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IIM METAL NEWS

A monthly publication of The Indian Institute of Metals

Hon'ble Minister of State for Steel and Rural Dev. Shri Faggan Singh Kulaste commenced the Function with the traditional lighting of the lamp

IIM Honorary Membership is conferred on Mr. T V Narendran

IIM Platinum Medal is awarded to Dr. Amol A Gokhale

Inauguration of Exhibition by Hon'ble Minister of State for Steel

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Inauguration of IIM-ATM by President, IIM

ATM - 2K22

Memorial Lectures Speakers

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Vol. 25 No. 11 November 2022

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Dr. N Eswara Prasad

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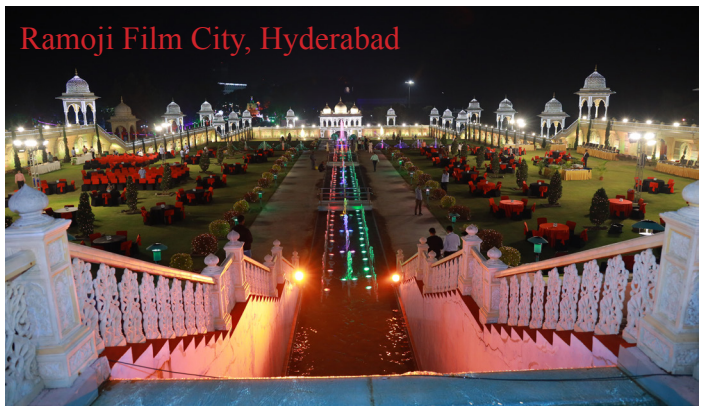

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Inaugural Speech @ IIM-ATM 2022

(IIM President's speech has been delivered by Shri Satish Pai, Senior most Vice President of IIM & MD, Hindalco on behalf of Dr. Samir V Kamat, IIM President & Chairman, DRDO & Secretary, DD R&D.)

Chief Guest of the Day, Honourable Minister of State for Steel and Rural Development, **Shri Faggan Singh Kulaste** Ji; **Professor B. J. Rao,** Vice Chancellor of University of Hyderabad & Guest of Honour today; **Professor B .S. Murty,** Director of IIT-Hyderabad and Vice President, IIM; **Dr. G. Madhusudhan Reddy,** Director of Defence Metallurgical Research Laboratory and Chairman of IIM Hyderabad Chapter; **Shri Kushal Saha,** Secretary General IIM; **Dr. Amit Bhattacharjee,** Convener of IIM ATM 2022; Former Presidents of IIM, other dignitaries gracing the occasion today, ladies & gentlemen,

A very good morning to all of you! It is my pleasure to be here and address you all this morning.

I would like to start by saying a few words about the Indian Institute of Metals or IIM as it is called. The Indian Institute of Metals is a scientific society, primarily meant for professionals in the field of metallurgy and materials science. It was formed in 1947 at Kolkata, with a modest membership of 42. Today, the IIM has 8000 plus members and has 56 chapters spread across the country.

Unlike many professional societies or institutions meant for industry, scientists or engineers, IIM is a unique institution, in that, it has representation from across academia, R&D institutions, and the industry sectors, and therefore, is well placed to contribute significantly to the growth and welfare of the country, through its membership and activities, which include organising national and international technical conferences and programmes, research activities, publications, etc. IIM is now recognised throughout the world as one of the premier metallurgical organisations. As the country looks to ever-increasing self-reliance, IIM can catalyze the country in achieving Atma Nirbharta in Materials.

The Annual Technical Meeting (ATM) has been a flagship event of IIM, that is eagerly awaited by the country's metallurgy and materials science community. On several occasions, there has even been a significant representation from overseas participants. The present edition, being hosted by the Hyderabad and Visakhapatnam Chapters, in association with the Defence Metallurgical Research Laboratory (DMRL), Hyderabad, and other leading institutions in and around Hyderabad, is the 76th ATM, and provides an opportunity for delegates and invitees from research laboratories, industries and academia, to get together and discuss the recent accomplishments, latest developments, and the opportunities and challenges that lie ahead. I understand that more than 850 people have registered to participate in this year's event. It is perhaps a reflection of the fact that the event is happening in physical or in-person mode after 2019. The events in 2020 and 2021 were held primarily in online mode due to the COVID pandemic, which hopefully, is behind us now.

