good corrosion resistance is widely used in nuclear reactors, liquid-fueled rockets, turbine blades, and sheet metal parts of aircraft. In this work, IN718 has been reinforced with Boron carbide (B_4C) to further enhance its properties such as strength, hardness and wear resistance. Laser Directed Energy Deposition (LDED) which is a Metal Additive Manufacturing technique was used for the fabrication of IN718/ B_4C composites with differing weight percent (2 and 5 wt%) of B_4C. Single tracks were initially deposited and analyzed to determine the optimum process parameters for the subsequent deposition of IN718/B_4C block samples which were used for the determination of mechanical properties. The height, width and depth of the tracks were determined using image analysis. Single track studies revealed significant dilution of the substrate due to the high laser absorption coefficient of boron carbide. Using criteria for aspect ratio ($AR \geq 3$) and % dilution ($10 \leq \% D \leq 50$) an optimum set of process parameters (laser power of 500 W and scan speed of 720 mm/min) were identified for subsequent deposition of block samples. Microstructural characterization of the block samples using Scanning Electron Microscopy revealed the in-situ formed borides and carbides. Their composition was confirmed with the help of Energy Dispersive Spectroscopy and Wavelength Dispersive Spectroscopy. Mechanical testing of the IN718/B_4C (2 wt%) composite revealed an increase in hardness (by 28%) and ultimate tensile strength (by 18%) when compared to that of IN718. Cracks were observed in as-deposited composite samples with 5 wt% B_4C.

Keywords: Laser Directed Energy Deposition, IN 718, B_4C, Dilution, Cracks

PMA_073

Microstructure evolution and Mechanical Properties of Ti6Al4V Processed Below β-Transus Temperature using Additive Friction Stir Deposition

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Abstract

Additive Friction Stir Deposition (AFSD) is a solid-state processing technique that produces dense parts with fine equiaxed microstructures, improving the mechanical performance of alloys. This study presents the first demonstration of processing Ti6Al4V below the β transus temperature (986°C) using a closed-loop temperature-controlled AFSD system. When processed below the β transus temperature, the material undergoes dynamic recrystallization within the α + β phase region, resulting in a fine equiaxed α structure with an average grain size of 3–4 µm. This contrasts with all previously reported studies of AFSD of Ti6Al4V, where processing above the β transus temperature typically results in a microstructure characterized by fine α laths within the prior β grain boundaries. This study also investigates variations in microstructure and mechanical properties along the build direction. Additionally, it examines the effects of processing temperatures on the microstructure evolution of Ti-6Al-4V, demonstrating the potential to achieve a fine equiaxed structure in the as-deposited condition using AFSD.

Keywords: Additive Friction stir Deposition, Additive Manufacturing, Ti-6Al-4V, Microstructure, Mechanical Properties

PMA_023

Influence of SLM Process Parameters on Meltpool Morphology and the Density of NdFeB Permanent Magnet

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Abstract

NdFeB magnets, known for being the strongest commercially available permanent magnets, find applications in a wide variety of industries due to their exceptional magnetic strength and compact size like in electric vehicles, medical devices, and wind turbines. By adopting additive manufacturing (AM) to manufacture NdFeB magnets which offer design freedom, lightweighting with minimal material wastage, the potential application of NdFeB can still be boosted. The major challenges in achieving success with AM of NdFeB is achieving the high dense part and the microstructural change resulting from rapid heating and cooling which significantly alter the magnetic properties compared to the conventionally manufactured NdFeB alloy. In this research work, laser-based metal additive manufacturing, SLM is used to manufacture NdFeB as the SLM process can be used to generate more fine and complex geometries. The effect of major process parameters like laser power and laser scanning speed on the gas atomized NdFeB powder was evaluated and studied the melt pool morphology. Based on the study on NdFeB meltpool behaviour, process parameter was optimized to achieve dense part by SLM process. It was found, the samples built with relatively lower energy density built successfully till end but appears to be porous in general and needs further improvement of parameter to get further dense part. Samples built with relatively higher energy density failed during the process. There was direct corelation between the energy density and porosity and integrity of the part. Finding the balance is the key to achieve successful part by SLM process. The results are promising towards creating next generation NdFeB magnets with complex geometries

Key words: Metal additive Manufacturing, NdFeB, SLM

PMA_052

Developing and Analyzing Functionally Graded Materials in LPBF Using DEM and Partitioned Dispenser Chambers

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Abstract

Functionally graded materials (FGMs) are engineered materials characterized by gradual variations in composition, microstructure, or properties throughout their volume. These variations are intentionally designed to achieve specific combinations of properties or functionalities that cannot be realized with single-component materials. By tailoring the composition or microstructure, FGMs can exhibit a range of properties, including mechanical strength, thermal conductivity, electrical conductivity, and wear resistance. Traditional methods for generating FGM components include powder compaction, electrodeposition, thermal spraying, plasma spraying, and various vapour deposition techniques such as chemical vapour deposition (CVD), chemical vapour infiltration (CVI), and chemical vapour synthesis (CVS). However, many of these traditional processes are part-specific and costly, with the functional gradation often limited by the dimensions and the need for specialized tooling. Additive manufacturing, particularly through powder bed fusion, offers a more precise and cost-effective alternative for producing functional end-use products without the need for part-specific tooling. The powder bed fusion method has the unique capability to create functionally graded materials with varying gradation rates, providing additional features and flexibility beyond what conventional methods can achieve. However, generating FGMs within the plane of spreading poses significant challenges, as controlling the multi-material spreading process is difficult. This study employs the Discrete Element Method (DEM) to develop a methodology for spreading functionally graded materials on the build platform. The approach involves partitioning the dispenser chamber in the Laser Powder Bed Fusion (LPBF) process. The quality of the spreading was found to depend on several factors, including the recoater's profile, the speed of the recoater, and the thickness of each layer.

After establishing the framework for FGM spreading, two industrially significant materials, Inconel 718 and 17-4 PH stainless steel, were used to spread on the build platform. These materials were selected because their combination is ideal for aerospace components and power plant applications. The produced FGM parts were then examined for microstructural evolution and composition variation using a scanning electron microscope. Furthermore, the mechanical properties of the components were analyzed and compared across different scales of FGM gradation.

Key words: Additive manufacturing, Discrete element method, Functionally graded material, Powder bed fusion

PMA_075

Printability Studies on AZ31 Mg Alloy using Wire Arc Additive Manufacturing Process

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Abstract

Additive Manufacturing process (AM) is a promising technology for manufacturing complex shape components in a single cycle. However, it is still not well established to manufacture all the engineering materials, specifically magnesium (Mg) alloys. Since few decades, Mg has exhibited significant promise for use in aerospace and automotive applications owing to its attractive properties, including high specific strength, lightweight, good damping capacity and recyclability. Further, Mg is the lightest engineering metal because of its low density (1.73 gcm^{-3}), which can reduce the weight of vehicles and fuel consumption. Hence, the demand for Mg in the aerospace and automotive industries is growing tremendously day by day.
The manufacturing of Mg alloys by conventional techniques is difficult because of the processing challenges at both ambient and elevated temperatures. Therefore, AM techniques are under consideration to fabrication Mg alloy components. In this study, single tracks and thin walls were printed by a CMT-welding-based wire arc additive manufacturing (CMT-WAAM) process at various parameters, such as wire feed speed (WFS), scan speed (SS), and dwell time. Further, the effect of these parameters on printability, microstructure and mechanical properties of as-printed parts has been investigated. A WFS of 6 m/min with SS of 0.4 m/min, 0.5 m/min, and 0.6 m/min showed inconsistent single tracks, indicating printability is not up to mark. However, the printed tracks are comparatively consistent at the WFS of 8 m/min and 10 m/min, exhibiting better printability. The printability of AZ31 Mg alloy cannot be defined solely by single-track deposition. Hence, thin walls were deposited at different dwell times to understand the stability of layer over layer, which can define the printability of Mg alloy components. A total of 6 thin walls were deposited at various dwell times ranging from 10 to 60 seconds with an interval of 10 seconds. It was observed that the layer stability and printability at 40 s was comparatively better than other printed parts.
Furthermore, all deposited parts exhibited coarse equiaxed grains from bottom to top section with different average grain sizes. Consequently, microhardness varies from the bottom to the top section. Mechanical properties, such as ultimate tensile stress (UTS), yield stress (YS), and elongation percentage (% El) are different along build and travel directions.

Keywords: Wire Arc Additive Manufacturing, Magnesium Alloy, Microstructure, Mechanical Properties

PMA_084

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

PMA_018

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.

PMA_078

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 (ΔH_{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.

Keywords: Mechanical Alloying, Cu-Ru, Immiscible, ball milling, XRD, DSC, SEM, TEM

Reference: C. Suryanarayana, Mechanical alloying: A critical review, MATER. RES. LETT, 10 (2022) 619 - 647; https://doi.org/10.1080/21663831.2022.2075243

PMA_083

A Study on static spheroidization of direct energy deposited Ti-6Al-4V alloy Saumya Guptaa*, Subhadeep Sinhab, Shibayan Roya

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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 allotropicallyinto 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 ($T_β$). They are associated with the Burgers' orientation relation (BOR) suchthat $\{0001\}_α || \{110\}_β$ and $<11\text{-}20>_α || <111>_β$ [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, throughthis presented work, the aim is to study the effect of various heat treatments on the DED-builtTi64 part and its response toward the heterogeneous spheroidization and associated kinetics that might contribute to overcoming the current limitations in the AM processes.

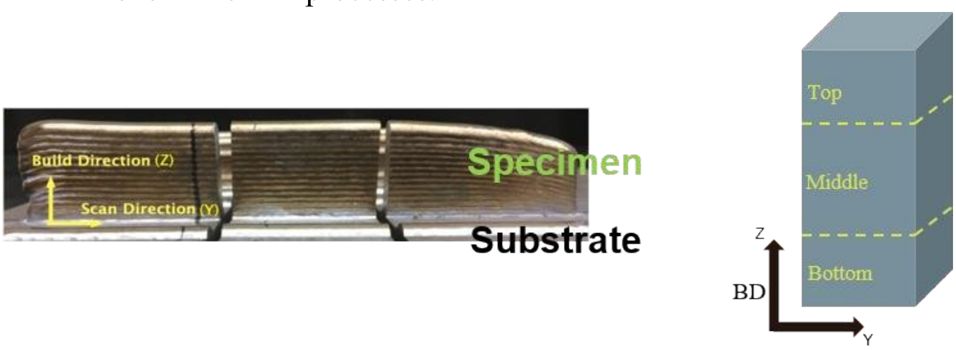

Fig. 1: Figure shows the DED deposited Ti-6Al-4V block (left), and its representativeschematic (right) depicting the top, middle, and the bottom sections.

Key words: Titanium alloys, Additive Manufacturing, Spheroidization, Microstructure, Heattreatment.

MSD_021

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

REFRACTORIES,CERAMICS & CASTING

Oral Abstracts

Impact of advanced refractory material on performance of reheating furnace

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Abstract

A reheating furnace is used to heat stocks before the shape change happens in the rolling/forging process. For heating the stock, generally mixed gas is used in steel plants that comprises of coke oven and blast furnace gases. This mixed gas is a by-product that is normally produced from steel plants. During burning of mixed gases inside the furnace, heat is generated which heats the stock by conduction/convection /radiation process. Thermal efficiency of furnace is the ratio of heat delivered to a material and the heat input. In the steel industry, thermal efficiency of reheating furnace depends on number of factors such as Calorific value of gas, type of refractory material and process technology. All the contributing factors should be optimized during reheating of stocks to obtain better efficiency of the reheating furnace. Application of an advanced refractory material for skid insulation and adopting better maintenance practices has optimized the reheating process which led to increased thermal efficiency by improving the life of the reheating furnace.

In this trial, refractory material andalusite based 60% alumina castable was used for insulationg the lining of skid pipes of heating and pre-heating zones of a pusher type reheating furnace. This resulted in achieving a lining life of 16 months as compared to a lining life of 6 months for previously used refractory material for insulation purposes. The trial resulted in an increase in the life of refractory material by 166%.

Key words: Furnace, Stock, Heat, Efficiency, Maintenecce, Refractory , Skid, Insualtion

RCC_009

Iron Making by Direct Reduction Process Route & Challenges to Refractory

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Abstract

The Majority of the world's steel is produced thru either one of the two routes; the Integrated Blast furnace – Basic Oxygen Furnace [BF- BOF] route or the Direct Reduced Iron – Electric Arc Furnace [DRI- EAF] route. One route most popular in India is DRI- Induction Furnace [IF] route. In the former, the Blast Furnace uses Iron Ore, Sinter, Pellets, Coke and Pulverized Coal as a raw material to produce hot metal for conversion in BOF. Although it is still a most popular and cost effective route, blast furnace hot metal production has declined over the year due to diminishing quality of Iron Ore, high cost of metallurgical grade coke and environment problem associated with this process.

These factors have contributed to the development of alternative routes of iron making, of which Direct Reduction [DR] Processes are expected to emerge as preferred alternative in the coming days. This study reviews the different DR process used to produce Direct Reduced iron and provides an analysis of the quality requirement of Iron – bearing ores used for these process. This study also discussed the optimization of Refractory campaign Life and the study of position of Air tubes along the kiln length, distribution patterns of Air inside the Kiln, attrition formation, shell temp rise, Refractory erosion pattern, correlation with high feed rate, the quality of input materials like Coal, Iron ore and Pellets.

Key words . DRI , Induction Furnace , Basic Oxygen Furnace , Electric Arc Furnace , Air Tubes

RCC_019

Enhancing Relining Efficiency and Durability in Reheating Furnace Skid and Post Beams: A Novel Plastic Refractory Solution

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Abstract

The skid and post beam configuration in reheating furnaces plays a crucial role in maintaining operational efficiency and longevity. Traditionally, a steel pipe circulates cooling water while refractory material is applied to the outer surface to prevent steel deterioration. However, challenges arise from mechanical impacts, thermal shocks, and erosive damage, leading to frequent furnace stoppages and water leakages. This necessitates a refractory solution capable of withstanding thermo-mechanical loads and temperature fluctuations while facilitating faster repairs to avoid prolonged downtime and furnace damages.

In response, a joint solution with the newly developed plastic refractory was devised. This innovative material offers enhanced mechanical strength, erosion resistance, and thermal properties compared to traditional alternatives. Its application results in significant reductions in installation time, downtime during maintenance, and energy consumption. Trial applications of the plastic refractory in walking beams demonstrate an energy saving of over 25% compared to previously dense materials. The plastic refractory (80%) boasts superior Modulus of Rupture (MPa) and lower bulk density and thermal conductivity, minimizing heat loss from skid pipes. Compared to on-site castable installations, the plastic solution reduces installation time by approximately 75%, further enhancing productivity and operational efficiency.

This paper discusses the development, properties, and application of the plastic refractory in reheating furnace skid and post beams. Through its implementation, significant advancements in relining efficiency, durability, and energy savings are achieved, paving the way for enhanced furnace performance and reduced operational costs.

Key words : Reheating Furnace, Skid and P

ost Beams, Plastic Refractory, Relining

RCC_028

Lime Enriched Mag-Dolo-Carb Refractories…… An approach to address the Low Basicity Slag in Si-killed Steel

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Abstract

In secondary steel making process, maintaining the slag basicity is the most important art of making steel. In case of Al killed steel process, the killing process is done by introducing Al metal, so maintaining basicity above 2 is not a problem. But in case of Si killed steel, when the killing is done by introducing Si metal or ferrosilicon, it disturbs the slag basicity. In such situation of low slag basicity, the solubility of MgO increases at a rapid rate, so normal magnesia carbon brick is not able to retain MgO grains within the brick structure. As the dissolution increases, the brick structure gets loosened and the slag penetration starts at a faster rate, and the cyclic process goes on. To address this problem, a basic refractory is required where MgO dissolution will not happen. The best refractory of this nature is dolomite, where MgO and CaO grains present, but all the MgO grains are forming a solid solution in CaO matrix. So, The MgO grains does not come in direct contact with the low basicity slag and as a result, the dissolution rate of MgO grain slows down. In other words, the refractory life enhances. In XRD study, both CaO and MgO will exhibit separate peaks, but there will be no dolomite peak, because they are in solid solution form. The present case study describes how lime enriched Mag-dolo-carb refractory performs in Si killed steel ladles. The developed bricks have been used in steel plants and a comparative study has been made, which clearly indicates the superiority of developed mag-dolo-carb bricks in case of Si killed steel ladles.

RCC_036

Coke Oven Heating Wall Repairing with Fused Silica Gunning Technology

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Abstract

The maintenance of coke oven heating walls is crucial for optimizing performance and extending the lifespan of coke ovens in integrated steel plants. Conventional repair techniques using silica bricks necessitate vacating and cooling adjacent chambers, leading to significant production losses and operational downtime. This present work reports the advantages of fused silica gunning technology as an advanced solution for repairing coke oven heating walls. Fused silica gunning involves applying a high-quality, silica-based refractory material using a gunning machine, which ensures precise and efficient repairs. This technology allows for the maintenance of damaged heating walls without requiring entry into the chamber, thus enhancing safety and minimizing disruption to ongoing operations. This technology is operational in coke oven 1 located in JSW Steel, Dolvi works. The results demonstrate that fused silica gunning not only mitigates the production losses associated with traditional methods using silica bricks but also improves repair quality and operational efficiency. This innovative approach represents a significant development in refractory repair technology, offering robust solutions for the refractory maintenance.

Top of Form
Bottom of Form

Fig. 1. Fused Silica Gunning Repaired Heating Wall

Key words: Coke Oven, Heating Wall, Fused Silica, Gunning Technology

RCC_037

Next Generation Snorkel Gunning Solution

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Abstract

With the flourish demand of clean steel, the requirement of RH snorkel is increasing. Hence the demand of excellent quality snorkel gunning mass is increasing for life enhancement of the snorkel as well as minimum maintenance and idle time. Maintenance of RH Snorkel by gunning mass application is an imperative process and very significant part of the service to extend the life of a snorkel. This gunning practice is essential to protect the outside castable part as well as the inside brick lining surface of a snorkel and is done at regular interval in hot condition after the completion of each cycle of the degassing process. The role gunning mass is important with respect to good adhesion and erosion and corrosion resistance, but the art and since of gunning , water and air pressure and skill of the applicator can not be out of place for life improvement.

In this paper, we will discuss the development of a new generation magnesia-based snorkel gunning mass by selecting the variety of Magnesia its granulometry and manufacturing technique. To impart good stickability and thus reducing its rebound losses by adjusting the binder type with suitable granulometry for better erosion resistance to prolong the campaign life of snorkels. For maintaining the healthy condition of snorkel it is essential to judge the type of cracks in hot condition and accordingly decide the start of gunning activities even at the early stage of Snorkel. Type of machine its nozzle distance from the target body and flow rate of the mass is suitably manoeuvred to achieve optimum thickness of gunning. Compatibility of gunning mass with the substrate body is also an important aspect and should be kept in mind while designing the bonding agent of the gunning mass for obtaining high temperature adherence and withstand steel turbulence.

RCC_038

Case Study on Life Improvement Journey of 350 Tons Capacity Steel Ladle at JSW Steel Ltd, Dolvi

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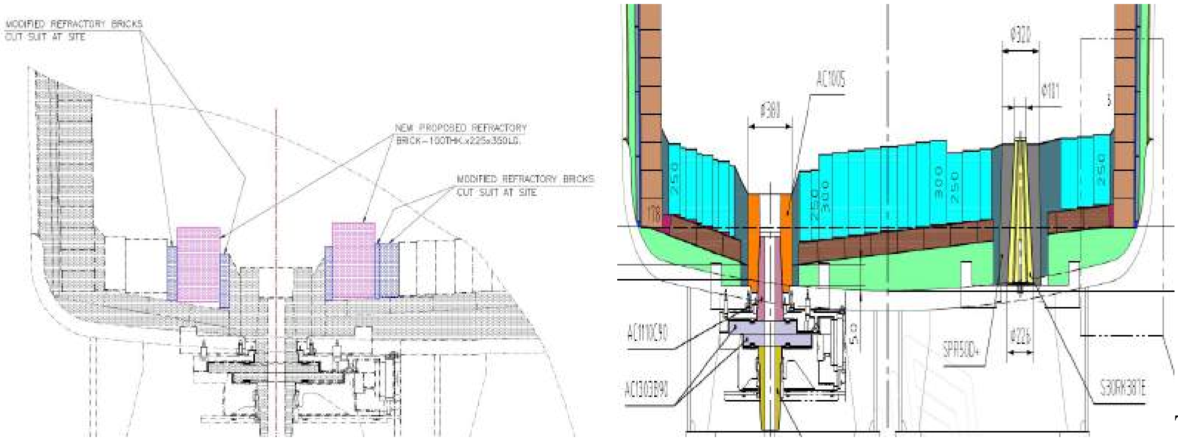
Abstract

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.

RCC_041



Top of FormBottom of Form

Fig. 1. Modified slope bottom design with vortex breaker and AMC

Key words: Steel Ladle, AMC, Corundum Spinel, Spinel Carbon, Vortex Breaker

Evolution of tundish refractory erosion and slag engineering in continuous casting

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Abstract

Steel chemistry, tundish covering flux, steelmaking slag entrainment, and process parameters significantly affect tundish erosion during continuous casting sequence. Any unwarranted erosion leads to hot spots in the tundish and safety hazards. Casting a wide range of steel grades in the same tundish while achieving consistent high tundish campaigns to improve process cost and safety is a challenge for steelmakers. In this work, steel, refractory, and slag samples were collected during the continuous casting process. The measured compositions were used for thermodynamic studies to understand the cause of refractory erosion. It was found that chemistry especially Mn%, O ppm in steel, ladle slag composition, and the amount of entrained slag significantly alter tundish slag and its reactivity with tundish refractory. A customized tundish flux was designed and introduced systematically to cast specific chemistry grades, resulting in substantial improvement in refractory erosion and increased sequence length with zero tundish failures.