Despite all the negative effects it caused, COVID has also brought in new workstyles and cultures. Today, more than ever, the world can connect and work online globally in a networked fashion. There can be

no better example than the international symposium AMDAM, which was conducted very successfully yesterday in hybrid mode. There were several hundred people in the audience and about 100 people attended online. Speakers from Australia, Singapore, Japan, Europe, and the US, delivered their lectures from their usual workplace or residence, without having to travel here. There were in-person lectures too.

At the same time, having physical meetings such as this one, connecting with one another and forming new professional relationships, contribute crucially to the growth of the individual, the profession, and indeed, the society and the country as a whole.

The topic of the International Symposium, 'Accelerated Materials Development and Additive Manufacturing', was chosen to reflect the current global trends in materials discovery, development and deployment. The idea is to go, with respect to new materials or applications, from concept to product, as quickly as we can, and at as minimal cost as possible. Discussions on such topics can serve and support India's aspirations to grow to become a global leader.

The topics for the two panel discussions scheduled later today, ''Role of Innovation and R&D in Indian Industries: Roadmap to AtmaNirbhar Bharat, and beyond, to Global Leader' and 'Strategic Material Security: Technological and Geopolitical Perspective', have again been chosen, so that deliberations can happen on these important topics, and a productive exchange of ideas can take place, all to support the country's march towards AtmaNirbharta and beyond.

Looking forward to the rest of the event, a very interesting and informative programme awaits all of us. There are plenary and keynote lectures, and several invited & contributed presentations distributed over several technical sessions. Keeping in tune with the uniqueness and true spirit of IIM, the technical sessions have again been carefully formulated, to have a nice balance between topics of interest and relevance to delegates from industry, academia, and the Research and Development sectors.

Sessions like Industry 4.0, mineral processing, green manufacturing, and light-weighting, have a strong industry focus, while sessions such as correlative microscopy, ultra-high temperature materials, advanced functional and composite materials, represent current trends in materials research and development. Sessions on ICME and additive manufacturing are designed to explore in greater depth and continue the deliberations from the International Symposium conducted yesterday. In addition to the technical sessions, more than 400 poster presentations, a metallography contest and an interesting technical exhibition are also being featured as part of the 76th ATM.

I am glad to note, that just like the sessions, there is a well-balanced participation as well, in terms of delegates and invitees spanning the academia, R&D and industry sectors. I don't want to take much of your time other than to wish all of you an exciting and productive three more days. Enjoy, learn and have a fruitful time at the event in this wonderful venue. Thank you very much.

****

Prof. N. P. Gandhi Memorial Lecture

Hydrometallurgy and Electrochemistry: Keys to a Sustainable, Secure Indian Economy

Rajiv Shekhar
Director, Indian Institute of Technology (ISM) Dhanbad

I. Introduction

It is indeed my proud privilege to be invited to deliver the prestigious Prof. N. P. Gandhi Memorial Lecture. I am grateful to the IIM management for bestowing this honour on me. Several eminent personalities have shaped my academic career, the most notable being my PhD Supervisor from Berkeley, Prof. James. W. Evans. Prof. Evans, along with Profs. Julian Szekeley, H. Y. Sohn, and Keith Brihmacombe, was responsible for introducing CFD modelling in process metallurgy, aiding metallurgists to 'see through' and scale-up opaque metallurgical reactors. Prof. Evans instilled in me the spirit of independent thinking and the "keep-it-simple" philosophy. I have also been inspired by the Late Dr. R. P. Das of CSIR-IIMT Bhubaneswar (IMMT), one of the best hydro-metallurgists India has produced. Finally, I am grateful to all my students, who taught me the nuances of metallurgy, materials processing and computational fluid dynamics (CFD). Prof. Aparna Singh's (IIT Bombay) persistent questions in an UG course forced me to understand the nuances of chemical kinetics. I am especially proud of two of my PhD students, Dr. Kali Sanjay (IMMT Bhubaneswar) and Dr. Amit Gupta (ABSTC Mumbai) who are currently one of the leading hydro-metallurgists and of aluminum ddsmelter designers, respectively.

The world is inexorably marching towards a sustainable economy replete with renewal energy resources, electric mobility, and green hydrogen. India is no exception. The thrust towards renewable energy and electric mobility has shifted the focus towards the underlying metals such as lithium, cobalt, nickel, and rare earth elements (REE). A typical electric vehicle (EV) battery pack requires around 8 kg lithium, 35 kg nickel, 20 kg manganese and 14 kg cobalt. EV-charging stations require significant amounts of copper. Solar panels use large quantities of copper, silicon, silver, and zinc. Wind turbines require iron, copper, and aluminum [1] REE are necessary components for a wide range of critical consumer and defense related products: cell phones, hard drives, electric vehicles, guidance systems, lasers, and radar and sonar systems [2]. Clearly, non-ferrous metals are critical to the growth and security of the Indian economy.

Sustainability and a carbon-free economy are poised to be the two important pillars of the Indian, and the global, economy. Sustainability in our context relates to the economic production of non-ferrous metals from low grade ores with minimal generation and maximum utilization of wastes. Generation and transport of green hydrogen and modifying, if not replacing, commercial processes to reduce fossil fuel consumption are two important pathways to a carbon-free economy.

Extraction of non-ferrous metals from low-grade ores preclude the use of pyrometallurgical processes because of copious energy consumption by gangue. Thus, hydrometallurgy becomes an economically viable option for treating low grades of critical non-ferrous metals such as Ni, Co, and REE. Leaching, precipitation, solvent extraction, gaseous reduction of metals from aqueous solutions, and electro-winning are the key hydro-metallurgical unit operations. Hydrogen is produced most economically by coal/methane gasification, but this process simultaneously generates CO. Hence electrolytic generation of green hydrogen has emerged as the cleanest carbon-free process. Long-range transport

of hydrogen will be a major requirement in a hydrogen-fuelled economy. Here we will show how electrolysis can play a critical role. Modification of fossil fuel guzzling processes, for example, cement production and utilization of fly ash from coal-fired power plants shall aid in speeding up our race towards a carbon-free economy.

The title 'Hydrometallurgy and Electrochemistry' may look odd for electrolysis is usually the final step of hydrometallurgy. However, there are subtle differences between the two. Electrochemistry in hydrometallurgy usually refers to aqueous electrolysis. In aluminium-smelters pure alumina is produced from bauxite through hydro-metallurgical precipitation but the metal is produced by molten salt electrolysis. Similar is the case with REE extraction. In addition, there are several processes which use aqueous electrolysis for processes unrelated to metals extraction such as green hydrogen, cement production, and remediation of heavy metal contaminated soils. It is well known that mineral processing unit operations are key to the extraction of metals from low grade ores. The absence of mineral processing from the title is a testimony to my lack of adequate exposure and expertise in this critical area.

In this lecture, I shall briefly enumerate the (i) hydrometallurgical route for processing laterite ores and fly ash, (ii) electrochemical production of neodymium, ammonia, and cement, and (iii) electrokinetic remediation process for in-situ treatment of red mud from alumina refineries. This will be followed by a discussion on the importance of computational fluid dynamics (CFD) skills in 'Scale-up'.

II. Hydrometallurgical processing

A. Nickel and cobalt

The annual consumption of Nickel and cobalt in 2021 was 75 kt and 100 t respectively, most of which was met through imports [3]. India has no commercially exploitable nickel and cobalt ores. Chromite overburden in Sukinda, Odisha with 0.03-0.04% Co and 0.7% Ni and polymetallic nodules with 0.1% Co and 1% Ni are low grade resources of interest. Residues, spent catalysts, slag and scrap are secondary resources for Ni and Co.