Key words : refractory erosion; sequence length; tundish; hot spot; casting

SCA_026

Investigation of Interaction Mechanisms Between Cerium Oxide-Containing Slag and MgO-C Bricks Using X-ray Diffraction and Computed Tomography

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Abstract

This study investigates the interaction between MgO-C refractory bricks and steelmaking slag, with a particular focus on the influence of 5.59 wt% Ce_2O_3 at elevated temperatures. The comparison between slag containing cerium oxide and slag without it revealed significant differences in their penetration behavior into the refractory material. The slag devoid of cerium oxide exhibited a markedly deeper penetration into the refractory bricks compared to the slag containing cerium oxide.

To delve into the mechanisms driving these interactions, the study employed several advanced investigative techniques. FactSage thermodynamic software was utilized to trace the phase evolution providing a detailed understanding of the changes occurring in the material phases at high temperature. X-ray diffraction (XRD) analysis was employed to identify the specific phases present in the refractory material post interaction offering insights into the compositional changes resulting from the slag refractory interaction. Additionally, X-ray computed tomography (X-ray µCT) was used to visualize the extent of slag penetration into the refractory bricks providing a three-dimensional perspective on the interaction depth. The X-ray µCT scans demonstrated that cerium free slag penetrated up to a depth of 3mm into the MgO-C brick wall. In contrast, slag containing Ce_2O_3 penetrated only to a depth of 1.80mm. The underlying reason for the enhanced penetration of cerium-free slag was attributed to the presence of less stable oxides and higher fraction of the liquid phase. It causes more vigorous reaction between the slag and the MgO-C bricks leading to deeper penetration. On the other hand, the introduction of cerium oxide transformed low-melting phases into more stable and higher melting point rare earth phases. This transformation reduced the fraction of the liquid phase and stabilized the interaction zone thereby diminishing the penetration depth of the slag into the refractory bricks.

Overall, the study elucidates the crucial role of cerium oxide in modifying the phases evolved during interaction between steelmaking slag and MgO-C refractory bricks. By forming stable high-melting rare earth phases, cerium oxide significantly reduces the depth of slag penetration thereby enhancing the durability and performance of the refractory material in high-temperature steelmaking environments.

Keyword: Cerium oxide, Slag, MgO-C Bricks, FactSage, X-Ray µCT

RCC_010

Developmet of high abrasion and high alkali resistance lc based castables for cfbc boiler and cement applications

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Abstract

Increased process temperatures and higher chemical loads from use of alternative fuels and materials generate high thermo-mechanical and chemical stresses (such as volatiles like alkalis, chlorine and sulphate) that dramatically affect the refractory lining. Alkali and abrasion resistance are two key performance deciding factors in most of the boilers, incinerators, cement and steel applications. Some applications demand combination of both. However, increasing the alumina content to enhance abrasion resistance drastically decreases alkali resistance.

The objective of the present work is to explore the possibilities for developing Alumino-silicate based LC castables with two different Al_2O_3 contents (50% Al_2O_3 and 75% Al_2O_3) that exhibit effective resistance to both the abrasion and alkali in a single product without any content of Zircon and SiC.

The key factors taken into consideration for this developmental work include designing the microstructure to meet the conditions existing in the process and understanding the degradation mechanisms exerted on refractories from processing conditions. This paper presents the selection of appropriate raw materials to achieve the desired properties of physico-chemical, thermo-mechanical and abrasion resistance along with PLC. Furthermore, the design of fine matrix chemistry to generate an excellent alkali-resistant structure when alkalis come into contact with refractories has been investigated.

Keywords: Castables; CFBC Boiler; cement; matrix design; alkali resistance; abrasion resistance.

RCC_045

Characterisation of different carbon sources in Blast Furnace Trough castables

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Abstract

:Al2O3–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

RCC_032

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.

RCC-030

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

RCC_018

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

References:

- L. C. Damonte, P. C. Rivas, A. F. Pasquevich, F. Andreola, F. Bondioli, A.M. Ferrari, L. Tositti and G. Cinelli, Advances in Condensed Matter Physics. Volume 2017
- S. Basu, C. Nayak, A.K. Yadav, A. Agrawal, A.K. Poswal, D. Bhattacharya, S.N. Jha and N.K. Sahoo, J. Phys.: Conf. Ser., 2014, 493, 01203

RCC_020

Effect of Hf and Al on the Microstructure of a Refractory Complex Concentrated Alloy

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Abstract

Complex Concentration Alloy (CCAs) is among the high entropy alloy which has received most attention in the literature in last few years. In this class of CCAs, we have selected Refractory High Entropy Alloy (RHEA) which are in high demand for energy generation aero-space and high temperature material because of the special properties such as high melting point, strong oxidation resistance and thermal stability. These RHEAs where the constituent elements are of high melting points, we have selected alloys of almost equi-atomic are considered to find out their structure property correlations of the material.

In this study the effect of Hafnium and Aluminum in a totally new designed (Nb-Ti-Zr-Mo-Ta) CCA. The composition is melted in vacuum arc remelting in Argon atmosphere to make the alloys; subsequently the alloys are homogenized at 1300°c for 100 hours under vacuum. The As-cast structure were investigated using x-ray diffractometer, Scanning Electron Microscopy with EBSD and energy dispersive spectroscopy (EDS) for phase and microstructure evolution

In this paper, an extensive EBSD to find out the phase distribution and type of phase for these samples by varying Hf and Al. In this study, crystallographic characterization has been carried using TEM and found alternate lamella of BCC and HCP crystals. STEM map of lamella indicates the elemental partition between the phases. The micro hardness are also studied and co-related with the phases observed in the both alloys. Detailed characterization confirms that in as-cast condition two BCC phases with similar structure and chemically different composition are seen where as in homogenized condition three phases are observed. Compositional variation in both the alloys for Hf and Al does not bring any significant effect on the microstructure and phase formation.

Detailed mechanical property behavior is under the evaluation and is to be correlated in our further study.

Key words: CCAs, RHEAs, EBSD, TEM, Micro hardness.

SPC_131

Property Assessment and Characterization of Chemically Reclaimed Glass Fibers for Refurbishment of Railway Coaches

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Abstract

The superior strength-to-weight ratio, excellent corrosion resistance, high durability, flame retardance, and ease of fabrication of Glass Fiber Reinforced Plastics (GFRP) have promoted its application in railway coaches. As projected by Lucintel, the composites in the global passenger rail market are expected to reach an estimated $1.1 billion by 2030, with a CAGR of 5% from 2023 to 2030, which signifies the extensive utilization of GFRP composites in railway applications. This results in a rapid rise in production and consequent waste generation and underscores the need for sustainable solutions to repurpose, recycle, and reuse GFRP composites. The mechanical properties of GFRP composites fabricated using chemically reclaimed glass fabrics from waste GFRP composites, including flexural strength, interlaminar shear strength, tensile strength, and tensile toughness, are comparable to those of virgin GFRP composites. Consequently, these recycled GFRP composites are viable alternatives for railway coach applications. Typical applications include the interior of railway coaches, such as wall and ceiling panels, side panels, interior doors, and fittings such as seats, luggage racks, poles, grab handles, and toilet fittings. Chemically reclaimed glass fabrics can also be used in skin sheets of sandwich body panels employed for the exterior of railway coaches and sliding door assemblies. Reclaimed glass fabrics can be used for railway coaches in different forms, such as short fibers as secondary reinforcement, long chopped strand mats, continuous strand mats, and woven rovings. Refurbishing railway coaches with composites enhances both performance and sustainability. Using recycled GFRP composites for non-critical applications such as interiors, walls, ceilings, and handles reduces environmental impact and material costs. Reserving virgin GFRP composites for critical areas where superior mechanical performance is essential ensures safety and durability. This approach optimizes resource utilization and aligns with sustainable practices, offering a comprehensive solution for modernizing railway coaches.

Keywords: Glass Fiber Reinforced Plastics, recycling, reuse, sustainability

RCC_015

Development of Functionally graded Al metal matrix hybrid composite reinforced with CNT, Y_2O_3 & 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 (Y_2O_3), 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 Y_2O_3 (0-2.5 wt.%) were done simultaneously to prepare a graded structure upon consolidation. Mechanical and micro structural characterizations were carried out with the aid of SEM-EDS, instrumented indentations to establish structure property co-relation. Further characterization of the composite materials was conducted using X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM), indentation techniques and dynamic mechanical analyser (DMA). We found that milling the materials for more than 20 hours resulted in the uniform distribution of CNT, SiC, and Y_2O_3 within the aluminum matrix. Subsequent cryomilling (CM) with a ball-to-powder ratio of 100:1 further reduced agglomeration and effectively cleaved the nanotubes, thereby minimizing entanglements. XRD analysis revealed the formation of feasible reaction products during the processing steps. Thermal properties characterized through dynamic mechanical analyser (DMA) setup shows approx 50% reduced coefficient of thermal expansion values for the bulk FG composites and indicates promising stability at higher temperatures

Keywords: Mechanical Milling, Spark Plasma Sintering, Mechano-thermal processing, Powder Metallurgy, Nano Composites, Carbon Nanutubes, Cryomilling, Functionally graded Materials

RCC_033

Influence of SiC particles on thermo-mechanical properties liquid metal squeeze infiltrated A356-SiC composite

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Abstract

The increasing demand for high-power electronic systems demands material with exception thermal conductivity (TC) and low coefficient of thermal expansion (CTE) for efficient heat dissipation and structural integrity. While conventional materials like aluminum and copper fall short in meeting these requirements, metal matrix composites (MMCs), particularly aluminum matrix composites (AMMCs), offer promising solutions. Among various reinforcements, Silicon Carbide (SiC) has garnered significant attention due to its high thermal conductivity and low CTE.To overcome these limitations the present study aims to develop A356/SiC composite with varying volume fractions (20-65%) of SiC by liquid metal squeeze infiltration technique. The influence of SiC particle addition on TCand the CTE of the A356/SiC composite was studied. Theoptical microstructural characteristics, surface morphologies and phase composition were studied using optical microscopy, scanning electron microscopy (SEM) and X-ray diffraction (XRD) respectively.Relative density, hardness, thermogravimetric analysis (TGA) andcompression strength were studied. Detailed thermal characterizations (TC and CTE) of the A356 alloy as well as A356/SiC were carried out in both as cast and T6 heat treated conditions.XRD results confirmed that there are no detrimental phases like Al_4C_3 in the developed composite. When the volume fraction of SiC increased to 65%, under T6 heat treated condition, the thermal conductivity of the composite increased 19 % (147 W/mK to 176 W/mK) with respect to A356 alloy. Similarly the addition of 65% SiC to the base material significantly reduced the CTE of the composite from $22.61x10^{-6}$/˚C to $10.18x10^{-6}$/˚C (54% reduction) after T6 heat treatment with improved hardness and compressive strength. Thus the findings of this study contribute to the development of near net shape high-performance, lightweight composite materials for advanced thermal management applications in electronics, automotive, and aerospace industries.

Keywords: Al/SiC composites, liquid metal squeeze infiltration, SiC preform, coefficient of thermal expansion, thermal conductivity, thermal management, high-power electronics.

RCC_049

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.

RCC_022

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%.

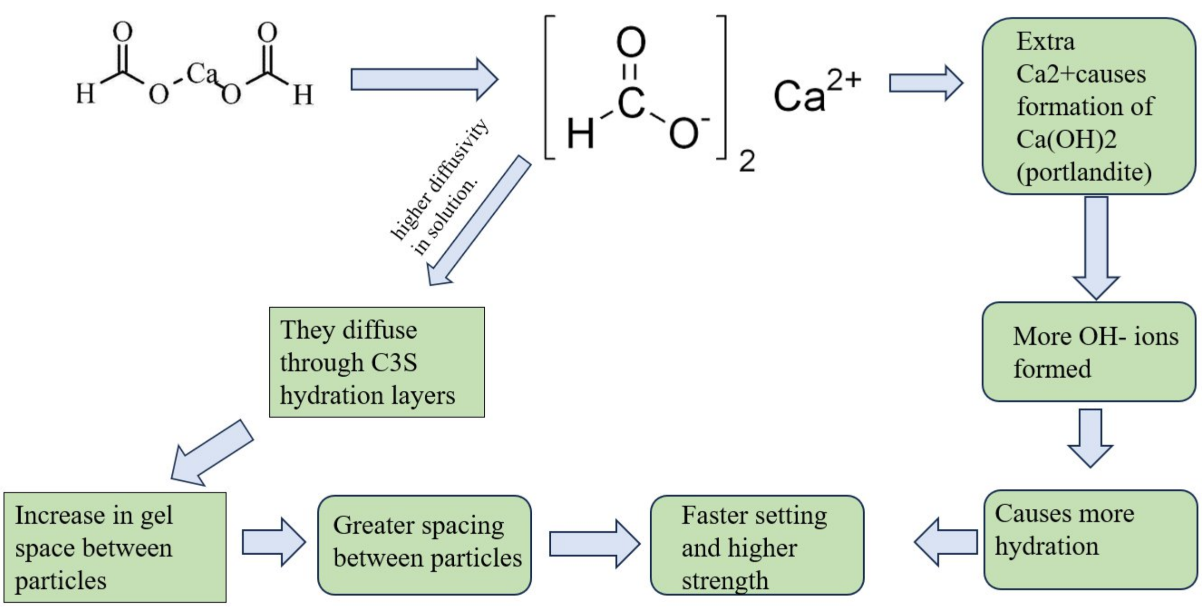

Fig. 1: Schematic showing the Role of Additive in CML setting time reduction

Key words: Cement, Mortar, Compressive Strength, Setting time, Calcium Formate

RCC-035

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 $Al_{13}Fe_4$) 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.

References:

[1] N. K. Mukhopadhyay and T.P. Yadav, Journal of the Indian Institute of Science, 102 (2022) 59-92.
[2] Y. Shadangi, S Sharma, V. Shivam, J. Basu, K. Chattopadhyay, B. Majumdar, and N.K. Mukhopadhyay, J. Alloys Compd. 797 (2020) 154258.
[3] Y. Shadangi, K. Chattopadhyay, N. K. Mukhopadhyay, IN Patent Application: 202411016352IN.

RCC_046

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.

MSD_017

Ceria (CeO2) and Gadolinium Doped Ceria (GDC) Reinforced 8YSZ Composite Material, Synthesized via Spark Plasma Sintering (SPS) Method for Advanced Thermal Barrier Coatings

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Abstract

Thermal barrier coatings (TBCs) are used to protect effectively the alloy base of hot apparatuses in gas turbines or in aero engines or for thermal insulation and also for resistance to corrosion of the many ceramic coatings. However, challenges of sustaining in higher temperature operating conditions of these device components results in delamination, degradation, and untimely failure of the top coating material. In this regard, researchers are trying to develop new ceramic coating materials to compete with the mandate requirement of innovative TBC systems of future. This work focused on reinforcing Ceria (CeO_2) and Gadolinium doped Ceria (GDC) in conventional yttria stabilized zirconia (8YSZ) TBCs ceramic oxides by Spark plasma Sintering technique in pursuit of enable them to operate beyond the 1200°C stability limit. Which were reported using (7YSZ) TBCs. 8YSZ gives superior strength as compare to GDC because GDC reduces at high temperature. Combing both GDC and CeO_2 in 8YSZ can also be reported for various applications like, electrolytes in Solid Oxide Fuel Cell (SOFC) and Oxygen Sensors and Thermal Barrier Coating (TBC). It is the key issue to address the GDC-8YSZ system to optimize the mechanical properties without sacrificing the Thermal/electrical properties. For these three different compositions of 8YSZ is taken into account i.e. 8YSZ, 8YSZ +10 wt. % CeO_2, 8 YSZ + 10 wt. % GDC, 8YSZ + 5 wt. % CeO_2+ 5 wt. % GDC. The synthesis via Spark Plasma Sintering (1300°C, 5 minute and 30MPa) and various characterizations (of phase, microstructural and mechanical properties) are done. Phase analysis has indicated formation of composite with dilation of 8YSZ lattice upon CeO_2 and GDC addition. Densities of GDC- 8YSZ electrolytes were observed to degrade from ~97.7% to 92.8% as the GDC and CeO_2 content increases attributed to poor sinterability of ceria. Crystallite size of GDC- 8YSZ electrolytes were observed to increases from ~40.45 nm to ~50.58 nm as the GDC and CeO_2 content increases. Grain size of GDC- 8YSZ electrolytes were also observed to increases from ~0.89 μm to ~2.28 μm as the GDC and CeO_2 content increases. The present study describes the mechanical properties like micro-hardness (H), fracture toughness (K_{IC}) using Vickers indentation method. lattice strain and lattice parameter of GDC- 8YSZ composite are corelated with obtained mechanical properties, which shows their limitations towards TBC application. The performance of these samples is also evaluated in terms of thermal conductivity and thermal stability issues

RCC_050

Synthesis and characterization of Hafnium Pyrophosphate for Luminescence applications

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Abstract

Hafnium (Hf) and zirconium (Zr) have received substantial interest because of their intriguing properties mainly in the nuclear and semiconductor industry. Due to low neutron-capture cross-section and strong resistance to corrosion, zirconium is used as a cladding material, on the other hand hafnium possess high neutron-absorption capacity, thus used as control rod material in nuclear reactors. The Hafnium oxide (HfO_2) possess high dielectric constant ~25, band gap ~6 eV, refractive index ~2.9, and high hardness. Therefore, HfO_2 has been chosen over silica for use as the gate dielectric in silicon devices. The ubiquitous optical properties of hafnium oxide have attracted the researchers to study other forms of oxides of hafnium viz. hafnium pyrophosphate, HfP_2O_7. The Hafnium Pyrophosphate (HfP_2O_7) is the most promising candidate for phosphors to act as host matrix because of its interesting cubic crystal structure, excellent chemical & thermal resistance, and optical properties. The research on Hafnium pyrophosphate for luminescence & phosphor applications is very limited and scarce.

The aim of this study is thus to synthesize a phase pure highly crystalline hafnium pyrophosphate solid material using hafnium nitrate (~99.8% Hf w.r.t to Zr) solution which was extracted from zirconium scrub raffinate. The thermogravimetric analysis results are shown that the decomposition of diammonium hydrogen phosphate and other nitrates occurred at ≤400°C and no mass loss observed thereafter. Similarly, the phase pure powders of HfP_2O_7 with cubic structure, Fig. 1 was successfully prepared and the powder diffraction patterns were well matched to the literature data. The Hf-O and P-O-P vibrational bands in HfP_2O_7 were also revealed by FT-Infrared Spectroscopy. A cubical type of morphology of the heat-treated powders were observed in FE-SEM. Further, the optical properties of as prepared HfP_2O_7 will be discussed in this work.

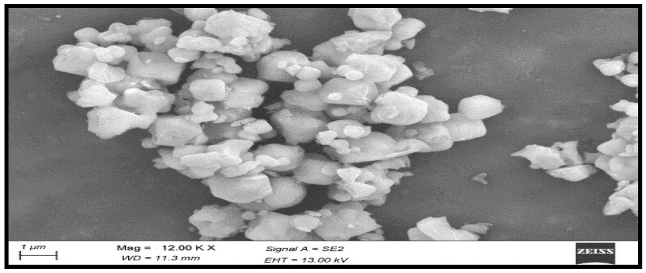

Fig. 1 : FE-SEM micrograph of HfP_2O_7 powder

Key words : Hafnium oxide, Hafnium Pyrophosphate, Phosphors, luminescence

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SOLIDIFICATION & CASTING

Oral abstracts

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.

SCA_033

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

SCA_019

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

SCA_048

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 3rd 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

SCA_059

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

SCA_007

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.

SCA_034

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

SCA_041

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.

SCA_049

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.

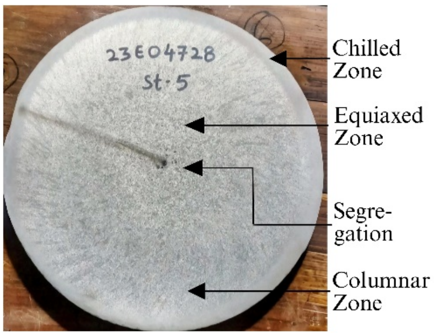

Fig. 1: Macro-structure of round billet

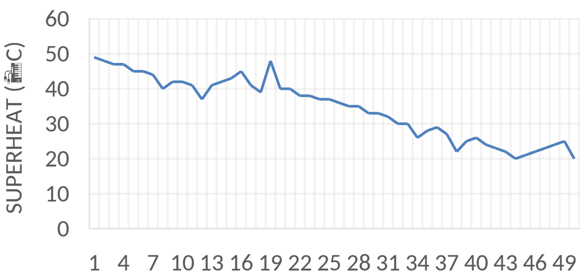

Fig. 2: % Equiaxed zone versus superheat

Keywords: macro-structure, segregation, continuous casting

SCA_067

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

MPR_391

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.