CSIR-IMMT developed a flowsheet for the extraction of Ni from chromite overburden (see Fig. 1a), which was tested in an in-house 10 tpd (tons/day) pilot plant. IMMT also demonstrated the process to extract Cu, Ni, and Co from polymetallic nodules (see Fig. 1b) in a 500 kg nodules/day plant at CRDL, Hindustan Zinc Limited, Udaipur.

NML has also tested the pyro-hydrometallurgical route for the extraction of Cu, Ni and Co from polymetallic nodules through reduction roasting – ammoniacal leaching route in 100 kg scale.

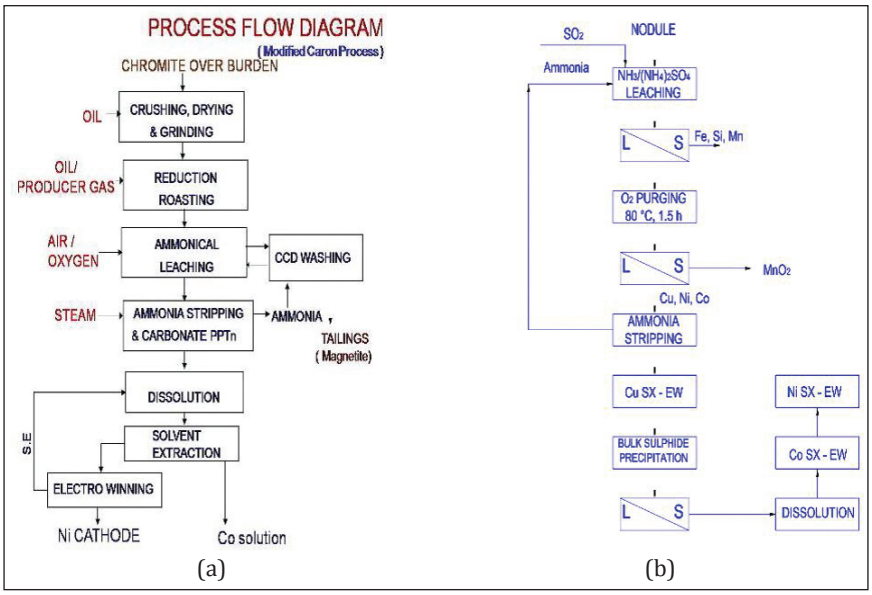


Fig. 1 : Process flowsheets demonstrated by CSIR-IMMT Bhubaneswar for the hydrometallurgical extraction of (a) Ni from chromite burden and (b) Cu, Ni, Co, Mn from polymetallic nodules.

IMMT also successfully commercialized the production of 0.1 ktpd (kilotons/day) Co metal and 0.1 ktpd $CoSO_4$ from super alloy scrap/sludge for Ms. Rubamin Ltd., Baroda. Currently IMMT has completed the process flowsheet and complete engineering package of extracting Ni and Co from 1500 tpa (tons/annum) maraging steel scrap. Unfortunately, large-scale production of Ni and Co from chromite overburden using the conventional ammoniacal leaching route is not economically feasible and efforts are being made through high pressure acid leaching that will reduce the cost of chemicals for improving the techno-economics. In fact, several novel flowsheets for the extraction of critical non-ferrous metals from Indian laboratories have been reported in the literature. However, the effect of scale has not been adequately investigated. As the scale increases, mass transfer becomes the dominant reaction mechanism. Consequently, a rigorous fluid flow, heat, and mass transfer (referred to as CFD) analysis is essential for the optimum design and scale-up of hydro-metallurgical reactors to maximize metal recovery from low grade ores. Unfortunately, detailed CFD analysis is conspicuous by its absence in the domain of non-ferrous extraction.

B. Fly ash processing

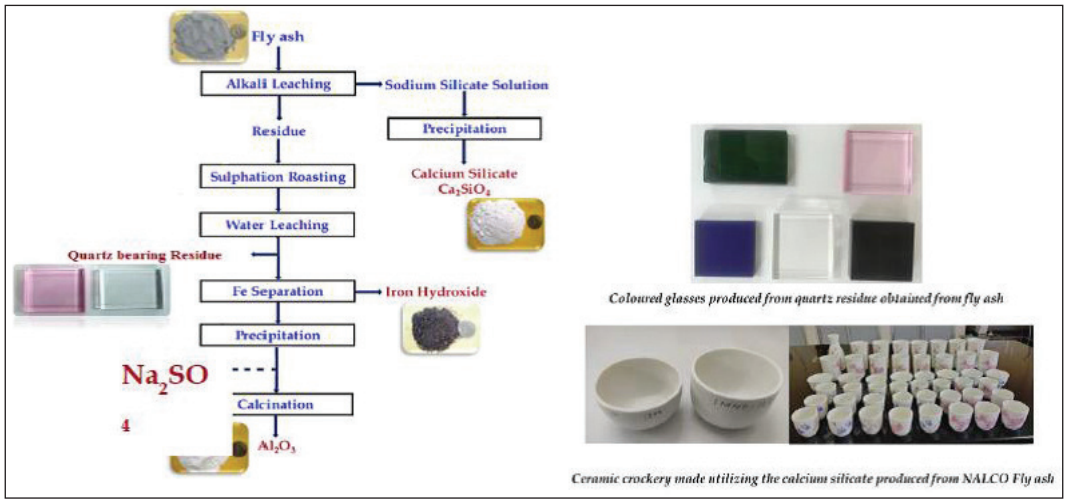
In FY 2020-21, 92.41% of the 232 Mt of fly ash has been utilized, a remarkable feat. The major modes of fly ash utilization are in the manufacturing of cement, bricks and tiles, reclamation of low-lying areas and roads and flyovers. Unfortunately, 1738.19 Mt of legacy ash was available as on 31/03/21 [4]. Consequently, the rate of fly ash utilization must be increased substantially. Based on a review of literature and US patents, Sahoo et.al. [5] described the recovery status of major elements such as Al, Si, Fe and Ti, trace elements, and REEs. IMMT developed a process flowsheet [6] for the recovery of alumina, calcium silicate, iron oxide and a quartz bearing residue from fly ash containing 25 – 28% Al_2O_3, 60 – 62% SiO_2, 3 – 4% Fe_2O_3, and 1 – 1.5% CaO (see Fig.2a).

The IMMT process was tested at bench scale with a TRL level of 4 – 5. Coloured glasses and ceramic pottery were made from quartz reside and calcium silicate respectively (see Fig. 2b). Alumina can be used for aluminium smelting. IMMT has further proposed to recycle the Na_2SO_4 effluent to produce NaOH and H_2SO_4 by electrodialysis. Again, scaling of the fly ash process will be a major issue.

III. Electrochemical processing

A. Neodymium Extraction

Neodymium is produced by molten salt electrolysis [7]; the process is similar to aluminium smelting. 2 wt.% high purity Nd_2O_3 is dissolved in a molten NdF3–LiF (molar ratio of 48:52). Electrolysis is carried out at a temperature of 1050 °C, which is greater than the melting point of neodymium.



(a) (b)

Fig. 2 : (a) IMMT flowsheet for the processing of fly ash and (b) coloured glasses and ceramic pottery made from quartz reside and calcium silicate respectively.

Unlike aluminium, vertical electrodes (W/Mo cathode, graphite consumable anode) are used. The cell operates at a high current density of 10^4 A/m^2 and a cell voltage of 3.6 V. Liquid neodymium 'deposits' at the cathode and collects to form a liquid layer in the cell bottom, from where it is removed at regular intervals. However, the cell size is small and operates at a total current of 3 kA compared to 500 kA in modern aluminium cells. Typical cells produce roughly 2–3 t of Nd metal per month. A major challenge is to scale Nd cells.