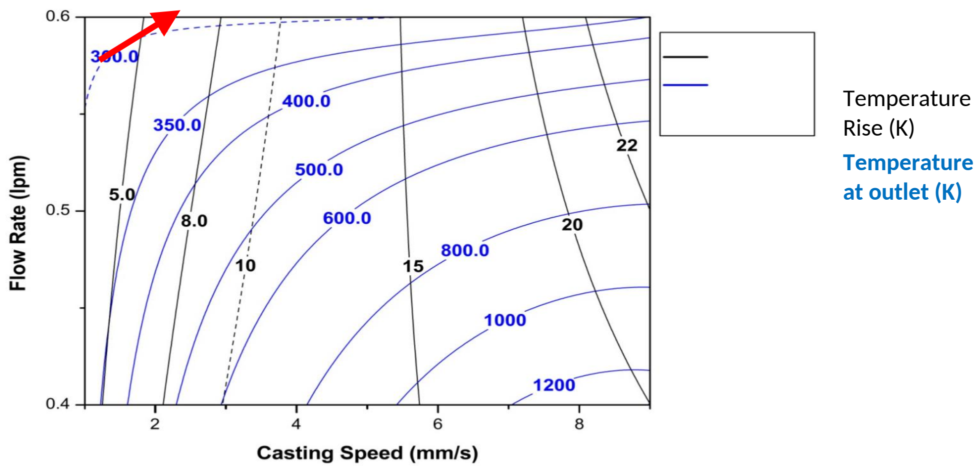

Figure 1 - Variation of the outlet temperature of the U-Zr cast slug and the temperature rise of cooling water at different casting speeds and flow rate.

Keywords : Continuous casting, metal fuel, computational analysis

[1] SCA_058

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

SCA_022

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.

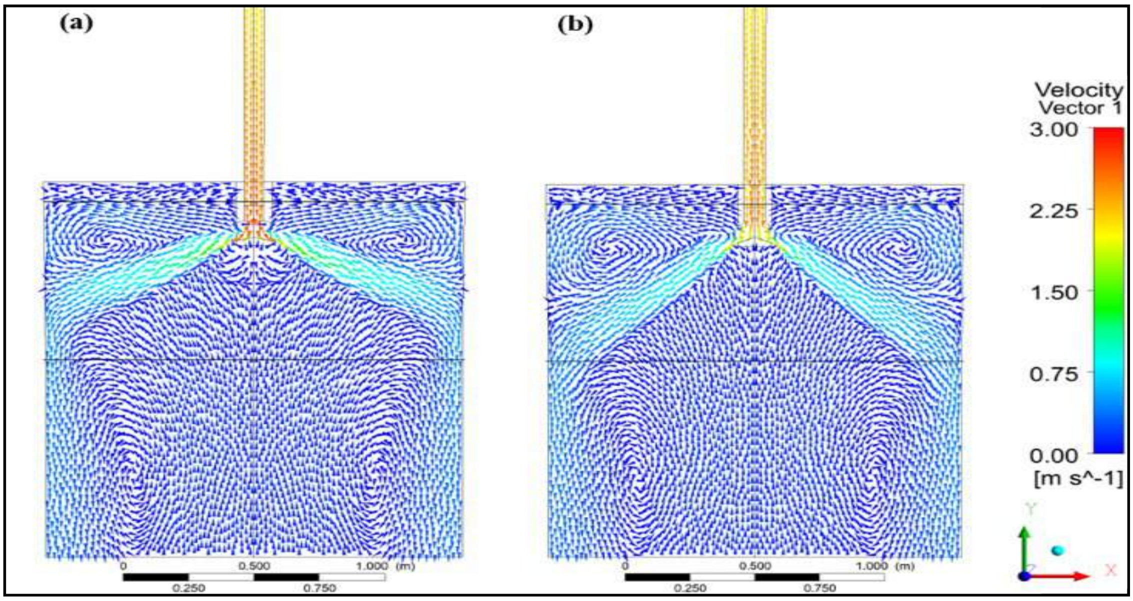

Fig. 1: Velocity vector at mid plane thickness a) 15° port angle; b) 25° port angle

Keywords: submerged entry nozzle, pot angle, port shape, meniscus level fluctuations, caster, mold

SCA_023

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.

SCA_030

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.

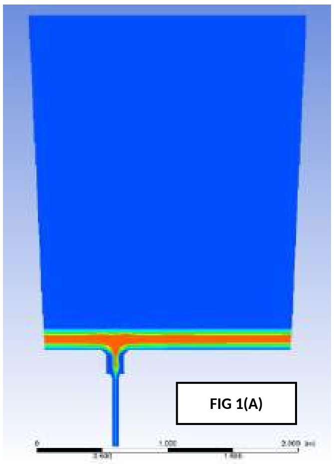
FIG 1(A)

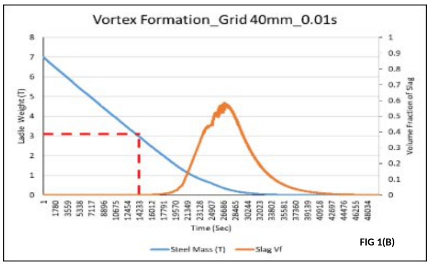

FIG 1(B)

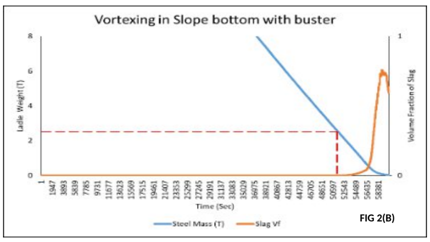

FIG 2(B)

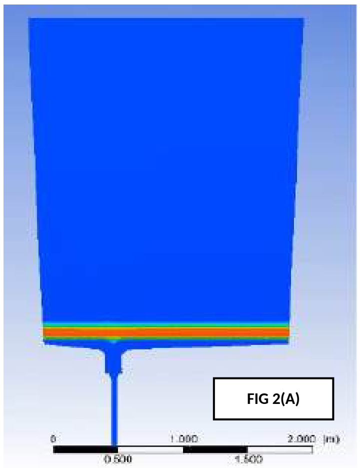
FIG 2(A)

Key words : Vortex, Slag entrainment, Tundish

SCA_050

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

SCA_053

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

SCA_047

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.

SCA_43

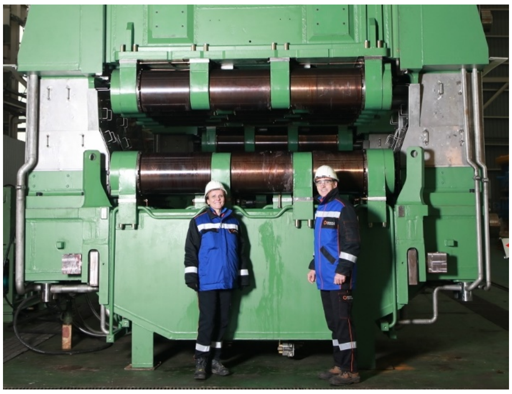

Fig. 1: SRD segment for ultra-thick slab casting and hard reduction

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.

SCA_029

Development of near-net shaped cast nanocomposite parts using high shear mixing technique

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[3]National Institute for Interdisciplinary Science and Technology (CSIR), Thiruvananthapuram

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-xTiB_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

SCA_046

A novel approach for simulating the solidification process in a Bridgman setup

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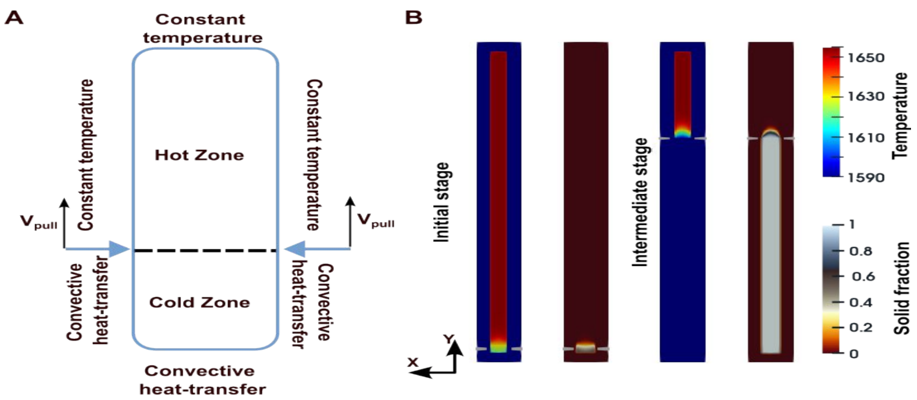
Abstract

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.

SCA_065

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;

SCA_068

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)

SCA_011

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.

SCA_040

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

SCA_055

STRUCTURE & PROPERTY CORRELATION

Oral abstracts

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Processing, Microstructure and Deformation behaviour of third generation medium-Mn advanced high strength steels

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Abstract

Medium-Mn steels (3-12 wt.% Mn) have emerged as promising candidate for the third generation advanced high strength steels (AHSS) in automotive applications, primarily due to their ability to reduce vehicle weight and consequently lower greenhouse gas emissions. To further enhance the strength-to-weight ratio in medium-Mn steel the addition of Aluminium has been investigated recently. This study focuses on Fe-8Mn-4Al-0.25C-0.6Si wt.% Al-added medium-Mn steels which were processed through different routes like hot rolling, warm rolling and cold rolling, and thereafter intercritically annealed at different temperatures. The investigation involved understanding of microstructure evolution, mechanical properties assessment and deformation behavior.

The processed steel exhibited varying phase constituents and morphologies depending on the rolling method and annealing temperature. The microstructure consisted of δ-ferrite (<10%), retained austenite (28-66%), and remaining α-ferrite/tempered martensite. Hot rolling and annealing produced lath-like microstructure, intercritical rolling and annealing produced ultra-fine-grained mixed lath-equiaxed type microstructure, while cold rolling and annealing resulted in mostly equiaxed type microstructure. Through optimized intercritical annealing treatment, the steels demonstrated an exceptional combination of strength and ductility in the range of 58-60 GPa%. This extraordinary performance was attributed to multiple strain hardening mechanisms, namely, transformation-induced plasticity (TRIP) and twinning-induced plasticity (TWIP) effects, contributing to progressive work hardening across the deformation range. Notably, lath and equiaxed austenite grains, sharing similar compositions but varying sizes, exhibited different degrees of mechanical stability. The deformation-induced martensite was found to nucleate from deformation twins/twin bundles in the retained austenite.Top of Form

Keywords: medium-Mn steel, third-generation AHSS, intercritical annealing, retained austenite

SPC_015

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, AHSS
SPC_026

The role of processing and microstructural parameters on the development of precipitates in micro-alloyed high strength steel

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Abstract

The nano precipitate strengthened advanced high strength steels with improved formability received tremendous interest from automobile industries due to its weight saving potential. The ultra-high strength with enhanced ductility can be realized through developing nanoscale precipitates in a single-phase ferrite matrix. In micro-alloyed steels, various types of precipitates occur during thermo-mechanical processing depending on the composition, temperature, and processing conditions. The interphase carbide precipitates, which occurs during the transformation of austenite to ferrite have been studied extensively in the present study. There are some other precipitates influenced by the microstructural parameters such as dislocations, grain boundaries and their impact on the mechanical properties were also studied. This work focuses on the characterization of various types of the precipitates developed during on the thermo-mechanical processing of a V-Nb-Mo micro-alloyed steel. The microstructural and crystallographic details of the materials were studied by employing two potential instruments namely transmission electron microscope (TEM) and transmission Kikuchi diffraction (TKD). An attempt was made to characterize the same sample/area/region using both techniques and correlated the grain boundaries character with nanoscale precipitates. It is observed that high-angle grain boundaries (HAGB) and dislocations are the preferred sites for nucleation and gets coarsens faster due to the rapid diffusion through disordered lattice. The rapid consumption of the solutes leads to the formation of the precipitates free zone (PFZ) near the dislocations and HAGBs. The low energy sites such as low-angle grain boundaries (LAGB) and coincidence site lattice (CSL) boundaries evidenced with less precipitates and acted as less favored nucleation sites. The pre-existing dislocations in the high temperature austenite phase locally alters the lattice orientation resulting the development of domains of interphase precipitates. This hybrid characterization of precipitates strengthened micro-alloyed steels provides broad understanding about the role of microstructural parameters on the development of precipitates during thermo-mechanical processing.

Keywords: AHSS, precipitates, correlative microscopy, TEM, TKD

SPC_017

78th Annual Technical Meeting
The Indian Institute of Metals

Growth mode and kinetics of austenite reversion transformation in 3rd generation AHSS: A in-situ synchrotron and ex-situ TEM study.

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Abstract

Reversion of martensite (✔ ’) to austenite ([redacted]) has recently been applied to many advance high strength steel (AHSS) for grain refinement in austenitic stainless steels, to enhance the strength and toughness in many maraging steels [1]. Since the 2000s austenite reversion transformation has drawn immense attention to develop duplex microstructure (ferrite and austenite) to harness the multiple strengthening mechanisms. These mechanisms include dislocation slip in ferrite, phase transformation and twinning in austenite. The goal to achieve an excellent combination of strength and ductility. This technique particularly applied to develop Medium Mn steel [2] a third-generation advanced high-strength steels for future automotive applications. In this study, we examine the effect of two different initial microstructures of a medium Mn steel on the kinetics of austenite reversion and elemental partitioning using the in-situ synchrotron and ex-situ S/TEM based elemental and automated phase/orientation mapping. These microstructures are cold-rolled tempered martensite (TCR) and hot-rolled and quenched (HRQ) martensite. The combination synchrotron lattice parameter evolution and S/TEM elemental mapping suggest that the austenite growth during the initial stage of holding (~1800 sec) by carbon diffusion without any Mn partition. On the other hand, for the cold rolled and tempered martensite, the austenite growth even at initial stage has contribution of both carbon and Mn partitioning. Synchrotron data after cooling to RT indicate that although the quench martensite samples form a large amount of reverted austenite during the holding they are thermally less stable compared to the austenite that forms in cold rolled and tempered martensite. The rate of austenite reversion during the inter-critical annealing, the thermal stability of reverted austenite significantly influences the final microstructure (specifically the relative phase fraction of ferrite, austenite and the fresh martensite) which can alter the mechanical properties of these AHSS steels.

Key words: In-situ synchrotron X-ray diffraction, Medium-Mn steel, Austenite reversion, Elemental Partitioning, S/TEM automated elemental, phase/orientation mapping.

SPC_069

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

MSD_013

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

SPC_022

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.

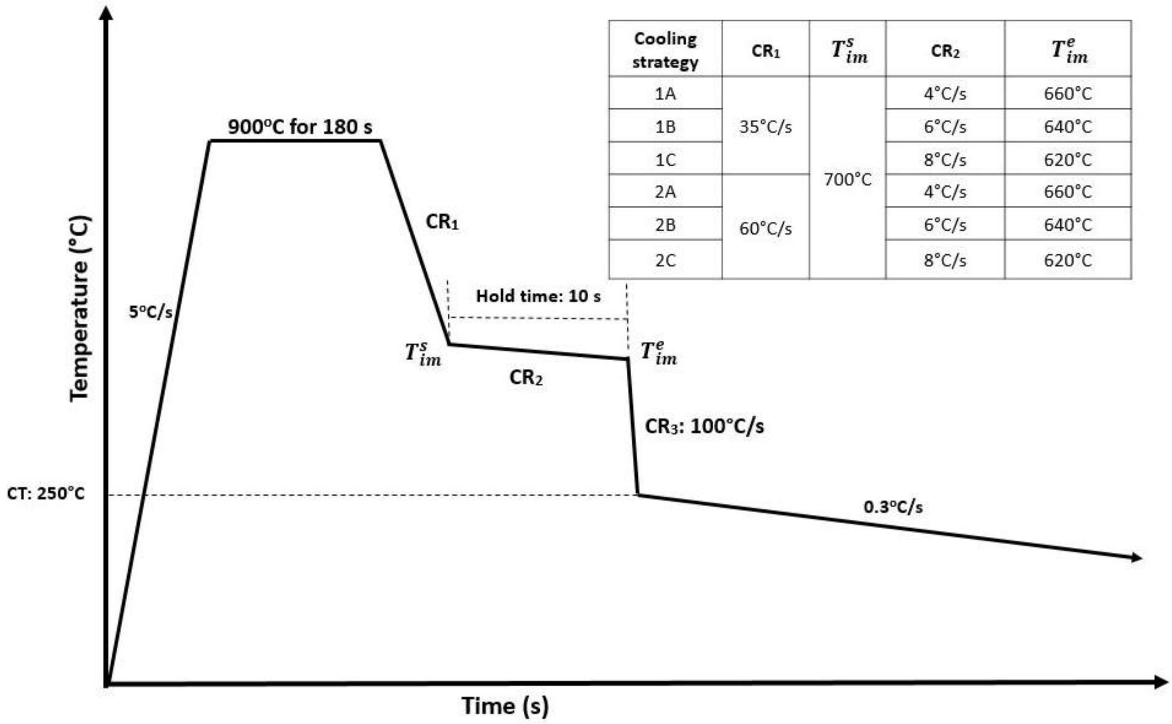
The present investigation involves a laboratory-cast low carbon manganese steel, alloyed with chromium and niobium to produce hot-rolled DP steel with tensile strengths ranging from 600 to 780 MPa. The two-step cooling strategy implemented on the run-out table (ROT) control the austenite transformation 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_{im}^{e}), from 660°C to 620°C, followed by rapid cooling at 100°C/s to CT of 250°C. A constant intermediate start temperature (T_{im}^{s}) 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_{im}^{e} 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_{im}^{e}: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_{im}^{e}: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_{im}^{e}: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.

SPC_046

Key Words: Dual phase, hot strip mill, run out table, CCT, intermediate start temperature(T^s_{im}), intermediate stop temperature (T^e_{im}), UTS.



Cooling strategy	CR_1	T^s_{im}	CR_2	T^e_{im}
1A	35°C/s	700°C	4°C/s	660°C
1B			6°C/s	640°C
1C			8°C/s	620°C
2A	60°C/s		4°C/s	660°C
2B			6°C/s	640°C
2C			8°C/s	620°C

Fig. 1: Schematic representation of two-step ROT simulation performed on DIL 805A/D thermomechanical simulator to produce hot rolled-DP steel

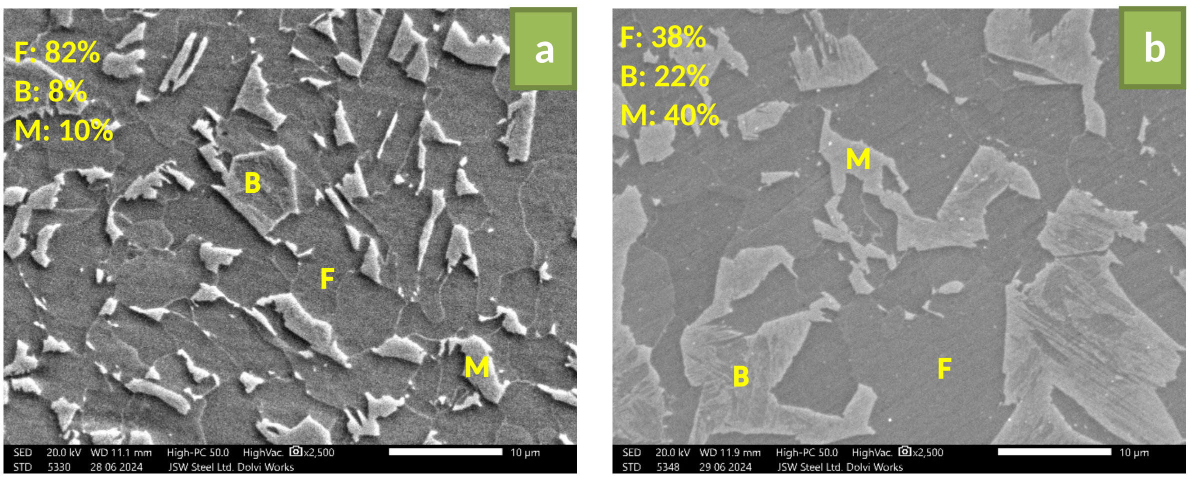


Fig. 2: Effect of cooling strategy on the developed microstructure in DP steels: a) Strategy

1A [CR_1:35°C/s, CR_2:8°C/s (T^e_{im}:620°C)] b) Strategy 2A [CR_1:60°C/s, CR_2:4°C/s (T^e_{im}:660°C)]

SPC_046

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

SPC_123

Microstructure, flow and work hardening behaviour of Ni-based superalloy BZL12Y

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Abstract

The nature of correlation between microstructure, texture, flow and work hardening behaviour during compression of the alloy BZL 12Y deformed under compression, has been investigated in the present study. The alloy microstructure in as cast condition contains γ, γ' and MC type of carbides. The lattice parameters of both the γ and γ' phases reveal extensive solid solution formation. The 0.2 and 2.0% yield strength values observed in compression lie respectively, in the range of 711-768 and 853-903 MPa. Flow curves of the samples exhibit single (2% deformation) and two-slope (4-10% deformation) behaviour (Fig. 1 a). The flow behaviour of 2% deformed sample follows the Ludwik constitutive equation, while that of 4 to 10% deformed samples is elucidated by Ludwigson constitutive equation. All the deformed samples have demonstrated three typical stages (I, II and III) of work hardening curves,with the exception of the sample deformed for 2%, which exhibits only stage I work hardening(Fig. 1 b). Deformation mechanism associated with the present samples involves the frequent crossing of multiple slip systems as a result of active pile-ups of dislocations.