B. Cement

Process modification will focus on exploring alternative methods to manufacture existing CO_2-intensive products by (i) reducing operating temperatures and pressures and (ii) generating concentrated streams of CO_2 that are easier to capture. Electrochemical synthesis of cement is one such example [8]. Lime, a key ingredient for cement, is synthesized electrochemically and will be of high purity with the desired reactivity, consequently improving cement production efficiency. As shown in Fig. 3, the electrochemical cell converts solid $CaCO_3$ to solid $Ca(OH)_2$ following the overall reactions: $2CaCO_3$ (s) + $4H_2O$ (l) → $2Ca(OH)_2$ (s) + $2H_2$(g) + O_2(g) + $2CO_2$(g). More research is required to ensure the commercial feasibility of the electrochemical synthesis of cement.

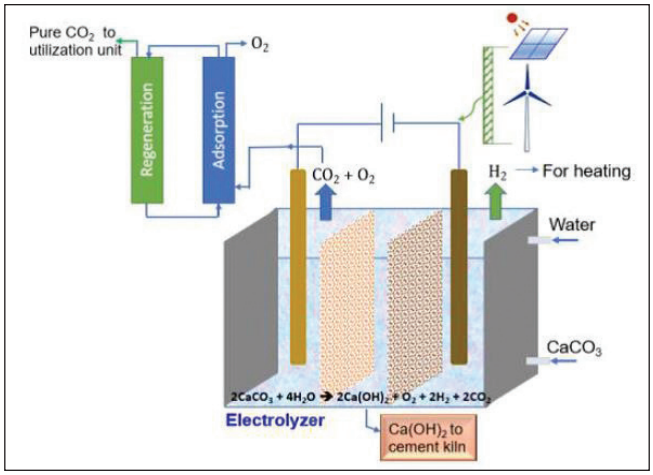


Fig. 3 : Electrochemical synthesis of cement.

C. Ammonia

A major impediment to a burgeoning Hydrogen economy is the bulk transport of hydrogen. This is primarily due to the low energy density of gaseous Hydrogen at atmospheric pressure, which is only 0.01 MJ/L compared to 32 MJ/L for gasoline. Liquefying it at -253 °C can significantly increase it to a respectable 8 MJ/L, but the process is expensive. Compressing gaseous Hydrogen to 700 bars will provide an energy density of around 5 MJ/L. These are the two approaches that are technically ready for commercial use, but the economics is not viable. Use of Ammonia as a Hydrogen carrier can successfully circumvent the vexing predicament explained above. The main advantage of this route is that ammonia liquefies at around 10 bars at room temperature or at -33 °C at atmospheric pressure. Its energy density is around 15 MJ/L which is even higher than that of liquid Hydrogen. Moreover, the industry has access to existing infrastructure worldwide due to its extensive use to produce urea in the fertilizer industry.

Currently, Haber-Bosch process is the most widely established method of generating ammonia in the industry, worldwide. This technology requires pressures above 100 bar and a temperature of 500 °C. There is a compelling need for substituting this energy intensive process with a more environmentally friendly alternative. Electrochemical synthesis of ammonia is one such alternative. Here, pure nitrogen gas is added to the cathode of an electrolytic cell undergoing water electrolysis. In acidic conditions, the cathodic reaction produces ammonia: $N_2 + 6H^+ + 6e = NH_3$ [9]. The major challenge is the low current efficiency of the ammonia evolution reaction due to the high ionization potential of nitrogen and low solubility of nitrogen in water. Consequently, research is focused on the development of catalysts and the search for an electrolyte which has high solubility for nitrogen.

IV. Electro-kinetic remediation of red mud

Limiting the spread of toxic pollutants from process industries should be an important objective of metallurgical engineers. One such toxic source is red mud generated in the Bayer process where bauxite ore is leached of produce alumina. India produces about 9 Mt of red mud annually. Red Mud is a highly alkaline waste with a pH of about 12-13, containing traces of toxic heavy metals (Chromium, Arsenic, Cadmium etc.) and radionuclides [10]. However, the pace of red mud utilization has not picked up substantially even though cement industry has

started using it. Hence there is a need for the in situ remediation of red mud. Electro-remediation, primarily used for removing heavy metals from soil, could be one such method. In electro-remediation, the contaminants in the liquid phase in the soil are moved under the action of the electric field, primarily by electromigration and electroosmosis, to wells (porous ceramic tubes) from where they are then pumped out (see Fig. 4). During electro-remediation, electrolysis of water occurs at the electrodes releasing H^+ (anode) and OH^- (cathode) which then migrate towards the cathode and anode respectively. Since the mobility of H^+ is much greater than that of OH^-, the high alkalinity of the soil may be neutralized by the acid front moving towards the cathode, while simultaneously removing the metal contaminants [11]. The main design parameter is the two-dimensional configuration of electrodes. It has also been shown that electro-remediation can also reduce the rate at which heavy metals dissolved in rainwater can permeate through the underlying soil [12].

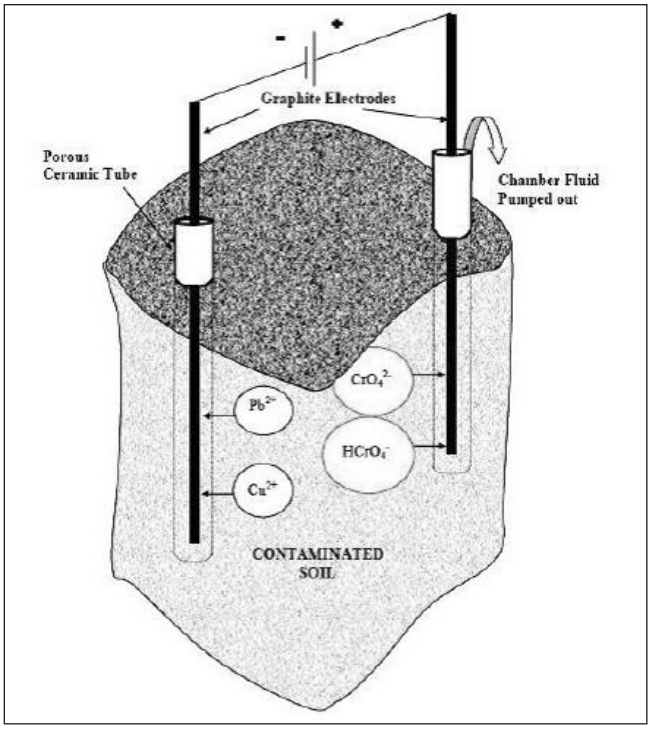


Fig. 4 : Schematic diagram of electro-remediation

V. Importance of CFD in Scale-up

To illustrate the importance of CFD in scale-up, let us consider a solvent extraction unit. It has two components: a pump mixer and a settler. The aqueous and organic phases are mixed in a pump mixer leading to the dispersion of organic droplets in the aqueous phase. Herein, the metal ions are transferred from the aqueous phase to the organic phase through the aqueous-organic droplet interface. The inter-phase transfer of metal ions in the mixer requires a high level of turbulence and small droplet sizes (for large aqueous-organic interfacial area). The two-phase aqueous-organic mixture flows from the mixer to the settler where the separation of the two phases occur by gravity. Efficient and fast separation requires large organic droplet sizes, which is facilitated by droplet coalescence.

The mixer assembly should have the following characteristics: (i) generate enough shear to create small organic droplets and (ii) ensure that the droplets start coalescing before they enter the settler. Clearly, there is a need to generate the 'optimum' bubble size distribution in the mixer, which, in turn, depends on the fluid flow pattern in the mixer. The nature of fluid flow in the mixer is a function of the design and operating characteristics of the impeller: type of impeller, the ratio of impeller to tank diameter, clearance from the bottom, position and number of baffles, and RPM of the impeller.

An ideal settler should have a quiescent, plug flow which promotes coalescence and settling of droplets. Unfortunately, the inlet to the mixer is much smaller than the width of the settler making it difficult for the incoming flow to spread out uniformly across the width "without introducing undesirable features such as turbulence, short-circuiting and flow reversals. [13]" Consequently, internal features such as picket fences are added to achieve plug flow. The configuration, number, and positioning of picket fences affect flow in the settler.