(a)

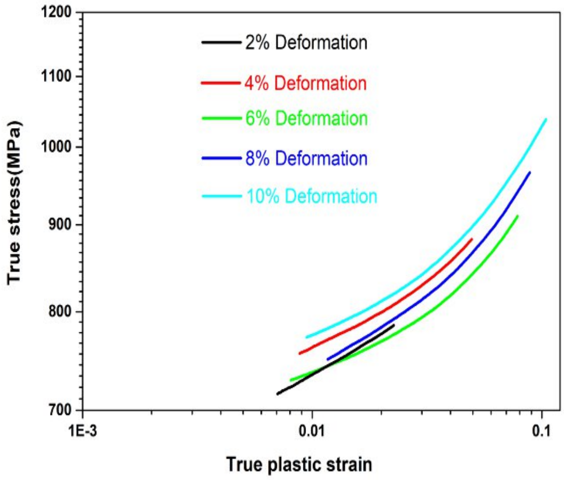

Fig.1 (a) True stress vs true plastic strain curve of the deformed samples 2-10% (log-log scale)

(b)

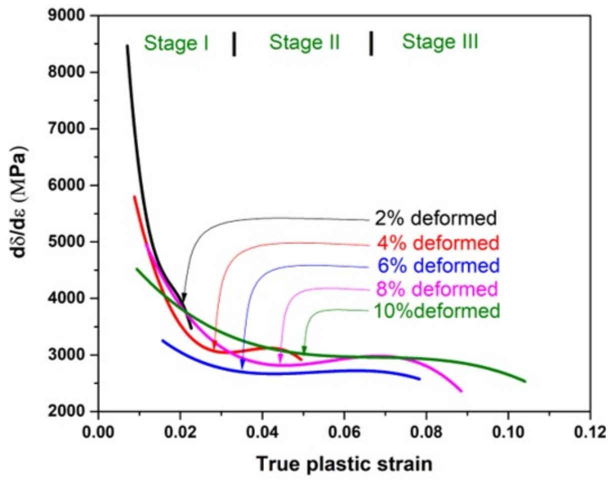

Fig. 1 (b) Work hardening curve of the deformed samples 2-10%

Keywords: Nickel base superalloy, microstructure, work hardening.

Effect of borosilicate glass on high temperature deformation behaviour of Alloy 690

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Abstract

Borosilicate glass is the matrix of choice to immobilize Indian high-level nuclear waste before its disposal, by the process of vitrification that usually works in temperature range of 800-1100°C. Borosilicate glass is extremely corrosive at such high temperatures to structural materials of vitrification equipment that are in direct contact with the molten glass such as process pots, thermowells, thermocouples, etc. Alloy 690, due to its high Cr content, is a preferred material for vitrification applications. During the vitrification process, Alloy 690 is simultaneously: (i) exposed to corrosive nature of borosilicate glass; (ii) under low stress conditions arising from sustained loads such as their self-weight, weight of glass, etc.; (iii) at elevated temperatures (800-1100°C); and (iv) for long process cycles, severely affecting the alloy's creep property. This necessitates having an understanding of the operative mechanisms and prediction of life span of the vitrification equipment when tested under the simultaneous presence of the above mentioned four conditions.

Carrying out creep experiments to simulate the vitrification conditions at a laboratory scale was rather very challenging. For this purpose a special creep test specimen was designed and qualified which can accommodate exposure to molten borosilicate glass during creep experiments. Alloy 690 and borosilicate glass used in this study composed of Ni-32Cr-11Fe (wt.%) and SiO_2-25 B_2O_3-22NaO-10Fe_2O_3-5TiO_2 (wt.%). Uniaxial tensile creep rupture tests were carried out using specially designed cylindrical creep specimens at temperatures from 800 to 1000°C and applied stress of about 0.2 - 0.7 of the yield strength at the respective temperature. The creep data was analysed in terms of creep strain, creep life, minimum creep rate and reduction in cross sectional area.

Exposure to glass had reduced the creep life by 1/5th to 1/3rd and increased the minimum creep rate of the alloy. The stress-exponent (n) calculated for all tested temperatures and stress regimes represented that creep was governed predominantly by climb assisted dislocation creep mechanism. The minimum creep rate increased and the creep life decreased as the stress increased, at all temperatures. Accumulation of creep strain in the alloy during the secondary creep was observed to be quite large when crept with glass, while the alloy exhibited a prolonged tertiary regime when crept without glass. At intermediate stress condition at 800 and 900°C the alloy exhibited multiple minima, unlike an ideal creep curve (creep rate vs. time) exhibiting a single minima. [1, 2] Usually, creep rate decreases with time within the primary creep regime representing a normal transient behaviour. This multiple minima were similar to the inverse transient behaviour exhibiting an initial increase in the creep rate, is

attributed to elastic interactions between solutes and dislocations, resulting in the viscous glide of dislocation, as reported in [1, 3, 4, 5].

References:

[1] Kumar et al.; JMR&T, 17(2022), 1553.
[2] Hatakeyama et al.; Mater. Sci. Eng. A, 814(2021), 141270.
[3] Kihara et al.; Metall. Trans. A, 11(1980), 1019.
[4] Burton et al.; Philos Mag A, 48(1983), 299.
[5] Kihara et al.; Metall Trans A, 11(1980), 1019.

Keywords: Alloy 690, creep, borosilicate glass, Creep deformation mechanism

Studies on laser surface alloying of Ti6Al4V alloy with FeCoCrMnTi multicomponent system

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Abstract

Titanium and its alloys are extensively used in medical, aviation and automobile sector due to its high strength to weight ratio and corrosion resistance. However, it is hampered by its low hardness, poor wear and erosion resistance properties which may be improved by various surface modification methods like, thermal spray, PVD, CVD, etc. Laser surface alloying (LSA) involves melting of thin layer of substrate surface and simultaneous deposition of alloying elements in the melt pool to develop the alloyed zone. In the past, Laser surface alloying has been successfully applied to improve hardness, wear resistance and high temperature oxidation resistance of metal and alloys. LSA is also successfully applied on titanium and its alloys for improving wear, corrosion resistance and high temperature oxidation resistance for biomechanical components [1]. In the present study, Laser surface alloying of Ti6AL4V has been carried out using multicomponent system of FeCoCrMnTi alloy (in equimolar composition). By pre-deposition of precursor powder to a thickness of 0.6-0.8 mm and subsequent melting using a 6.6 kW fiber optics delivered Yb-YAG diode laser (LDF 6000-40, Laser line, Germany) with a wavelength of 900–1100 nm and an optical fiber beam delivery system (spot diameter = 3.6 mm) and nitrogen as shrouding environment. The process parameters for the current investigation are laser power (kW) and scan speed (mm/s) while maintaining constant heat energy flux {Energy flux = laser power/(scan speed*spot diameter)}. So, the process parameters used are 2kW – 20mm/s and 3kW-30mm/s. Followed by a detailed correlation between microstructure and process parameters these optimum process parameters for LSA has been derived. Overlap of 25% is maintained between two alloyed tracks to maintain uniform alloyed zone thickness. Detailed microstructure and phase analysis has been carried out using FEG-SEM and XRD. Processing under optimum parameters led to improvement in hardness (800 - 1300 HV0.05) and decrease in wear rate (0.0043 mm^3/min for 2kW-20 mm/s and 0.00472 mm^3/s for 3kW-30 mm/s as compared to 0.02mm^3/s for as received substrate). Mechanism of wear has been established.

Key words: Titanium, Laser, Alloying, Ti6Al4V, FeCoCrMnTi, multicomponent, pre-deposition, Wear.

Reference

[1]. Dutta Majumdar, J. and Manna, I., 2011. Laser material processing. International materials reviews, 56(5-6), pp.341-388.

SASH modeling of superni 625 alloy: correlating microstructure, deformation micromechanism and tensile characteristics

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Abstract

Ni-based superalloy 625 comprised high strength, creep strength, fatigue strength and corrosion resistance at elevated temperature, which made it a promising alloy for high-temperature applications. The current study focuses on the development of secondary phases, tensile properties and deformation behavior of cast superni alloy 625 (HN) with ageing treatment. The experimental procedure includes ageing treatment of homogenized alloy at 700°C for various intervals of time up to 1000h followed by hardness and microstructural evaluation with the help of SEM-EDS and TEM. Subsequently, tensile test of selected aged samples was conducted followed by fracture analysis. The results revealed γ" precipitates as the major strengthening phase. A gradual increment in average precipitate size and area fraction of γ″ phase with ageing time was observed. Furthermore, primary MC-type carbides transformed into secondary carbides through following phase transformation paths: (I) MC+ $\gamma \rightarrow M_{23}C_6$ and (II) MC+ $\gamma \rightarrow M_{23}C_6 + \delta$. The yield strength increased till 650h of ageing (by 310MPa) along with reduction in ductility. The strength deterioration on further ageing can be attributed to a non-conventional slip-to-twin transition in the shearing of γ″ phase caused by the coarsening of coherent γ″ precipitates over a critical size (~60 nm).

Microstructural evolution during long term thermal aging of Ni-based superalloy IN740H

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Abstract

This study investigates the microstructural evolution of the γ'-strengthened Ni-based superalloy IN740H during prolonged thermal aging at 800 °C for varying durations: 4 hours (as-received), 100 hours, 1000 hours, and 10,000 hours. Multi-scale characterization techniques including EBSD, XRD, SEM, EDS, and S/TEM were utilized to study the microstructural evolution. The alloy exhibited exceptional thermal stability, with only minimal grain coarsening observed i.e., grain size increased slightly from 110 μm in the as-received condition to 135 μm after 10,000 hours of aging. The length fraction of coincident site lattice (CSL) boundaries remained stable, underscoring the alloy's resistance to thermal degradation. A key microstructural change was the precipitation of $Cr_{23}C_6$ at grain boundaries, which evolved from discrete islands to continuous chains with aging. Additionally, γ' precipitates coarsened significantly, growing from 18 nm to 200 nm. Initially driven by γ/γ' interfacial energy, this coarsening was dominated by strain energy in later stages, leading to a morphological shift from spherical to cuboidal shapes. This evolution was linked to an increasing positive lattice misfit between the γ' precipitates and the γ matrix, rising from 0.2% after 100 hours to 0.46% at 1000 hours, and stabilizing at 0.51% after 10,000 hours. TEM and STEM analyses revealed that Ni, Al, and Ti preferentially segregated into the γ' precipitates, while Cr remained in the γ matrix. These segregation trends, confirmed by partition coefficients ($K^{\gamma'/\gamma}$), significantly impacted the γ' precipitate misfit and morphological evolution. Overall, the microstructure of IN740H demonstrated minimal grain coarsening accompanied by γ' coarsening with morphological changes during long-term aging.

Keywords: Microstructural evolution, γ' precipitate, γ' coarsening, Ni-based superalloy

Optimization of Heat treatment in α-β Titanium alloy during development of Ring forging to improve low mechanical properties through Structure-Property correlation.

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Abstract

During the development of a Ring Forging from an α-β Titanium alloy of specification AMS 4928 (Ti-6Al-4V) alloy, mechanical properties were not meeting the specified drawing requirements of the first two batches. The tensile specimens were prepared from the heat treated Ring forgings [Solutionising followed by Annealing]. Mechanical properties of the 1st batch were not meeting with respect to Elongation values. The 2nd batch of Ring forgings was not meeting the requirements with respect to Proof as well as Ultimate Tensile Strength (UTS) values.

The failed tensile specimens of both the batches were subjected to Microstructure examination. The 1st batch showed completely transformed β structure, which explains the drop in elongation value (poor ductility). Investigation with respect to furnace data revealed presence of temperature rise beyond the β-transus temperature, which could have resulted in completely transformed beta. The 1st batch is quarantined as re-heat treatment cannot improve transform a completely transformed β microstructure to a satisfactory Solutionised and Annealed microstructure.

However, 2nd batch did not reveal typical Solutionised & Annealed Microstructure. Therefore, a series of heat treatment trials were conducted on a one-inch section of a Ring forging at laboratory scale from 2nd batch to obtain typical Solutionised and Annealed Microstructure. Tensile specimens were prepared from this section of Improved Heat treatment, which met the specified drawing requirements. Further, mechanical properties & microstructure was proved on the cross section (actual thickness) of Ring forging.

Ring forgings of 2nd batch were re-heat treated as per the improvised Heat treatment cycle to achieve good mechanical properties. This paper discusses how a structure-property correlation study can be used for improving the mechanical properties in Ti-6Al-4V alloy.

Key words : Ring Forging, α-β Titanium alloy, Mechanical Properties, Completely Transformed β Microstructure, Heat treatment.

Estimation of β-transus temperature of Ti-6Al-2V-1Fe-1Cr alloy

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Abstract

Titanium alloys are widely used as structural materials in the field of automotive, aerospace, and medical industries due to their excellent high-temperature specific strength and corrosion resistance. Ti-6Al-4V alloy is most popular for structural applications due to its better combination of mechanical properties and biocompatibility. However, the presence of large prior β grains and thick α lamellae in Ti-6Al-4V alloy restricts its use in as-cast condition. In the present study, we investigated a new two-phase (α+β) Ti alloy Ti-6Al-2V-1Fe-1Cr (Ti-6211), which has finer prior β grains. Presence of strong β stabilizer (Fe, Cr) leads to increase the amount of β phase fraction in this alloy. Higher amount of β phase fraction, finer prior β grains leads to increase the strength and ductility as well as decrease the β-transus of this alloy than Ti-6Al-4V alloy. Apart from this, lesser toxicity can be expected from this alloy due to presence of lower amount of V.

The alloy was cast in a vacuum arc melting furnace and studied for the microstructure and chemical composition. Metallography, thermal analysis, and CALPHAD approach were used to estimate the β-transus temperature. The estimation of β-transus is important for developing the TMP processing parameters. Microstructure studies reveal the presence of basket weave structure with finer β grain size (~572 ± 240 μm) and higher β volume fraction (~ 16%) than Ti-6Al-4V alloy in as-cast condition. CALPHAD calculation estimates the β-transus to be ~ 976°C. Thermal analysis by differential scanning calorimetry (DSC) and differential thermal analysis (DTA) provides the temperature range of 750°C to 975°C for α to β phase transformation.

Based on the thermal analysis, metallographic studies were carried out on heat-treated samples to estimate the exact β-transus. The samples were heat treated with a heating rate of 5°C per minute in the range of 750°C to 975°C and soaked for 30 minutes at target temperature before rapid quenching in ice water. The micrograph of the sample heat treated at ~970°C shows the presence of acicular or martensitic α, which confirms the β-transus of 970 ± 5°C. The error of 5°C is due to the inaccuracy in temperature measurement and delay in quenching. Finally, the β-approach curve (β volume fraction of as a function of temperature) was determined within the temperature range 750°C to 970°C.

Keywords: Ti-6Al-2V-1Fe-1Cr, Microstructure and chemical composition, Thermal analysis, β-transus temperature

Study on microstructure evolution and its effect on ultrasonic response of CP70 Titanium alloy for spacecraft application

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Abstract

Commercially pure Titanium (Grade 4), also known as CP70 is used as liner material in realizing composite overwrapped pressure vessel for spacecraft propulsion systems. Pressure vessel consist of cylindrical part and end domes made of CP03 and CP70 Titanium respectively. These grades of Titanium are considered for its good low-cycle fatigue performance and high failure strain. The geodesic isotensoid shaped liner are realized out of hot closed die forgings. CP70 being a single-phase alloy, mechanical properties and ultrasonic response are very sensitive to microstructure.

To understand the relation between microstructure and ultrasonic response, a series of deformation experiments were conducted using Gleeble simulator and hydraulic press over a temperature range of 760-925°C. Flow curves were analysed to determine the critical conditions for dynamic recrystallization. This data was implemented in pan-cake forgings through single and multi-step upsetting. Deformation around 840-880°C showed the presence of elongated, fine equi-axed and partially recrystallized grains across the upset pan-cakes. Above 900°C, presence of transformed microstructure was observed. Ultrasonic response in terms of signal to noise ratio (S/N) of forged pan-cakes was recorded and compared. Finer grain size microstructure shows better ultrasonic response compared to coarser and elongated grains. Both single and multi-step upsetting at 880 and 900°C followed by annealing at 660 and 700°C showed fine equi-axed grains with good S/N (> 12 dB w.r.t 0.8 FBH). Flow hardening, flow softening and steady state flow were observed with change in temperature and strain rate.

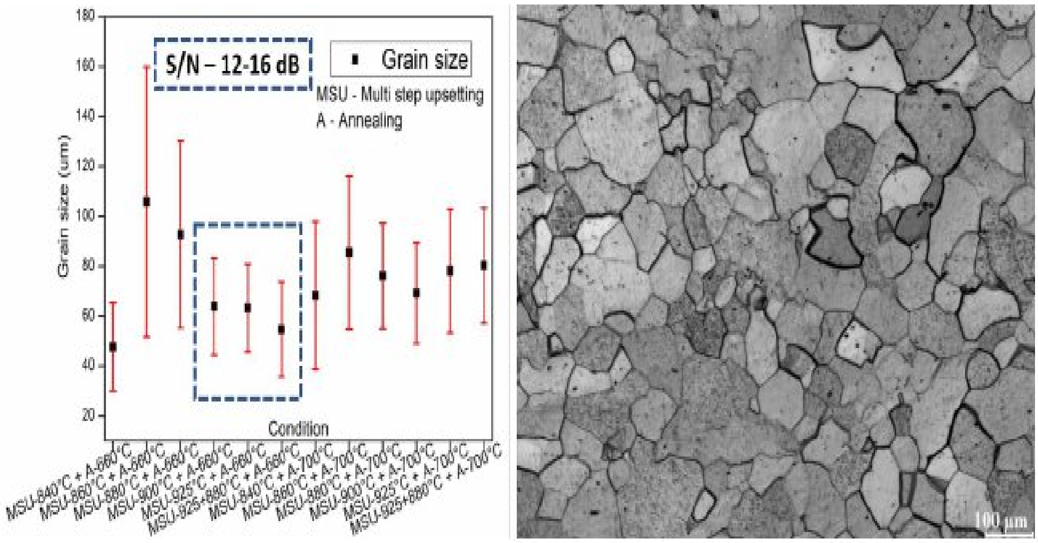

Fig. 1: Comparison on grain size achieved vs ultrasonic response and typical equi-axed microstructure obtained from multi-step upsetting

Key words: CP70 Titanium, Thermo-mechanical processing, Microstructure evolution, Ultrasonic test response

Ductile-Brittle Transition Temperature determination of India-specific Reduced Activation Ferritic-Martensitic (IN-RAFM) steel by Small Punch tests

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Abstract

IN-RAFM steel is a modified version of conventional grade 91 steel, with the substitution of Mo by W and Nb by Ta to reduce induced radioactivity. These steels exhibit exceptional resistance to irradiation swelling, and superior mechanical properties compared to austenitic stainless steels. These attributes make them promising candidate material for breeding blankets of International Thermonuclear Experimental Reactor (ITER) and future fusion reactors, where structural materials experience intense neutron irradiation (~14MeV energy), and higher thermo-mechanical loads. However, a primary drawback of these ferritic-martensitic steels is their inherent susceptibility to irradiation embrittlement.

Irradiation embrittlement manifests as a decline in ductility and fracture toughness, accompanied by an increase in the ductile-to-brittle transition temperature (DBTT). Conventionally, DBTT is determined through impact testing on Charpy V-notched (CVN) specimens with dimensions of 10 × 10 × 55 mm^3. Due to the relatively large volume of Charpy specimens, it is often challenging to irradiate sufficient number of specimens for the DBTT determination within the limited irradiation volume available in the reactors.

In such situations Small Punch (SP) testing, which utilizes 8 mm diameter and 0.5 mm thick disk samples, has proven to be effective. During SP test, a disc specimen is clamped between two dies and loaded centrally by a hemispherical punch till failure. The applied load is recorded as a function of specimen bottom deflection (or) punch displacement, from which various mechanical properties are determined. By carrying out SP tests at a range of temperatures, transition temperature curve similar to the one obtained from Charpy impact tests is generated. The transition temperature thus obtained from SP test can be correlated with DBTT determined from CVN impact tests.

In this study, SP tests were performed on IN-RAFM steels at temperatures ranging from room temperature (32° C) to -193° C. The load-displacement curves were analyzed to determine the fracture energy at different temperatures. From the fracture energy-temperature data, SP transition temperature (T_{SP}) was determined by tanh function fitting. T_{SP} was correlated with the DBTT determined by standard CVN impact tests. Obtained SP-CVN transition temperature correlation was compared with literature reported values. Fractured surfaces of the SP tested samples were examined under Scanning Electron Microscope and fractography results were corroborated with the deformation behavior in SP tests in ductile, brittle and transition regions.

Key words : IN-RAFM, Small Punch tests, SP and CVN transition temperature correlation, Fractography

MSD_051

Dislocation Strengthening of Low-carbon Martensitic Steel by Accelerated Cooling

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Abstract

Steels for structural applications are required to possess a combination of mechanical and other material properties such as high strength, large ductility, superior toughness, good weldability etc. Often, these properties are contradictory in nature and pose a serious challenge to the steel manufacturers to meet the requirements. For example, increasing carbon content of the steel would increase strength but at the cost of toughness and weldability. The purpose of the present work was to demonstrate the possibility of increasing strength of a low carbon steel with accelerated cooling technique to form a heavily dislocated martensitic microstructure.

Continuous cooling experiments were performed with a low carbon (< 0.1wt%) steel sample containing some amounts of manganese and silicon in a Gleeble simulator with varying cooling rates after austenitizing at 950 ^{o}C for 3 minutes. Metallographic study revealed that the microstructure changed from ferrite-pearlite to ferrite-bainite-martensite in the cooling rate regime of 0.5 – 20 ^{o}C/s. By contrast, the steel evolved into a fully bainitic or martensitic microstructure with further increase in cooling rate to 50 – 100 ^{o}C/s. The microstructural changes led to a three-fold rise in hardness, hence strength, of the sample.

Further analysis based on Electron Back-scattered Diffraction images revealed the sample cooled at the maximum rate to contain the highest density of dislocations. These were characterized with a network structure of low to medium angle misorientation lines, resembling a highly dislocated lath structure of the martensite. The resultant hardness due to the dislocation substructure matched with that of a steel containing thrice the carbon content. The accelerated cooling technique may thus be used to significantly reduce carbon content of steel products for structural applications with the advantages of better weldability and toughness.

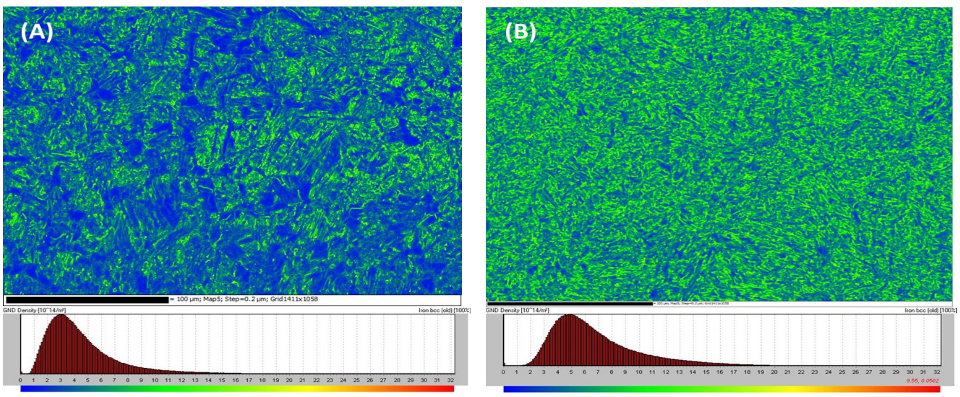

Fig 1: Increased dislocation density with faster cooling in (B) over (A) for a low carbon steel

Keywords : steel, microstructure, dislocation, electron back scattered diffraction, hardness
SPC_031

Industrial Viability of Nanostructured Bainitic Steel

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Abstract

Strong demand from the automotive industry for steels with a specific combination of properties is driving the industrial world to explore more in advanced high-strength steels (AHSS). As the world is moving towards running vehicles more efficiently with energy resources like lithium-ion batteries, solar power, hydrogen energy, etc., the urge for feature-rich steel to be used in automobiles is also increasing. Apart from that, crash safety of passengers, formability, and weldability of steels would be the most important characteristics required to develop them at a mass production scale. Decades of research on nanostructured bainitic steels have shown a very fascinating combination of properties about this material i.e. high strength along with ductility due to its fine Nano-scale micro constituents, bainitic ferrite, and retained austenite. Its capability to show the TRIP effect under loading conditions makes it a better material to be used in an automobile body for crash resistance. Low-temperature isothermal transformation helps in achieving a very high interfacial density but makes the process very slow making it industrially non-viable in terms of processing time and cost. So, to overcome this difficulty, ausforming, a potential method used to enhance the transformation kinetics followed by low-temperature isothermal holding has been used in this research. Different ausforming strains 7%, 15%, 30%, and 60% have been used to understand how much deformation is helping in increasing the transformation kinetics.

An attempt was made to understand the critical strain value which is accelerating the transformation kinetics because excessive deformation showed an increase in austenite stabilization and thus an increase in its final phase fraction in the specimen. Austenite contributes to improved toughness and ductility but over-stabilization might lead to undesirable properties like reduced hardness or strength. A decrease in hardness from 380HV to 360HV and corresponding strength from 1220MPa to 1152MPa was observed with increasing ausforming strain from 7% to 60%. Thus, optimizing the process is important to achieve optimized properties. Increased ausforming strains led to changes in phase morphologies. A detailed study was carried out to look into the carbon redistribution using 3D atom probe tomography, focusing on carbides, transition carbides, or carbon clusters. Our study revealed the formation of austenite films of a few 16.92nanometers of width with a maximum carbon percentage of 10.41 at.%. Carbon clustering inside bainitic ferrite was studied for many different sized carbon clusters ranging from 3-7nm and their distribution in the entire specimen volume. One of the clusters with 14.13 at. % carbon was observed without any precipitation of cementite in the ferrite matrix. This insight into carbon redistribution enhances the understanding of microstructural evolution and properties optimization by thermomechanical treatment followed by isothermal holding. The main aim of this research is to do preliminary

lab-scale processing to replicate it to the industrial pilot plant scale in the future with the help of hot rolling followed by isothermal holding.

Keywords: nanostructured bainite, ausforming, 3D atom probe tomography :

SPC_066

Understanding the TRIP effect in hot- and cold-rolled Al-added medium-Mn steels: insights into austenite stability and martensitic transformation kinetics

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Abstract

A third-generation low-density TRIP-aided steel has been subjected to a novel thermomechanical process involving two different deformation routes. While the first one employs hot rolling, the second one pursues cold rolling after hot rolling, prior to intercritical annealing treatments. These samples are named as hot rolled-annealed (HRA) and cold rolled-annealed (CRA), respectively. The effect of associated microstructure evolution on the mechanical properties of these samples has been assessed. The morphological variation, local strain distribution, recrystallization behavior, and phase transformation have been studied using the scanning electron microscope, electron backscattered diffraction, X-ray diffraction, and dilatometry techniques. Both HRA and CRA samples are noted to comprise α/α-′ ferrite/martensite and austenite phases, along with banded δ-ferrite, owing to higher Al content. However, the HRA sample contains lath-shaped austenite-ferrite microstructure, while CRA reveals nearly equiaxed morphology. Furthermore, variations in the deformation routes prior to the annealing schedule lead to differences in austenite reverted transformation behavior, recrystallization characteristics, and mechanical stability. Interestingly, the tensile properties are notably superior in HRA, with a tensile strength of 1100 MPa and a total elongation of ~ 35%. This is primarily attributed to the varying transformation ratios of austenite to martensite phase (TRIP effect) during deformation, influenced by the varying austenite stability and ferrite (α and/or δ) deformation. In-situ digital image correlation during tensile tests and interrupted tensile tests reveal that the deformation response is dictated by the variations in austenite stability. HRA initially exhibits lower austenite stability, which then significantly increases during tensile deformation. In contrast, reduced austenite stability with tensile deformation is observed in CRA. The noted role of austenite stability and the contribution of δ-ferrite deformation in dictating excellent properties are of particular interest for the design and development of high-Al-added manganese steels.

Keywords: Al-added Medium-Mn steel; TRIP effect; Austenite stability; Interrupted tensile test; In-situ DIC; Olsen and Cohen model

SPC_101

Effects of tempering on tensile behaviour of Fe-C-Mn-Si carbide free bainitic steel

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Abstract

Tempering leads to the redistribution of carbon within the matrix, causing carbon to precipitate either as intermittent carbides or cementite. The current work aims to correlate the microstructural developments due to tempering with the resulting tensile behavior of a carbide-free bainitic steel. XRD results showed variations in the retained austenite (RA) volume fraction starting from 300°C, along with changes in the carbon content within the matrix. Complete dissociation of RA was observed at 500°C, transforming into other phases. To investigate the dissociated phases, TEM was performed. The 300°C sample showed no dissociation of RA, but there was some precipitation observed from the ferrite matrix. The HRTEM method was used to analyze the fine precipitates (~10 nm) present. It revealed that ε-carbide was present in the matrix at 300°C and it precipitated from the bulk. At 400°C, XRD showed that nearly 50% of RA had dissociated, and about 40% of dislocations had been annihilated, resulting in the formation of cementite, as confirmed by TEM results. The 500°C sample in TEM showed intense precipitation of carbides in the matrix, which was previously carbide-free in the AR condition. The precipitates were confirmed as cementite through SADP and HRTEM analysis. Tensile tests were performed on these tempered samples. The as-received (AR) sample showed high strength and elongation, while the ET-300 sample exhibited higher yield strength (YS) but a reduced ultimate tensile strength (UTS). The ET-400 sample showed higher YS but a lower UTS, even lower than the ET-300 sample. A drastic decrease in strength and elongation was observed for the 500°C sample, as no RA was present in the matrix to provide elongation. The Voce hardening equation was used to understand the strain hardening behavior, where two derived parameters were calculated after fitting the true stress-strain graph to the equation. The parameters k_1 and k_2 were calculated for all the tempered samples. k_1 appeared to be the same for all the tensile-tested samples. Variation in the dislocation annihilation rate (k_2) was observed, showing an increase with rising tempering temperatures. Dislocation annihilation was higher at 500°C, as the matrix had a lower carbon concentration, reducing the ability to pin dislocations. The increase in temperature led to more carbon segregation from the matrix, resulting in a lower ability to pin dislocations, which made slip easier without obstacles, ultimately leading to lower strength.

SPC_115

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;

ESU_135

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

SPC_018

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 (T_C) 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.

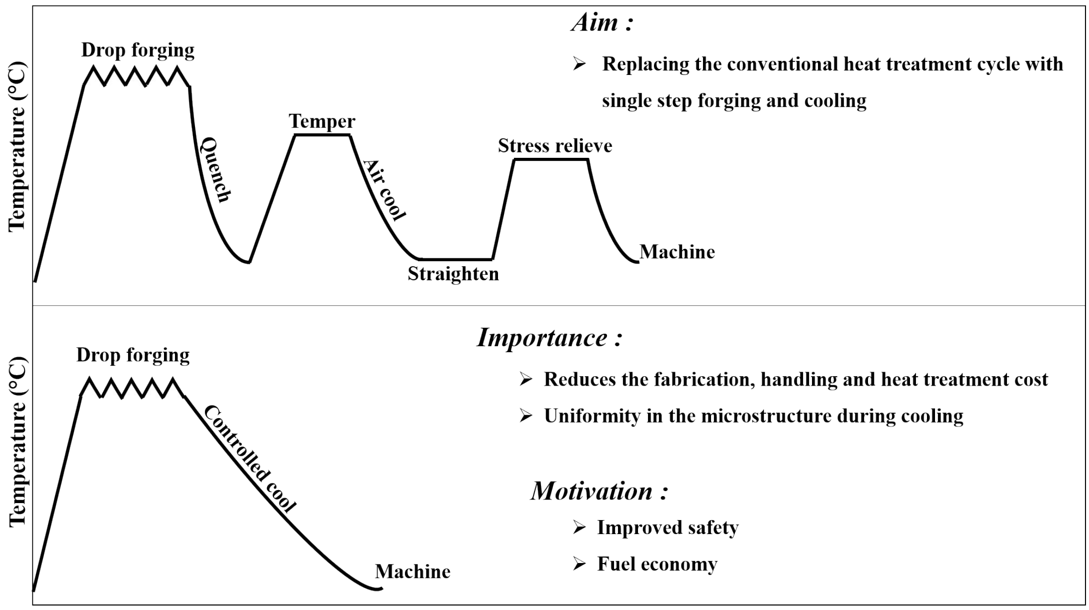

Fig. 1: Replacing the conventional heat treatment cycle with single step forging and cooling

Key words: Carbide free bainite, tensile strength

SPC_122

Effect of solute segregation in Cu-Al alloys: Coupling Molecular Dynamics and Monte-Carlo simulations

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Abstract

It is well known that segregation of solute atoms takes place to defects such as dislocations and stacking faults, which affects deformation behaviour of materials. In this study, we focus on the strengthening effect of segregation to dislocations and stacking faults. For this study, we have chosen commercially pure copper (Cu) and Cu-8wt. % Al (Cu8Al) alloys, which are both single phase Face Centered Cubic (FCC). These samples were subjected to quasi-static interrupted tensile tests at room temperature. The tests were interrupted at an interval of 0.2 strain with various delays (from 0 (no delay) to 120 minutes) between unloading and reloading. We find that interrupted curves show higher flow stress as compared to the uninterrupted curve and the increase in flow stress varies with the delay time, being higher for longer delay. In order to identify the role played by various strengthening mechanisms, we have performed hybrid Molecular Dynamics (MD) and Monte Carlo (MC) simulations of deformation of both commercially pure Cu and Cu8Al samples. Our simulations show that both Cottrell effect and Suzuki effect contribute to the increase in flow stress, with higher contribution from Cottrell effect.

Keywords: Tensile tests; MD-MC simulations; Stacking faults; Cottrell atmosphere; Suzuki effects.

SPC_052

Diffusion-induced phase growth kinetics in CoNi/Al and CoCrNi/Al diffusion couples

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Abstract

Solid-state diffusion plays a crucial role in several material phenomena, including precipitation, oxidation, grain growth, and phase transformation. Interdiffusion between metals and alloys is a common phenomenon in engineering materials and is integral to processes like diffusion bonding, bond coating, flip-chip technology, and brazing. Phase evolution studies in the interdiffusion zone are essential to assess the mechanical and operational performance of the assembly. At present, limited work has been done to understand the influence of atomic diffusion on the phase formation in binary and ternary alloys.

This study investigates the phase growth evolution in CoNi/Al and CoCrNi/Al diffusion couples (DC) annealed at 630°C for durations of 48, 96, 144, and 192 hours. Annealing at such a high temperature leads to the development of distinct phases in the interdiffusion zone (IDZ), which are characterised using scanning electron microscopy (SEM), electron dispersive spectroscopy (EDS), electron probe microanalyzer (EPMA), and micro-X-ray diffraction (XRD). BSE micrographs show that the addition of chromium (Cr) to binary CoNi alloy, forming a ternary CoCrNi alloy, leads to an increase in intermetallic phases within the IDZ(Figure 1). Upon closer examination, a transition zone with segregated phases is observed in the CoCrNi/Al DC at longer annealing hours. As annealing time increases, the phases developed in the IDZ expand, enabling the calculation of phase growth kinetics in the diffusion couple. These results provide valuable insights into atomic diffusion and phase development in binary and ternary alloys, highlighting their potential for high-temperature joining applications.

Keywords: Interdiffusion studies, phase growth kinetics, correlative microscopy

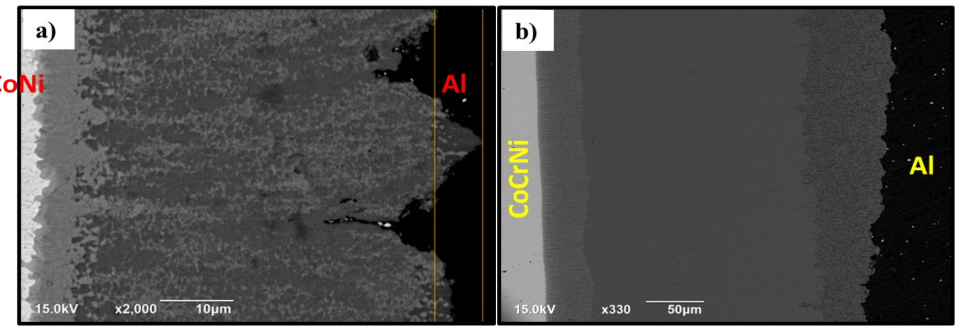

Figure 1: BSE micrographs showing Interdiffusion zone in a)CoNi/Al and b) CoCrNi/Al diffusion couples.

SPC_067

Role of nanosized SiC particles on the microstructural evolution and mechanical behavior of FSPed AA5083 alloy

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Abstract

The incorporation of nanosized SiC particles (n-SiC) into the aluminum alloy matrix substantially increases the driving force for dynamic recrystallization, resulting in enhanced mechanical properties. Therefore, aiming to improve the performance of these alloys, this study used innovative stir casting followed by friction stir processing (FSP) method for developing fine grained-high strengthen AA5083-SiC nanocomposites. AA5083-2wt.%SiC nanocomposite was found superior among all the nanocomposites upto 3wt.%, in terms of microstructure (~4 um) and tensile strength (YS: 224 MPa) as compared to the unreinforced AA5083 alloy (~6 um and YS: 152 MPa). Microstructural investigations (SEM-EBSD, TEM) confirmed the uniform n-SiC & intermetallics distribution along the grain boundaries and within the fine recrystallized grains. Dominant mechanisms for microstructural evolution by recrystallization phenomena included CDRX and PSN (dispersion strengthening). Along with improvement in hardness the wear resistance of the nanocomposite was increased by the homogenously distributed n-SiC particles. Overall, the entire study revealed the pronounced role of n-SiC particles in the advancement of microstructure and mechanical behavior of the alloy.

Keywords: AA5083 alloy; Friction stir processing; Recrystallization; Grain refinement; Electron microscopy.

SPC_126

Effect of Zr addition on microstructure and mechanical strength of Al-Ce based alloys

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Abstract

The microstructure and mechanical properties of as-cast and heat-treated Al-2.1Ce, Al-2.1Ce-0.15Zr (at. %) alloys are investigated in this present work. The alloys were melted by vacuum arc melting under Ar atmosphere on a water-cooled copper mold, followed by suction casting into 6 mm slab. As-cast alloys were directly aged at 350 °C and 400 °C to understand the aging response of the alloys at these temperatures. Microstructural characterization and compositional analysis of the alloys were done by using Optical Microscope (OM) and Scanning Electron Microscope (SEM). The microstructure of as-cast alloys consists of primary Al and eutectic phase, a mixture of Al and $Al_{11}Ce_3$. The eutectic phase exhibits bimodal distribution of (fine and coarse) eutectic structure along with different morphology. Fine and coarse eutectic structure show rod like and plate like morphology respectively. Addition of Zr in Al-2.1Ce alloy reduces the size and spacing of the finer eutectic structure by 16 % and no effect of refinement on coarse eutectic as compared to Al-2.1Ce alloy. The structural and phase analysis of the two alloys were determined by using XRD, which confirm the presence of Al and intermetallic a-$Al_{11}Ce_3$ phases. The binary Al-2.1Ce alloy has an average micro-hardness of 57 Hv, whereas the ternary Al-2.1Ce-0.15Zr alloy has micro-hardness of 63 Hv. This improvement of hardness is possibly due to the much finer eutectic microstructure present in the Zr added alloy. Isothermal aging of Al-2.1Ce alloy at 350 °C and 400 °C does not show any response to aging, whereas the Zr added alloy demonstrates a significant response to aging at same temperatures. Comparatively better aging response is observed at 350 °C and peak hardness remains stable even after 500 h. Zr added alloy exhibits better tensile properties at room temperature (RT) and elevated temperature (200 °C and 300 °C).

Key words: Al-Ce alloy, bimodal eutectic microstructure, high temperature mechanical properties.

References:

1. Wang, Weiyi, Qinglin Pan, Geng Lin, Xiaoping Wang, Yuqiao Sun, Xiangdong Wang, Ji Ye et al. "Microstructure and properties of novel Al-Ce-Sc, Al-Ce-Y, Al-Ce-Zr and Al-Ce-Sc-Y alloy conductors processed by die casting, hot extrusion and cold drawing." Journal of Materials Science & Technology 58 (2020): 155-170.
2. Wang, Weiyi, Qinglin Pan, Geng Lin, Yi Yu, Xiangdong Wang, Yaru Liu, Yuqiao Sun et al. "Internal friction and heat resistance of Al, Al–Ce, Al–Ce–Zr and Al–Ce–(Sc)–(Y) aluminum alloys with high strength and high electrical conductivity." Journal of Materials Research and Technology 14 (2021): 1255-127

SPC_135

Microstructure and creep behaviour of SiC nanoparticles reinforced Mg-5.0Al-2.0Ca-0.3Mn alloy

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Abstract

The influence of SiC nanoparticles (SiC_{np}) additions on the microstructure and creep behaviour of squeeze-cast Mg-5.0Al-2.0Ca-0.3Mn (AXM520) alloy is investigated. The concentrations of the SiC_{np} are varied from 0.5 to 3.0 (wt.%), and the nanocomposites (NCs) are abbreviated as NC0.5SiC, NC1.0SiC, NC2.0SiC and NC3.0SiC. The microstructures of the AXM520 alloy and NCs consist of α-Mg, a eutectic of α-Mg and $(Mg,Al)_2Ca$ (C36), and an Al_8Mn_5 phase. Additionally, the SiC phase is also present in the NCs. The continuous network of the C36 phase in the NCs is fragmented and becomes discontinuous with the increase in the fraction of the SiC_{np}. All the NCs revealed improved creep performance compared to the AXM520 alloy. The creep rate of the NCs decreases with the increase in the SiC_{np} content. The NC2.0SiC exhibited an improvement in creep resistance by 73.2% compared to the alloy. However, the creep resistance deteriorated since the amount of the nanoparticles was further increased in the NC3.0SiC, leading to agglomeration. The stress exponents vary from 5.0 to 6.7, and activation energies vary from 89.8 to 101.8 kJ/mol, implying that the creep in the materials is controlled by the climb of dislocation assisted by the pipe diffusion. The pile-ups of dislocations took place around the C36 phase and near the SiC_{np}. The additional strengthening owing to the presence of the SiC_{np} in the NCs was responsible for their improved creep performance compared to the AXM520 alloy.

Keywords: Magnesium alloy; Nanocomposite; Squeeze-casting; Microstructure; Creep

SPC_144

Influence of Zr content on the precipitation behaviour of cast Al-Cu alloy

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Abstract

Micro alloying of Al-Cu alloy is one of the crucial strategies to enable them for high temperature applications. The primary strengthening metastable θ' precipitate coarsens and transforms to stable θ precipitate upon extended elevated temperature (>200^{0}C) exposure leading to a significant degradation in almost all of the mechanical properties [1]. Simultaneous addition of Mn and Zr can effectively reduce the θ' precipitate coarsening by preferential segregation at the precipitate-matrix interface [2]. Although the synergistic effect of Mn and Zr is well studied, the individual effect of these elements are yet to be understood. In the present study, Al-Cu alloys with varying Zr content (0.1-0.4 wt%) were prepared via conventional melting-casting route. Under the transmission electron microscope (TEM), all the alloys show a uniform distribution of θ' precipitate throughout the microstructure. However, as the Zr content is increased, additional $L1_2$-Al_3Zr precipitates can be observed (Figure 1a). The $L1_2$-Al_3Zr precipitates possess excellent high temperature stability, thereby making them a beneficial addition along with the primary strengthening θ' precipitate. However, when the Zr content is low, the formation of Al_3Zr precipitates is significantly supressed leading to the presence of the Zr atoms within the solid solution (Figure 1b). The Zr atoms then segregate at the θ'-precipitate matrix interface.

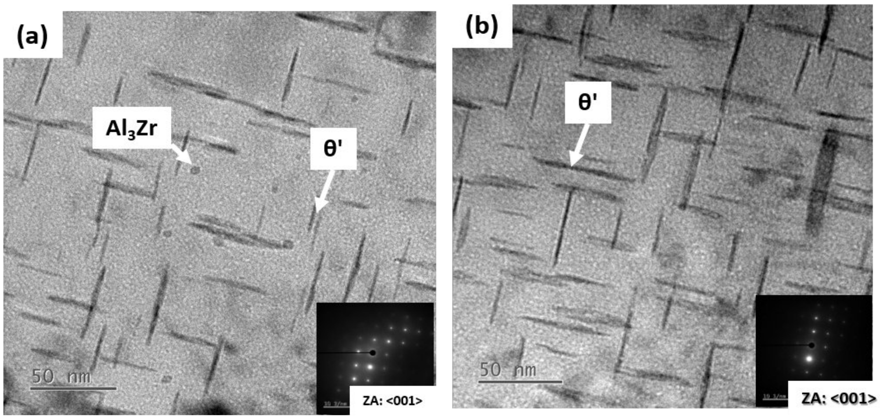

Figure 1: TEM micrographs showing the microstructures of (a) high Zr containing and (b) low Zr containing Al-Cu alloy

Keywords: Aluminium alloy, Transmission electron microscopy, Precipitates

References:

1. Porter, D.A. and K.E. Easterling, Phase transformations in metals and alloys (revised reprint). 2009: CRC press
2. Shyam, A., et al., Elevated temperature microstructural stability in cast AlCuMnZr alloys through solute segregation. Materials Science and Engineering: A, 2019. 765: p. 138279

SPC_147.

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.

MSD_022

Cutting-Edge Technologies to Produce Electrical Stee

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Abstract

Electrical steel (also called silicon steel) is a special steel tailored to produce specific magnetic properties, resulting in low power loss per cycle, low core loss, and high permeability, which is extremely sensitive to produce. Electrical steel is used in various applications, such as motors for electric vehicles, which is a booming market, as well as generators and transformers. NGO (Non-Grain Oriented) electrical steel is used for high frequency electric motors, while the high-energy efficient GO (Grain Oriented) electrical steel is intended for transformers and charging infrastructure.

Fives is as an international engineering group with extensive experience offering advanced technology for different applications. For the production of NGO and GO electrical steel, Fives provides process expertise, cold rolling mills and strip processing lines:

- Annealing & pickling line (APL)
- Cold rolling mill (CRM)
- Annealing & coating line (ACL)
- Decarburizing & coating line (DCL)
- Flattening & coating line (FCL)

Advanced technologies include:

- Thermal section for strip processing lines: a furnace with the best available technology for furnace atmosphere management, high H_2 atmosphere control, as well as smooth slow cooling and compact rapid jet coolers to achieve the required steel properties
- Induction heating technology for ultra-rapid heating
- Cold rolling: 20Hi cold rolling mills to achieve the desired thickness and flatness

This paper describes how advanced technologies used for production electrical steel lead to record performance:

- Strip temperature: up to 1,150 °C
- Rapid induction heating: 200 °C/s
- H_2 atmosphere: 0 to 95% dry or wet
- Cold rolling: 0.1mm rolling thickness on full width

Development of High-Strength Thin Gauge Non-Oriented Electrical Steel for Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs)

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Abstract:

Thin gauge non-oriented electrical steels are preferred material that are used in making core laminations of traction motor of electric vehicles (EV) and hybrid electric vehicles (HEV). For better efficiency these motors runs at higher frequencies and high rpm. At higher frequency, eddy current loss dominates the overall core loss which is proportional to the square of both operating frequency and sheet thickness. Therefore these materials are manufactured in thin gauges, i.e. 0.30 mm or less. Using substrate of high silicon content then becomes necessary to meet the high strength requirements along with low watt loss. In the present work, in order to achieve the require core loss at 400Hz along with high yield strength, a high silicon (~ 3.0 -3.2%) substrate were cold rolled to 0.25 mm thickness in two step cold rolling with intermediate annealing in between. Thus produced thin gauge sheets were studied for the evolution of microstructure, texture at different processing stage and the same were correlated with the influence of processing steps. Magnetic properties at high frequency after final annealing were correlated with the resulting microstructure and texture. The final annealed sheet showed the major fiber components as Gamma(<111>//ND), Alpha(<110>//RD) and Theta(<001>//ND) with enhanced Texture factor(ratio of Theta to Gamma fiber volume). Hence the obtained results showed that at the higher frequency applications, sheet thickness, grain size and crystallographic texture were more dominant in governing the final magnetic properties.

Key words : Thin gauge, Bulk texture, CRNO, Two-stage cold rolling, High frequency core loss, Electric Vehicles

Effect of cold rolling and heat treatment on structure and properties of Titanium alloyed lightweight Fe-7Al-0.35C ferritic steel

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Abstract

Fe-Al-C-based lightweight ferritic steels are known for their good ductility, though they often fall short in terms of strength. Efforts to improve their strength through alloying addition is found to be promising. In the present investigation, the effect of Ti addition in tailoring the strength and ductility of Fe-7Al-0.35C is explored by combining with the thermomechanical processing route. The alloys are processed through vacuum arc melting, followed by hot rolling, cold rolling and subsequently annealed at 800 °C for 1hr and water quenched. The microstructural characterization was performed using SEM and the mechanical properties at room and elevated temperature are evaluated using quasi static uniaxial tensile tests. Cold rolling and annealing of alloy led to grain refinement with the increase in Ti addition. This was attributed to the increase in the volume fraction of TiC at the expense of κ-carbides, resulting in the increased hardness at room temperature. Notably, the addition of Ti retained the strength of the alloy at room temperature while significantly improving the elongation by a factor of five, due to altered precipitate morphology. On the other hand, the high-temperature strength is increased by about 26% with Ti addition. Compared to existing alloys, Ti addition demonstrated substantial improvements in ductility at both room and elevated temperatures, with elongation increasing by factors of approximately 5 and 1.5, respectively. Thermodynamic based phase analysis is done for each phase (TiC and κ-carbide) present in the alloys, establishing their volume fraction, phase stability and thereby correlated with observed mechanical properties.

Key words: Low-density steel, Thermo-Calc, Precipitate strengthening, Tensile properties, Energy-dispersive X-ray spectroscopy (EDS)

Influence of Antimony Addition on Microstructure, Texture, and Magnetic Properties of 2.6% Silicon Non-Oriented Electrical Steels

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Abstract

Non-oriented electrical steel (NOES) is the most important core materials for rotating electrical machines and its magnetic properties depend strongly on composition, thickness, microstructure and crystallographic texture. Increasing magnetically favourable <100>//ND (θ-fibre) texture components in NOES is a key objective for improvement in magnetic properties. A study was conducted to examine the effect of the addition of Antimony (Sb) in a 2.6% Si alloy on the evolution of microstructure and texture and the resultant magnetic properties. All the properties were compared with the base grade without antimony addition. The material was subjected to hot rolling, hot band annealing, cold rolling and final recrystallization annealing in an industrial continuous annealing furnace. The microstructure and texture of material was characterized at different processing stages by optical microscopy and bulk texture X-ray diffraction (XRD). The alloy with Si - Sb showed a reduced intensity of unwanted γ-fibre (<111>//ND) when compared with the alloy of base Si grade. The final recrystallization texture showed predominant α*-fiber and θ-fibre with increasing addition of Sb. Higher texture factor (θ to γ - fiber ratio) was observed in the final annealed condition which resulted in better magnetic properties in, Si - Sb alloy. Magnetic induction (B50) and Core loss (W15/50) continuously improved as the Sb content increased. The results of this work showed that the addition of Antimony resulted in improved magnetic properties via improvement in the favourable texture in the final annealed sample.

Key words : Recrystallization, Bulk texture, Cube texture, Silicon steel

Optimization of Annealing Parameters for High Silicon Non-Oriented Electrical Steels

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Abstract

Electrical steels play a critical role in reducing CO_2 emissions due to their superior energy conversion efficiency compared to other magnetic materials. To produce high-quality non-oriented electrical steels with minimal core loss, precise control over factors such as grain size, impurities, residual stresses, and texture is essential across the entire production process—from steelmaking and hot rolling, through hot band annealing, cold rolling, to final annealing. The present study focuses on getting better properties with the optimization of annealing parameters. The primary objective was to identify the optimum annealing processing conditions that minimize core loss while increasing line speed to increase productivity. Annealing experiments were conducted such that it replicates the continuous annealing line conditions of the plant cycle. Hence the design of experiment was planned with variations in line speed as 60 mpm, 80 mpm and 100 mpm, and annealing temperatures as 800 °C, 900 °C, 1000 °C, 1050 °C, and 1100 °C. Experimental results demonstrate that there is a significant influence of annealing conditions on the microstructure and magnetic performance of the steel. Characterization techniques including Optical microscope, SEM-EBSD used to analyse the recrystallization behaviour and texture evolution in the annealed material and the magnetic properties has been characterised using Brockhaus MPG200D. Experimental results were utilized to generate contour maps to elucidate the best operating window during annealing by illustrating the relationship between line speed vs annealing temperature with respect to minimizing the core loss. The results reveals that the annealing temperature is most critical than the line speed to achieve the desired magnetic properties. Additionally, an empirical equation was developed to predict optimal processing conditions for achieving desired magnetic properties.

Key words : Non-oriented electrical steel, Coreloss

Effect of Cr addition in molten Zn to improve galvanised coating quality

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Abstract

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

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, $MgZn_2$

Reduction of streak shaped scale defects by improving the grain boundary strengthening in Ti-Nb stabilized ULC steel of Galvannealed product

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Abstract

Surface defects in galvannealed (GA) steel products significantly contribute to high rejection rates at both the manufacturing plant and customer levels. Among these, streak-shaped scale defects, similar to sliver defects from steelmaking, and appears randomly in titanium-niobium stabilized ultra-low carbon (ULC) steel coils. These defects, which become visible only after GA coating, manifest as pairs of parallel lines typically 1-2 mm wide and extending over 500 mm in length. Metallographic analysis reveals globular oxides dispersed along these lines, attributed to weak grain boundary regions that permit oxygen ingress from the wustite region, leading to internal oxidation. High temperatures, elevated oxygen presence, and prolonged residence times are key contributing factors. Lowering the temperature causes rolling issues, and residence time is dependent on mill conditions. To mitigate internal oxidation, enhancing grain boundary strength by adding surface-active elements is proposed. A plant trial was conducted with the addition of 10-15 ppm boron. Both trial and normal slabs were hot rolled under identical conditions. Results showed a significant reduction in defects per coil, from 8.5 to 1.7 in boron-added coils, demonstrating the efficacy of this approach in improving the quality of GA steel products.

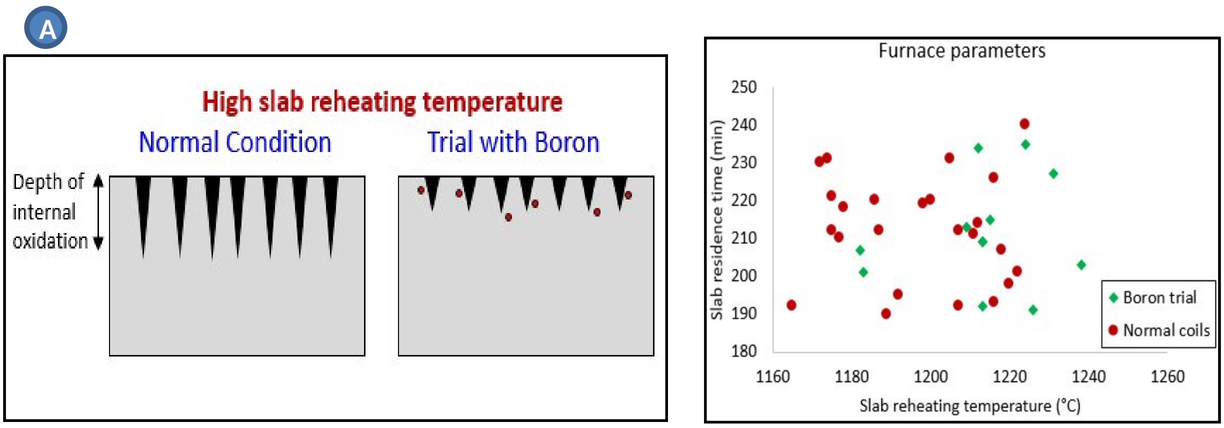

Fig. 1A: Internal oxidation phenomenon, 1B: Furnace parameters

Key words :Edge seam, Edger roll, Slab corner

Self-similar grain growth in nanocrystalline Ni-W alloys

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Abstract

Nanocrystalline pure FCC metals are known to exhibit abnormal grain growth. This has been attributed to the non-uniform segregation of impurities or sulfur rich second phase particles at the grain boundaries. Addition of solutes, such as W, has led to improved grain size stability in nanocrystalline Ni. Most reports have investigated grain growth behavior at higher homologous temperatures for grain size greater than 15-20 nm. Grain growth behavior of nanocrystalline Ni-W alloys was investigated in the present study for grain sizes below 10 nm. Parabolic grain growth was observed in the considered grain size regime. A grain size probability distribution function was plotted against normalised grain size to confirm statistical self-similarity among these alloys.

SPC_109

Microcompression behaviour of compositionally modulated multilayer Ni-W coatings produced by electrodeposition

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Abstract

The constant quest to balance strength and toughness in coatings has led to the invention of several novel materials. Nanocrystalline Ni-W coatings are hard but lack toughness due to their limited ductility owing to high residual stresses. This limitation has prevented their widespread use as a replacement for hard chrome in practical applications. Hence, a new approach called functionally graded material, characterized by varying microstructures and thus properties across volume, has been explored in recent times. In our present study, compositionally modulated multilayer (CMM) coatings of Ni-W are synthesized using pulse reverse electrodeposition. These coatings consist of alternating layers of Ni-1 at% W (soft) and Ni-15 at% W (hard), with three different layer thicknesses: 1, 0.5, and 0.1 µm. The goal of this novel design is to achieve a synergy between strength and ductility, leading to enhanced mechanical performance. Microcompression tests reveal that, unlike the traditional homogeneous coatings, the CMM coatings demonstrate significantly higher strain-hardening ability. Interestingly, significant fluctuations are observed in the strain-hardening rate along with a shift towards higher onset stress levels for the stage-III strain hardening, depending on the layer thickness. These findings elucidate the complex interplay between the hard and soft layers in influencing the deformation characteristics of the coatings. Investigation of the post-deformed micropillars using electron microscopy reveals significant evidence of concurrent deformation in both hard and soft layers. The study proposes a mechanism to explain the increased strain-hardening in multilayers by invoking the strain gradient plasticity caused due to lateral constraints arising out of the strength disparities in the layers, where the softer layers stabilize local shear and the interfaces act as barriers.

Keywords: Ni-W coatings; multilayers; electrodeposition; microcompression testing; strain gradient plasticity; Microstructure.

SPC_156

Improved Thermal Stability of Nanocrystalline Ni-0.8%Sn

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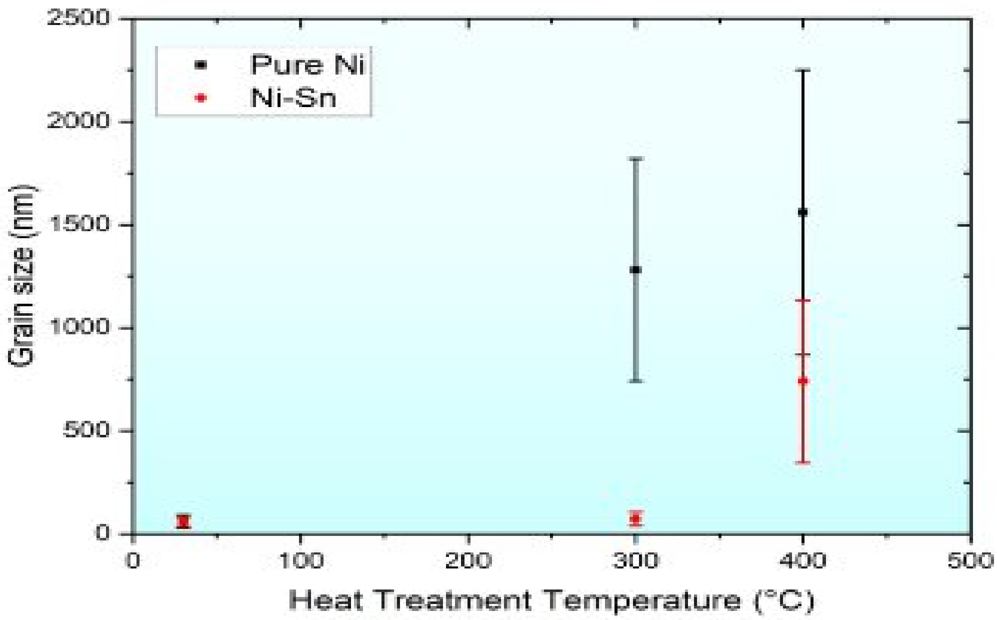
Abstract

Nanocrystalline (NC) materials show a very good combination of ductility and hardness along with high wear resistance, toughness, and corrosion resistance. However, they possess low thermal stability leading to deterioration in these properties. This drawback can be overcome by addition of elements that show poor solid solubility in NC matrix material. The Gibbs free energy of the system is lowered as a result of the preferential segregation of these alloying element atoms at the grain boundaries (GBs). When this system is exposed to high temperatures, solute atoms pin the GBs, preventing grain growth.

The current research aims to understand whether the GB segregated solute atoms can improve the microstructural stability of NC nickel by suppressing thermally driven grain growth. K.A. Darling et al. performed calculations to identify the solute amount to stabilize a grain size of 25 nm at 0.6 T_m for various binary systems [1]. Among others, the system of interest is Ni-Sn system, where 0.8 at.% Sn is expected to stabilize 25 nm grain size at a temperature of 872°C. Ni-Sn system is expected to show improved high-temperature properties due to reduced Gibbs free energy of GB segregated system. These solute atoms can potentially prevent stress-assisted grain growth that occurs during the monotonic loading of NC materials [2].

Fig. 1: Effect of annealing temperature on grain size of NC Ni and Ni-0.8%Sn



Ni-Sn alloy with different compositions is synthesized through electrodeposition. Wavelength dispersive spectroscopy shows variation in alloy composition with bath chemistry. The electrodeposited material is characterized using XRD, EBSD and TEM for measuring lattice strain, preferred orientation and crystallite size. DSC and microstructural characterization post-annealing show a significant improvement in thermal stability of the NC Ni after the addition of 0.8% Sn as shown in Figure 1. Microhardness measurement shows anneal hardening in Ni-0.8%Sn post-annealing at 300°C for 60 minutes and Ni-Sn shows delayed and gradual decrease in hardness with increase in annealing temperature. XRD and pole figures show (100) preferred orientation in as-deposited pure Ni and Ni-Sn which changes to (111) after annealing at 200°C for 60 minutes in case of pure Ni while it is retained up to 400°C and changes to preferred (111) and (311) orientations at 500°C and 600°C respectively for Ni-Sn, showing good thermal stability. Alloy fabricated in this research can be used in various applications such as parts of MEMS/NEMS devices, interconnects, and mechanically hard corrosion-resistant coatings.

Keywords: Electrodeposition, grain growth, grain boundary segregation, anneal hardening

References: [1] K. A. Darling et al., Computational Materials Science 84 (2014) 255–266

[2] D. Gianola et al., Adv. Mater. 20 (2008) 303–308

SPC_162

Effect of alloying element and extrusion parameters on the formation of Peripheral coarse grain (PCG) in Aluminium 6061 alloy

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Abstract

Aluminium alloys (6000 series) are widely used for demanding structural applications due to their lightweight with good mechanical properties. Al 6061 is an obvious selection for Automotive and aerospace application due to its high conductivity, excellent extrudability and ease of fabrication made this alloy. Extrusion is one of the major metals forming processes widely used in the manufacturing industry. During extrusion of aluminium alloys, defect like formation of coarse grains at the surface, known as a Peripheral Coarse Grain (PCG) occurred which affect mechanical properties and aesthetics of the extruded material. PCG is a layer of recrystallized coarse grains that form in the outer band of an extruded section. PCG can be controlled by altering the extrusion parameters such as, temperature, strain rate, ram speed and post forming heat treatment operations. Along with the extrusion parameters, the addition of the alloying elements in aluminium increases its response to heat treatment due to formation of intermetallic compound. Those intermetallic compounds restrict the recrystallization of the grain by pinning the grain boundaries and decrease the PCG as well as increase the strength of the alloy. The objective of this work is to understand the metallurgical origins and mechanisms of the formation of the PCG and reduction of PCG layer by 50% by optimizing the alloy chemistry and extrusion parameters.

Keyword: Al 6061, PCG, Alloy chemistry, Extrusion.

Electronic indicator of mechanical properties in metals and alloy

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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

MPR_451

78th Annual Technical Meeting
The Indian Institute of Metals

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 ($n = \log(\sigma)/\log(\varepsilon)$) 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.

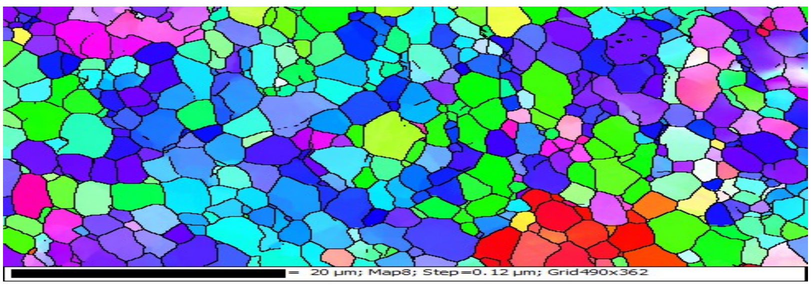

Fig. 1: Inverse Pole Figure (IPF) image of compressed samples at 975°C- 10^{-3} s^{-1}

Key words: Hot deformation, Work hardening, Strain-rate sensitivity, Texture and Hardnes

MSD_018

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

SPC_152

Study on the modification of the mechanical properties of magnesium-2 *at%* aluminium alloy using the cyclic extrusion compression process

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Abstract

Cyclic extrusion compression (CEC) is a promising severe plastic deformation technique for producing ultrafine-grained materials with high angle grain boundaries. In the CEC technique, the billet is extruded first, followed by compression in each pass. The main advantage includes providing high hydrostatic pressure, which can be used to process difficult-to-form materials such as hexagonally close-packed (hcp) metals at room temperature. Magnesium and its alloys are well known for their difficulty in processing at low temperatures due to the limited number of slip systems.
The present study is aimed to understand the influence of CEC process on the processing of Mg-2 *at%* Al alloy at room temperature. The effect of CEC process on the grain refining mechanisms of Mg-2 *at%* Al alloy at different temperatures was carried out with an effective strain of 0.73 in each deformation pass. Microstructural studies and mechanical properties evaluation will be carried out to understand the underlying deformation mechanisms at different temperatures. Finite element analysis using ABAQUS 6.14 will also be carried out to understand the equivalent stress and strain distribution.

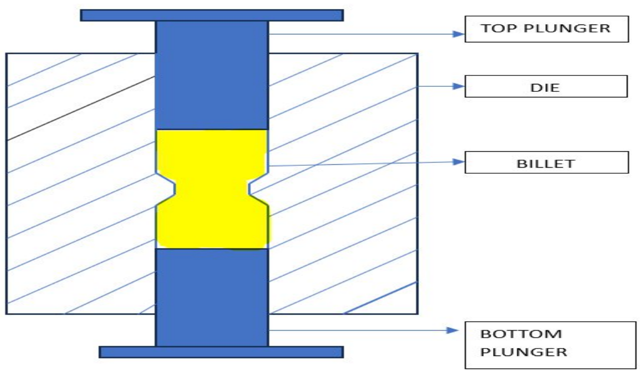

Fig.1. Schematic representation of the cyclic extrusion compression process.

Keywords: Cyclic extrusion compression; Magnesium; Grain refinement.

MFR_066

Recent fundamental scientific insights into nitriding of steels

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Abstract

Nitriding is a widely employed thermochemical surface treatment for enhancing the fatigue, wear and corrosion resistances of several steel components. Although these processes are widely employed in industry for more than 100 years, still some important scientific questions remained unanswered. Recently it has been shown that, in the process of equilibration of a ferritic iron-based alloy with gaseous nitriding atmosphere, the inwardly diffusing N into the ferritic solid-solution from gas atmosphere may bring the evolving solid-solution chemistry into immiscible region of the corresponding phase diagram. Distinct kinetic mechanisms of nitriding are operative in different alloy systems, depending on whether the alloy system has a region of immiscibility or not and whether the applied chemical potential of N in the nitriding atmosphere allows the evolving chemistry of the alloy to sample the immiscibility region or not. With this new kind of thermodynamic interpretation, it is now possible to precisely understand the experimental results reported in literature pertaining to nitrided iron-based binary alloys. Slow kinetics of nitride precipitation in nitrided ferritic Fe-Si and Fe-Al alloys has been attributed to the absence of immiscibility region in ferritic Fe-Si-N and Fe-Al-N systems whereas the slower precipitation of nitrides in ferritic Fe-Mo alloys has been attributed to the implausibility of sampling the immiscibility region of Fe-Mo-N system for typically applied nitriding conditions. Faster kinetics of nitride precipitation in Fe-Ti, Fe-V, Fe-Cr alloys has been attributed to the presence of immiscibility in Fe-Ti-N, Fe-V-N and Fe-Cr-N systems and the applied nitriding conditions allowing sampling of this immiscibility region. Recognizing the role of 'miscibility gap' in alloy systems to realize rapid kinetics during nitridation treatments opens up a new, unexplored alloy design strategy for development of steels with favourable nitriding response. Stainless steels subjected to gaseous nitriding at relatively low temperatures are known to dissolve colossal amounts of N. The cause for this colossal N solubility is not known. It has been shown recently that the Gas/solid equilibrium imposed spinodal decomposition of stainless steels is the cause for colossal levels of N solubility. Understanding and optimizing these metastable states are of great technological interest.

Keywords: nitriding; surface engineering; spinodal phase separation; nucleation; supersaturation

ESU_028

Hydrogen resistant steel: Can an engineered microstructure mitigate the hydrogen attack?

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Abstract

Hydrogen embrittlement resistance of steel is a function of locking ability of the diffusible hydrogen by various traps like dislocation, grain boundaries, precipitates etc. The effective hydrogen diffusivity varies with the nature of the traps and their density. Two microstructures ((X65-I and X65-II)) with different reversible trap density were developed. The specimens were saturated with hydrogen through cathodic charging and tested at high strain rate (Impact/DWTT) to low strain rate ($10^{\wedge-6}$ s^{-1}, through SSRT). The results were analysed with the correlative approach by combining, cathodic charging-TDS-K1C-TEM, to deduce the damage mechanism. The experimental results indicated the, slip transfer of dislocation with the help of diffusible hydrogen core. A Cottrell filed was noticed within the grain, and at elastic strain at dislocation-grain boundary interaction. The desorption results indicated that the major contribution in lowering the diffusion coefficient was from the diffusible hydrogen trapped at high angle grain boundaries.

Key words: X70 steel, grain boundaries, thermal desorption spectroscopy, hydrogen permeation, reversible and irreversible traps.

FAN_009

Energy-efficient Q&P Technology for Improved Mechanical Performance of Lean Alloy Steels

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Abstract

A majority of the manmade structures and machine components are made from steel. The suitability of any steel grade for a specific application depends on its ability to withstand a given load, resistance to fracture, shaping capability, etc. An increment in the strength of steel without compromising the ductility will allow the use of thinner gauge and therefore, the weight reduction of the component, leading to fuel saving and reduced greenhouse gas emissions. In this regard, different grades of steels have been evolved and are categorized into different generations, i.e. first, second and third-generation advanced high strength steels (AHSS), based on the strength-ductility combinations. Generally, for most of the steel grades, an increase in the strength of steel is accompanied by a concurrent decrease in the ductility. Therefore, it is required to search/develop a steel grade with a suitable microstructure so as to achieve higher strength levels without compromising much on the ductility.

In recent years, the quenching and isothermal partitioning (Q&P) process has shown to achieve multi-phase microstructure containing retained austenite, martensite, bainite and carbides. In this, the desired strength is provided by the hard phases such as bainite, martensite and carbides; whereas, the soft retained austenite phase improves the ductility and impact toughness of steel. The Q&P process involves forming a mixture of martensite and austenite by quenching the steel to a temperature between M_s and Mf, followed by isothermal holding for the carbon diffusion from martensite to the untransformed austenite, and thereafter quenching to room temperature. As an alternative to the isothermal holding, the heat remained with the hot-rolled coil after quenching on the run-out-table can also serve the purpose of carbon diffusion, and thereby, eliminating the need for an additional facility for isothermal holding. This energy-efficient process is known as the quenching and nonisothermal partitioning process, which has gained a lot of attention from researchers in recent times. Therefore, in the present work novel alloy steels and their processing schedules were designed/optimized using thermodynamic and kinetic simulation software as well as employing various empirical calculations. Subsequently, a comprehensive investigation was performed to understand/establish the composition-processing-structure-properties relationship to achieve ultrahigh strength combined with sufficient ductility and toughness. This has enabled to identify the suitable lean alloy compositions and its processing technology for production and use in structural, automotive, wear-resistant, etc. applications.

Keywords: Steel, Quenching and nonisothermal partitioning, Retained austenite, Toughness, Strength

SPC_011

Improving Fatigue performance in Hot Rolled & Pickled (SPFH590FB-P) Grade for Automotive applications

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Abstract

SPFH590FB is usually used in parts belong to Coupled Torsion Beam Axle (CTBA) assembly system in Passenger Vehicle (PV) segment, which demand better Hole Expansion Ratio (HER) & Fatigue Strength performance. During initial supply of material for press trial in SPFH590FB-P Grade, one of the leading Automakers reported the crack in the Fatigue test of the CTBA assembly system with actual Fatigue performance of 1.2-1.4 cycles against the target of 2 Lakhs cycles to failure minimum. Gap analysis, through microstructural characterization performed using SEM, revealed that gap in fatigue performance was due less Bainite phase fraction (2-5%) in all the cracked parts against 8-10% in all the non-cracked (OK) Parts.

But, one of the major concerns in hot rolling of SPFH590FB grade is maintaining necessary cooling cycle while complying to the target Coiling Temperature (CT) which should be sufficiently below Bs temperature to achieve necessary Bainite phase fraction which will ensure to meet Hole Expansion & Fatigue properties.

Based on literature study, chemistry design was modified from the earlier Fe-Cr-Mo-Nb-Ti based design (for which Bs temperature calculated to be 480^{0}C) to Fe-Nb-V-Ti based design (for which Bs was estimated to be 500^{0}C, due to which CT could be increased by 20^{0}C from the earlier target, which also resulted an improvement in the shape of as-hot rolled steel strips.

Material was produced with the new design and was supplied after the necessary in-house validation of Tensile & Hole Expansion tests (with actual values in the range of 71-78% against the 61-66% in the old design) which is metallurgically correlated to Bainite phase fraction observed in the range of 14-22% in the new chemistry as against 2-6% in the old design. Customer feedback states that Fatigue performance has been greatly improved with 2.4-2.6 Lakhs cycles to failure. Also, JSW has a competitive advantage due to decrease in Ferro-Alloy (FA) cost by INR. 800/MT due to revised (new) chemistry design.

Key words : CTBA, Fatigue, Bainite, Coiling Temperature

SPC_030

Study of Strain Rate Dependent Tensile Properties, Strain Hardening behaviour and Fracture Properties in Aluminium Containing Ferritic Low-Density Steels

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Abstract

Aluminium containing ferritic low-density steels (F-LDS) have densities 12-15% lower than conventional steels, making them potential candidates for automotive applications. The ductility of hot and cold rolled material in F-LDS was less than 2%, likely due to a high-volume fraction of brittle kappa-carbide (Fe_3AlC). However, after cold rolling followed by annealing samples exhibited improvement in ductility. The study investigated the tensile properties of two low-carbon ferritic low-density steels (Steel 1: 6.8Al-Fe and Steel 2: 9.7Al-Fe (wt%)) at strain rates of 1×10^{-4} s^{-1}, 1×10^{-3} s^{-1}, and 1×10^{-2} s^{-1}. These steels underwent cold and warm rolling as well as annealing. Various tensile properties were evaluated, including yield strength, ultimate tensile strength, strain hardening exponent, energy absorption up to 10% engineering strain, and strain rate sensitivity. The results showed that higher strain rates increased yield strength, ultimate tensile strength, and energy absorption in both steels. The strain hardening exponent was determined using the Hollomon and differential Crussard–Jaoul analysis. The electron backscattered diffraction (EBSD) and transmission electron microscopy (TEM) technique were employed to explain the strain hardening response in both steels. Both steels exhibited two distinct stages of deformation, describing their strain hardening behaviour depicted in Fig. 1. The study observed a decrease in strain rate sensitivity with increasing true strain in both steels. Steel 1 displayed higher strain rate sensitivity than Steel 2, resulting in a delayed necking tendency and higher total elongation. Micrographs of fracture surfaces revealed the presence of quasi-cleavage facets and secondary cracks at strain rates of 1×10^{-3} s^{-1} and 1×10^{-2} s^{-1} in both steels. At a lower strain rate of 1×10^{-4} s^{-1}, Steel 1 exhibited a dimple fracture due to its lower strength and higher total elongation, while Steel 2 displayed a quasi-cleavage fracture. The progression of voids in Steel 1 at a strain rate of 1×10^{-4} s^{-1} was characterized by establishing a relationship between actual thickness strain and the quantity of voids. This analysis provided insights into the steels void formation and growth mechanisms under specific conditions.

SPC_036

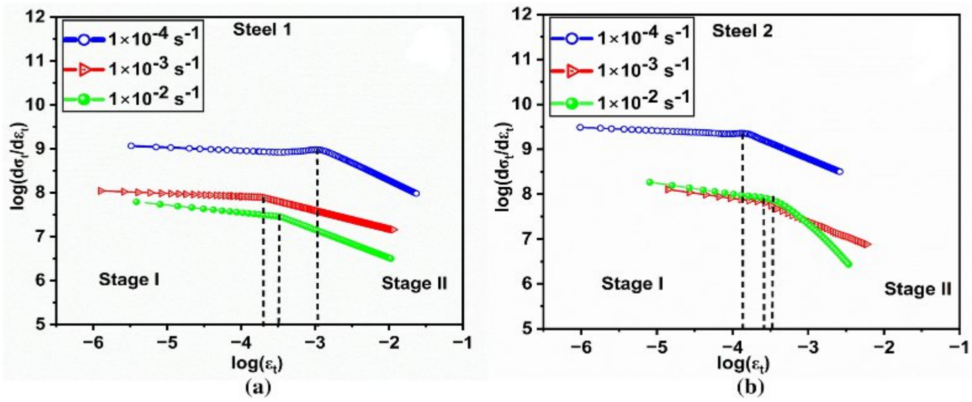

Fig. 1: Differential C-J analysis strain hardening rates plots; (a) Steel 1, (b) Steel 2 at strain rate of 1×10^{-4} s^{-1}, 1×10^{-3} s^{-1}, and 1×10^{-2} s^{-1}

Keywords: Ferritic low-density steels, Strain rate tensile properties, Strain hardening, EBSD/TEM and Fractography

Study of process parameters affecting niobium precipitation in hot rolled HSLA Steel

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Abstract

HSLA steels has gained their importance in the last two decades because of their to retain elongation while strength both (YS & UTS) is increased significantly with an small addition of alloying element such as Niobium, vanadium, titanium which are called as micro alloying element. 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.

The strengthening mechanism, which is responsible for restoration of ductility and impact toughness is ferrite grain size strengthening out of available and widely used micro alloying elements nb is potent grain refiner but nb added during steel making is getting dissolved in austenite matrix during reheating of continuous cast slabs and participate in grain refinement of prior austenite grain boundaries which when cooled result into fine ferritic grain size.

To ensure complete dissolution of niobium, process parameters related to reheating furnace (RHF) need to be controlled precisely because samples which failed to meet the minimum UTS requirement, were characterized with undissolved Nb using SEM-EDS analysis. In this study an attempt is made to develop multi-linear regression (MLR) incorporating all the necessary process parameters. This model is supposed to help to mitigate low UTS cases, Improved Quality assurance decisions. This effort going to help customers especially in automotive segment

MFR_129

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

SPC_098

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

PMA_003

Development of Hot Rolled Steel for Hot-formed Axel Housing Automotive Application

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Abstract

Axel housing are critical components for automotive vehicles. These components are manufactured through induction heating of hot rolled (HR) steel to 800-900 ^{0}C, followed by hot forming and air cooling. Key requirements of HR steel for the application are (i) Material to retain its strength in hot formed (HF) parts, and (ii) Impact property guarantee in as rolled and HF condition at sub-zero temperature. Attaining very high strength (UTS>600MPa), along with impact toughness guarantee at -20 ^{0}C and -40 ^{0}C is technically challenging for thickness range of 12-16 mm. Also, controlling the significant strength drop due to precipitate coarsening at HF part is difficult. Accordingly, appropriate alloy design and processing strategy needs to be adopted to develop these grades.

Plant trial was undertaken with a (Nb+V+Ti) micro alloyed chemistry. In developed HF grade, high strength after hot forming was retained primarily through refinement of ferrite (polygonal/bainitic) grains/plates, and precipitation strengthening. Some level of dislocation strengthening was also utilized to get the required HF strength. Nb and V based microalloying is used to get the said strengthening. Grain growth at high temperature processing (both during hot rolling and hot forming) were prevented by having very small amount of TiN precipitates. Suitable coiling strategy is used to partially supress precipitates at HR coil, resulting in better low temperature toughness at -20 ^{0}C and -40 ^{0}C. Supressed precipitates were utilised during hot forming step to retain the property in final component through precipitation hardening.

Hot rolled HF grade is successfully developed at Tata Steel Ltd. (India) for automotive customers.

Fig: Hot formed Axel Housing Component [Representative Image: Source -takshiauto.com]

Keywords: Hot Rolling, Hot Forming, Microalloyed steels, Axel Housing, Automotive steel
SPC_009

Effect of ageing on precipitation and strengthening behaviour in a W-containing maraging steel

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Abstract

Maraging steel is a class of high strength material, primarily strengthened by intermetallic precipitates, used in aerospace, defense and other industrial applications. In the present work, the precipitation and its effect of strengthening upon ageing were systematically investigated in a W-containing maraging steel. TEM investigation of the aged samples indicated the presence of fine η – Ni_3Ti type precipitates in the steel (Fig. 1). The presence of η precipitates was further confirmed by atom probe tomography (APT) studies. However, along with Ni and Ti, a significant amount of Fe, Co, W and Mo was also observed in the η phase. Furthermore, the aged sample also exhibited W-Mo rich clusters, underlining the complex precipitation process in the steel.

Density functional theory (DFT) calculations were carried out to study elemental partitioning in η phase, revealing that Fe and Co partition to the Ni site and W and Mo to the Ti site. The steel showed significant improvement in strength upon ageing in the range of 470ºC - 510ºC, substantiating the role of precipitation hardening in the present system. Finally, the precipitation strengthening in the steel was modelled using a combination of molecular dynamics (MD) and discrete dislocation dynamics (DDD) simulation. The results obtained are of significant importance for predicting the precipitation strengthening in other maraging steels as well.

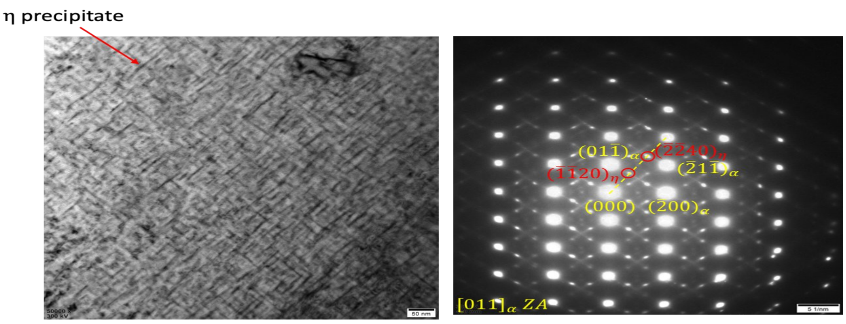

Fig. 1: Bright field TEM image and the corresponding SAD pattern showing the presence of η precipitate in the present steel after ageing at 510◦C for 3h.

Keywords: Maraging steel, Atom probe tomography, Density functional theory, Molecular dynamics simulation, Precipitation strengthenin

Tribological mechanism in Fe-based metallic glass coating under different sliding wear conditions

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Abstract

Fe-based amorphous coatings attracted widespread attention due to their exceptional mechanical and corrosion properties. Atmospheric plasma spraying is regarded as a simple and versatile technique to synthesize Fe-based amorphous coatings owing to very high cooling rate (10^7-10^8 K s^{-1}) associated with it, which promotes amorphous phase formation. In this study, atmospheric plasma spraying was used to prepare amorphous/ nanocrytalline composite coating (Fe-10Cr-10Mo-4B-2C-4P, wt.%). Hardness of the amorphous/ nanocrystalline composite coating is found to be 1214 H_V. High hardness of the coating is attributed to the formation of amorphous structure along with hard intermetallic phases such as Fe_3B, Fe_2B, Fe_5PB_2 etc. Dry sliding wear behavior of the coating was investigated under different sliding speeds with alumina ball as counter body material. Worn surfaces are characterized by long continuous parallel grooves with different widths, dark oxidative spots, cracks and delaminated worn regions. Sliding speed is found to have pronounced effect on the characteristics of the worn surface. Transition in wear mechanism was envisaged as low sliding speed resulted in predominantly abrasive wear, while high sliding speed led to mainly delamination with a minor amount of abrasive wear. Additionally, increase in sliding speed led to an increase in the extent of wear loss, which was correlated with flash temperature on the coating surface.

Key words: Keywords: Dry sliding wear; Atmospheric plasma spraying; Fe-based amorphous/ nanocrystalline composite coating; Wear mechanisms

SPC_035

Microstructure and mechanical properties of intercrtitically annealed 3.5 wt.% medium-Mn Steel

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Abstract

The contemporary drive for improved fuel efficiency and reduced net CO_2 emissions necessitates the development of lightweight alloys, particularly in the automotive industry, which is an influential contributor to CO_2 emissions. To boost fuel efficiency, a viable strategy involves reducing the weight of automotive vehicles. This can be accomplished by utilizing lightweight materials while ensuring that the mechanical properties remain uncompromised. As steel comprises 60-70% of automotive vehicle weight, reducing the mass of overall steel used in automotive would subsequently contribute to weight reduction and increase fuel efficiency. Medium-Mn Steel (MMS) that contains Mn in the range of 3 to 12 wt.%, has become a viable contender for the future generation of AHSS. These steels exhibit superior tensile properties compared to the first-generation AHSS, while also offering cost advantages over the high-Mn 2nd-generation AHSS.

In the present work, the impact of different heat treatment approaches, specifically intercritical-annealing (IA), on the tensile properties and evolution of microstructure in MMS grades. The effort aims to achieve an excellent balance of strength, work hardening, and ductility in these MMS grades by optimizing the RA content and its stability. Intercritical annealing of the cold-rolled (softened-annealed at 700 °C for 20 hours before cold rolling) 3.5 wt.% MMS sheet was carried out at temperatures of 660, 700 and 740 °C for 03 minutes. Even with such a short intercritical annealing time, a distinct variation in the tensile properties and microstructure evolution was observed with IA temperatures. Annealing at 660 and 700 °C gave a good combination of properties. IA at 660 °C exhibited superior elongation of 18% and relatively good UTS of 821 MPa. While IA at 700 °C exhibited very high UTS of 1225 MPa and fairly good elongation of 13%. As per the user requirement, a suitable annealing temperature can be chosen to obtain the desired properties and microstructure.

Keywords: Medium-Mn steel, intercritical annealing, AHSS, automotive

SPC_038

A Deep Dive into Dry Sliding Wear Behaviour of Low Carbon Steels Across Varied Microstructures and Normal Loads

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Abstract

The current research investigates dry sliding wear characteristics of two low carbon steels namely: LCu, (0.6 wt.% Cu), and HCu, (1.1 wt.% Cu). Thermo-mechanical processing commences with homogenization at 1250℃, succeeded by forging with a 60% reduction. Following this, both the steels undergo quenching from three temperatures: 820℃, 870℃, and 920℃ using chilled water (3℃-5℃). Post-quenching, the predominant structures comprise martensite, complemented by bainite, and marginal amount of ferrite. A pin-on-disc tribometer is used, applying a normal load of 10 N and 50 N with a constant sliding velocity of 1 m/s, to assess the specimens wear behaviour at room temperature. Specimens quenched from 920°C and subjected to a load of 50 N for both steels have shown superior wear resistance. At normal load of 10 N, poor wear resistance is observed for both steel compositions. The fluctuations in roughness parameters are a consequence of temperature escalation during wear, leading to consequential alterations in the formation dynamics of oxides. Roughness value variation, asperity height, asperity radius, and average peak count have all been included in the mathematical equations used to predict the temperature elevation during wear across different microstructures. The prevalence of martensitic morphology in the structures quenched from 920℃, alongside the development of thin (0.5 to 2 μm), homogeneous, and firmly adherent Fe_3O_4 layer during wear, enhances the wear resistance. Additionally, under a normal load of 50 N formation of Fe_3O_4 layer is enhanced. In specimens quenched from 820°C, the bainitic phase predominates and thick, brittle FeO layers emerge, causing a three-body wear phenomenon that results in the highest wear volume loss. Conversely, specimens quenched from 870℃ demonstrate an intermediate volumetric loss. The transitions in wear mechanisms are delineated through meticulous microstructural analysis encompassing pre- and post-wear specimen characterization, wear track examination, sub-surface morphology, and debris investigation.

Keywords: Sliding wear behavior, Martensitic-bainitic steel, Oxide layer, Coefficient of friction, Debris, and Frictional heating.

SPC_059

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

MPR_341

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

(a) **(b)**

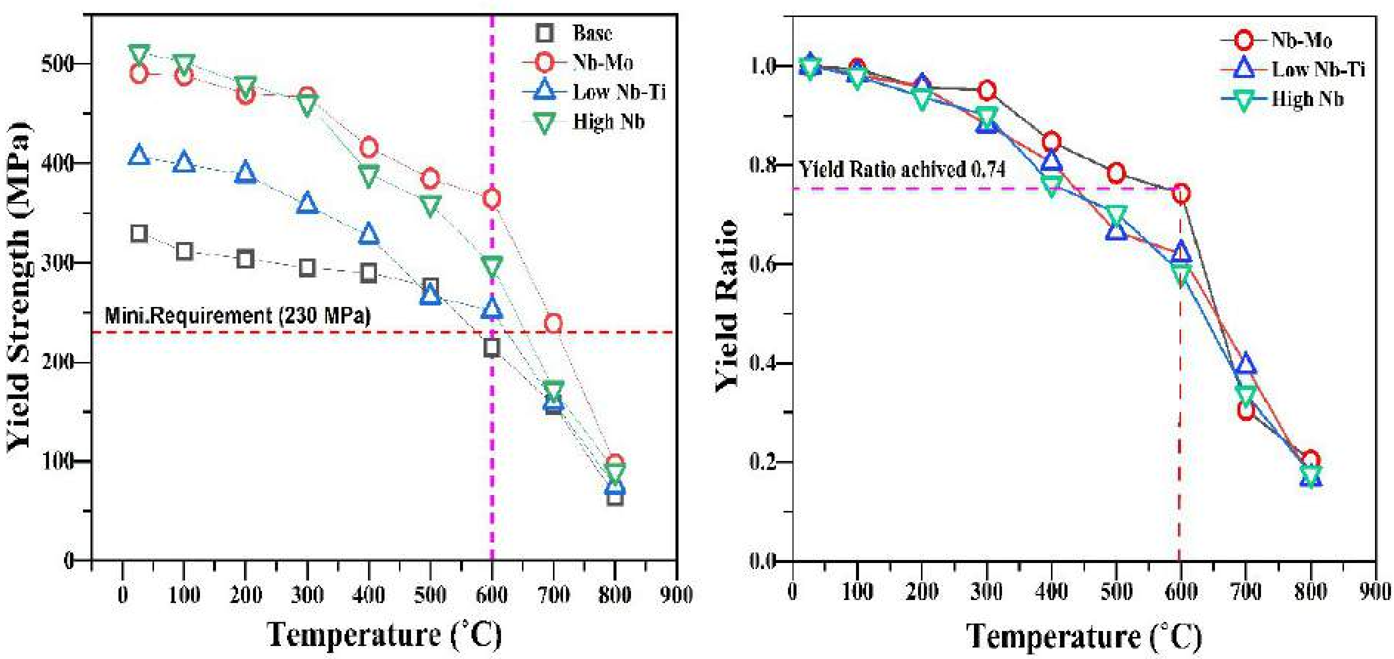

Fig. 1: Elevated temperature properties of four alloys (a) Yield Strength (b) Yield Strength Ratio

SPC_050

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 ε-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. ε-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

SPC_053

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.

SPC-095

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.

SPC_100

Development of high formability 430 (430HF) ferritic stainless steel grade suitable for deep drawn application

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Abstract

Grade 430 is a ferritic stainless steel used for cookware, and white goods applications. When the material is subjected to deep drawing applications, there is a tendency of luder band formations along with tearing and cracking phenomenon. The luder band formations hampers the aesthetic appearance and it requires an extra grinding process for removal. For making successful components, especially involving deep drawing, the material demands for elongation of minimum 25 % as well as minimum R – bar of 1.2 without hampering the strength. The effect of stabilizing element Ti is found to form carbides and nitrides that lead to the refining of the grains size which ultimately improve the properties of the material [1]. In this study, the effect of Ti addition less than 1000 ppm while heat making was analyzed. The equiaxed zone of the cast structure was achieved in the range of 73-77% while 55-60% equiaxed zone was found in conventional 430 processed without Ti addition. The micro, SEM, mechanical and texture analysis through EBSD was done and the results were compared with conventional 430 grade. The outcome of this study has shown 430 grade with Ti addition is improved version of normal 430 grade by ensuring finer grain size of ASTM No 8.0 or finer, 25 % minimum elongation and 1.2 minimum R- bar.

Keywords: Deep draw application, texture, EBSD, ferritic stainless steel

References

[1] Texture, orientation, and mechanical properties of Ti-stabilized Fe-17Cr ferritic stainless Steel by Junwei Fu et.al

MFR_051

A study on effect of strain rate, aging time and temperature on stress strain behavior of high nitrogen austenitic stainless steel

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Abstract

High Nitrogen Stainless Steel (HNSS) is a promising nickel-free austenitic stainless steel with potential for replacing traditional armour-grade steel in defense applications such as battle tanks. Its superior mechanical properties, including improved strength, ductility, and fracture toughness, combined with excellent corrosion resistance and lower cost compared to conventional options, make it a compelling candidate. HNSS contains over 0.4% nitrogen, contributing to these enhanced characteristics.

This study investigates the mechanical behaviour of HNSS under varying conditions. Samples were solutionized and subsequently deformed at different strain rates at room temperature. Aging treatments were conducted at 800°C and 900°C for various durations, followed by compression tests at different strain rates. Strain rate sensitivity was determined for both solutionized and aged samples.

Microstructural analysis revealed the formation of extensive slip bands in aged samples as strain rate increased. The correlation between hardness, microstructure, and mechanical properties was examined. The findings of this research contribute to a deeper understanding of HNSS behaviour and its potential for application in demanding environments such as armor systems.

Keywords : High Nitrogen Stainless Steel, Aging treatments, strain rates, defense applications , Characterization

MPR_120

Microstructure Improvement in Titanium Stabilized Ferritic Stainless Steel Grade-409L through Continuous Annealing Route for Deep Draw Applications

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Abstract

409L is a type of stabilized ferritic stainless steel that is commonly utilized in automotive applications, particularly in exhaust systems that need deep drawing of the component. The uniformity of the microstructure is crucial for achieving an even flow of material in the process of deep drawing. The equiaxed microstructure ultimately improves the R-bar (planar anisotropy), is resistance to thinning under stress.

This current study focuses on enhancing the uniformity of the microstructure, which is presently unattainable through the conventional process route of intermediate rolling with a thickness reduction of 12-16% at the Continuous Hot Annealing and Pickling Line (HAPL) of the hot rolled coil that is followed by a minimum of 70% cold reduction in a 20-Hi Sendzimir Z-Mill and subsequent bright annealing at Jindal Stainless Limited. The investigation is carried out by comparing, the microstructure and mechanical characteristics of coils from a single melt, processed at HAPL with and without intermediate rolling, while maintaining all other process parameters constant. The coils that were bypassed intermediate HAPL rolling exhibited a uniform microstructure with an optimal ASTM grain size of 6.5-7 and an R-bar value of 1.4. On the other hand, the HAPL rolled coil evaluated after bright annealing displayed a coarse-fine band type microstructure with a similar R-bar value of 1.37, along with identical mechanical properties. The reason for equivalent R-bar value in bright annealed condition is explained by the texture study performed on 14% cold rolled samples annealed at 970̊C at HAPL revealing strong γ-fibre texture component, beneficial for formability along with insignificant cube orientation, detrimental for drawability. Ultimately, the single cold rolling practice at the Z-mill is continued as equiaxed microstructure is successfully achieved.

Keywords: Deep drawing, Intermediate Rolling, Plastic strain anisotropy(R-Bar), Texture.

SPC_129

Properties Enhancement in Duplex Stainless Steel through Strain-induced Martensite Transformation (SIMTR) and its reversion

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Abstract

Duplex stainless steels (DSS) are used in demanding applications in oil, gas, paper & pulp and offshore industries owing to their exceptional properties. In recent years, fluctuating prices and limited resources of nickel have compelled stainless steel manufacturers to look for cheaper alternatives, thereby fuelling the development of cost-effective lean duplex stainless steels (LDSS). Commercial grades of LDSS such as UNS S32101 and UNS S32304 possess UTS levels of up to 600 – 700 MPa with total elongations of up to 30%. Increasing strength and ductility in these steel is challenging and widen market usage.

In the present work, an innovative thermomechanical processing (TMP) methodology has been evolved for the attainment of this seemingly unlikely combination of properties through cold rolling and short annealing treatment. LDSS heats were casted and subsequently rolled to 6mm thick strip with finishing rolling temperatures of 1080 ºC. The hot rolled LDSS steels were conferred heavy cold reductions to the tune 70-80% in through multipass rolling for effecting complete strain-induced martensitic (SIM) transformation. The cold rolled strips were subsequently conferred controlled annealing treatments at 1050ºC for inducing reversion of SIM to fine grained austenite. As a result, a considerable improvement in tensile properties of could be achieved with UTS: >1 GPa and Elongation: >60%, which will serve to widen their usage in structural, engineering and automotive applications for load bearing purposes. Both hot rolled and cold rolled developed duplex stainless steel showed better corrosion resistance than that of the bench mark AISI 316 stainless steel.

Keywords: Lean Duplex stainless steel (LDSS), Transformed induced plasticity (TRIP), cold rolling, corrosion

SPC_054

Effect of Grain Boundary Engineering (GBE) on the room temperature and high temperature tensile properties of 316L Stainless Steel

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Abstract

To improve the grain boundary structure-dependent properties, grain boundary engineering (GBE) technique was first employed in the 1980s [1]. GBE essentially focuses on incorporating a very high fraction of coincident site lattice (CSL) related special grain boundaries having significantly lower energy as compared to random high angle grain boundaries (RHAGB) [2]. Since the first demonstration of property improvement through the control of grain boundary structure, the GBE field has evolved a lot both in terms of theoretical and practical understanding related to how low-energy special boundaries (SBs) are formed during thermo-mechanical processing (TMP). Understanding behind the effect of processing parameters on the evolution of CSL boundaries is crucial for obtaining control over Grain Boundary Character Distribution (GBCD). While the major emphasis of GBE literature had been on corrosion resistance as well as associated phenomena [3], effect of GBE processing on the mechanical properties is not well explored. Hence to improve the practical application of grain boundary engineered materials and to design the high-performance commercial alloys more efforts are certainly required to understand how GBE affects the mechanical properties, especially at high temperatures of materials.

The present work utilizes GBE to potentially improve the tensile properties of 316L austenitic stainless steel (ASS) at room temperature and high temperature. TMP comprising of low extent of room-temperature rolling with thickness reduction of 5% followed by high-temperature annealing at 1050°C for 30 minutes was employed to create GBE microstructure containing a high fraction of low-energy CSL grain boundaries. The effect of TMP on the microstructural changes including the type of grain boundaries, their fraction and distribution was analyzed using scanning electron microscope (SEM) based electron backscatter diffraction (EBSD). More specifically, different grain boundary related parameters such as misorientation angle distribution, CSL fraction and connectivity of different types of special grain boundaries, triple junction statistics etc. were analyzed. The effect of TMP and hence the favorable grain boundaries on the tensile properties was characterized using uniaxial tensile tests at room temperature and high temperature (700°C) for GBE and Non-GBE samples. The results indicate that the GBCD optimized (i.e. GBE) sample exhibits improvement in ultimate tensile strength (UTS) and ductility, while the yield strength (YS) remains similar as compared to the Non-GBE material. This improvement can be attributed to enhanced deformation uniformity and increased resistance to intergranular cracking and crack propagation due to the formation of more than 71% low-energy CSL grain boundaries in the GBE sample.

SPC_062

Keywords: Coincident Site Lattice (CSL); Grain Boundary Engineering (GBE); Thermo-Mechanical Processing (TMP); Mechanical Properties.

References

[1] Watanabe, T. Res. Mech. 1984, 11, 47–84.
[2] Kumar M., Schwartz AJ, King WE, Acta Materialia, 50 (2002) 2599–2612
[3] Randle, V. Mater. Sci. Technol. 2013, 26, 253–261.

Characterization of Titanium Stabilized Grade 439 of Thickness>2 to 3 mm for suitability in Deep Draw Applications

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Abstract

Ferritic stainless steel (FSS) is important in modern industry because of its low cost, relatively good mechanical properties,
good stress corrosion cracking resistance, etc

The demand for high-performance materials in deep draw applications in modern automotive industry has led to the exploration of advanced grades of stainless steel. Grade 439, known for its formability and excellent oxidation and corrosion resistance at higher temperatures (~850°C), further enhanced by the addition of titanium which improves the microstructure and the material's performance under high-stress conditions.

This study focuses on the characterization Grade 439 stainless steel which is a versatile and cost-effective material that delivers a well-grounded balance of performance characteristics such as corrosion resistance, heat stability, and mechanical strength. Material with thk>2mm was processed with different %cold reduction to examine its effect on Texture evolution in Normal Direction parallel to the <111> direction required for Deep Drawing.

Comprehensive analyses, including Tensile Testing, Erischsen Cupping Test, Microstructural examination via Optical Microscopy, employed to evaluate the mechanical properties, Plastic Anisotropy, and Cupping value. Textural characterization via Electron Backscatter Diffraction performed which delineates the influence of texture on the material's deep drawing behaviour. Dependence of material's ductility and formability during the deep drawing process with distinct crystallographic orientations and texture component (γ-Fibre i.e ND//<111>) were prevised.

Keywords: Titanium Stabilized Ferritic Stainless Steel, Automotive, Deep Drawing, Plastic Anisotropy, Texture, γ-Fibre

SPC_145

Microstructural Influences on Impression Creep in 304HCu SS Welds: A Comprehensive Experimental and Computational Investigation

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Abstract

304HCu SS is a candidate structural material for super heater/ reheater sections in Advanced Ultra Super Critical (AUSC) power plants in which live steam parameters are 710/720°C and 301bar. The 304HCu SS super heater/ reheater tubes are designed to be used for a maximum temperature of 650°C in this step wise boiler constructed using martensitic, austenitic and nickel base super alloys. In the present study impression creep tests have been carried on 304HCu SS boiler tubes and its weld joints. These weld joints are fabricated in manual TIG welding method by a qualified welder. In the present study, characterization of the creep behavior of different microstructural zones, i.e., base metal (BM), weld metal (WM), and heat affected zone (HAZ). The tests were performed at constant temperature (873 K) at different indentation stress levels (525, 606, 666, and 730 MPa). Similarly at an indentation stress of 606MPa the tests were carried out at 898, 923, 948 and 973 K. The experimental observations show that weld metal exhibited superior creep resistance compared to base metal under all test conditions and it is ~15 times higher for weld metal tested at 923 K compared to the base metal. Both base metal and weld metal exhibited a true stress exponent of ~5, consistent with dislocation creep as the dominant mechanism. Activation energies were calculated as 404 kJ/mol for BM and 468 kJ/mol for WM, indicating a higher energy barrier for creep in the WM. Impression creep threshold stress calculated for base metal and weld metal are 197 and 203 MPa receptively. The superior creep resistance of WM is attributed to its higher nickel content, which significantly influences the activation energy for lattice self-diffusion assisted dislocation climb, the rate-controlling mechanism in this temperature and stress regime. Finite element analysis of the impression creep revealed that the plastic deformation underneath the punch occurs in the initial stages of creep. The plastic zone size obtained from FE analysis through Von mises stress distribution deviated by 8% from the plastic zone size measured from the optical micrographs of the tested specimen. This paper presents the findings of the experimental and computational studies on Impression creep behaviour of S304HCu weld joints.

SPC_159

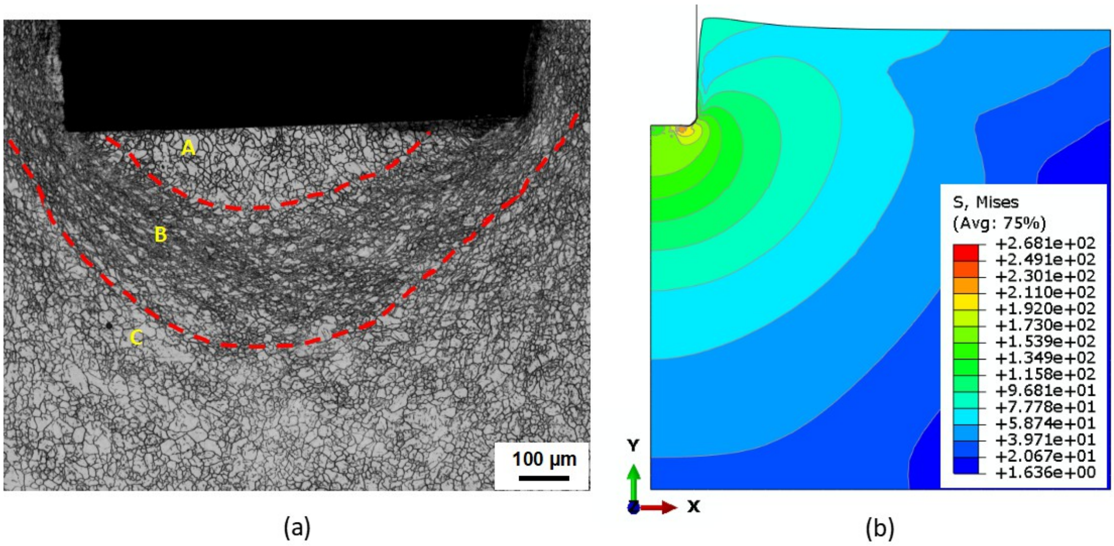

Fig. (a) Optical micrographs of area under punch, and (b) Von Mises stress distribution in 304HCu SS base metal impression creep tested at 948 K and 606 MPa for 138.5 h

Key Words: 304HCu SS; Impression Creep; Weld joint; Microstructure; Finite Element Analysis

Mitigation of Luders band or Stretcher Strains in formed components of Ferritic Stainless 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

FAN_064

Effect of micro-structure on mechanical behaviour

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Abstract

AMETEK's suite of materials analysis technologies, incorporating advanced systems from EDAX and Gatan, offers an integrated approach to the in-depth investigation of metals and metal alloys. EDAX's electron microscopy and energy-dispersive X-ray spectroscopy (EDS) provide high-resolution elemental mapping and quantitative compositional analysis, facilitating the study of phase distributions and microstructural variations within metallic systems. Gatan's instruments, particularly those utilizing advanced electron energy loss spectroscopy (EELS) and atomic-resolution imaging, enable precise characterization of atomic structure and surface morphology. These capabilities are pivotal for elucidating the crystallographic, electronic, and chemical properties of metal alloys at the nanoscale.
Furthermore, AMETEK's EDAX EBSD high-speed imaging systems capture transient phenomena such as mechanical deformation, phase transitions, and fracture dynamics in real time, enabling the study of metallurgical processes under operational conditions. This combination of technologies enhances the understanding of alloy behavior under stress, offering insights into fracture mechanics, fatigue, and failure analysis. AMETEK's comprehensive analytical framework supports both fundamental research and applied materials development, with significant implications for industries ranging from aerospace to automotive and metallurgical engineering, thereby driving innovation in material design and process optimization.