Over the years, several scale-up parameters and equations based on geometric and kinematic similarity have been developed. Unfortunately, "no single method has been successful for all situations, and the characteristics of the system must be understood as well as possible to maximize the chances for success [14]." Hence the best method of scale-up would be to supplement geometric and kinematic similarity considerations with CFD calculations validated by experiments.

Industrial-scale molten salt electrolysis systems are primarily rate limited by mass transfer, which in

turn depends on fluid flow. Consider the example of Hall-Heroult cells which operate at temperatures ~950 °C, which is achieved through joule heating of the electrolyte. Hall-Heroult cells are energy guzzlers and hence the major objective of research in aluminium smelters is the reduction of cell voltage and consequently the specific energy consumption. Any changes in existing cells must ensure that the cell is stable. Cell stability requires a nearly 'flat' electrolyte-aluminium interface, thereby preventing the liquid aluminium from coming in contact the carbon anodes. Flow in a Hall cell is driven be the electromagnetic field generated by the current in the bus bars and within the cell. In addition, a layer of solidified electrolyte (ledge) is formed at the walls of the cell to prevent contact between the insulating layer and the highly corrosive electrolyte. The shape of the ledge also affects the nature of fluid flow and hence cell stability and vice-versa. Thus, we have a situation where fluid flow and heat transfer are inter-dependent. Unfortunately, because of the high surface area to volume ratio, joule heating is not possible in laboratory-scale reactors. Therefore, development in Hall cells have primarily been through CFD. In India, Aditya Birla Science & Technology Centre (ABSTC), Mumbai is probably the only institution in India best equipped to indigenously modify and design smelters. One practical application has been the use of copper insert collector (CuCB) bar for energy reduction in 360 kA smelters [15]. Pilot experiments showed that the use of CuCB reduced the specific energy consumption by 600 kWh/t. The design and scale-up of neodymium cells would necessitate a similar approach.

Despite its importance, very few academic and R&D institutions in India are involved in the application of CFD for scale-up of hydrometallurgical and electrochemical reactors. This shortcoming emanates from academic institutions where the mathematical and computational prowess of students graduating from Metallurgical/Materials Engineering departments leave a lot to be desired. Although each department has a course on transport phenomena, sufficient emphasis is not given to mathematical modelling of metallurgical reactors with the help of software such as PHOENICS or ANSYS. Mathematical modelling is primarily restricted to extractive metallurgy and processing of iron/steel. This must change, otherwise chemical engineers, sooner than later, will encroach the domain of extractive metallurgists.

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Dr. Daya Swaroop Memorial Lecture

Failure Investigation & Analysis – A Powerful Metallurgical Tool

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I. Introduction

By simple definition, failure is the gap between expectation and performance. It represents an adverse situation wherein a component, material/ system fails to fulfill its intended function satisfactorily during its intended service life. Failures are an inevitable in the life span of any system, but the probability of these occurrences may vary in wider aspects.

Metallurgical failure analysis is the process to determine the mechanism that has caused a metal component to fail. It can identify the cause of failure, providing insight into the root cause and potential solutions to prevent similar failures in the future, as well as culpability, which is important in legal cases.

Failure & Causes:

Different causes of failure and their effect in the Industries is given in following chart:*

A part or an assembly is considered to have failed because of one of these three conditions:

- When it becomes completely unoperated
- When it is still operable but is no longer able to perform its intended function satisfactorily
- When serious deterioration has made it unreliable or unsafe for further use.

Major causes of failure may be one or some of the following:

- Deficiency in terms of design
- Improper selection of the material
- Multiple defects in material
- Error in assembly
- Improper service conditions.

Some of the frequently encountered sources of failure are as under:

- Presence of mechanical notches at points of high stress.
- Use of too sharp a fillet radius at a change in section diameter.
- Change in design or up-gradation of a part for use in service conditions that are more severe than in its former use.
- Deficiency in design resulting from the impossibility of making reliable stress calculations for complex parts.
- Presence of internal and external defects in castings, forgings and other wrought products; these may include segregation, porosity, inclusions, limitations, voids, cracks, etc. or ambiguous material processing specifications, improper/incomplete heat treatment practice followed, acid pickling, electroplating that can lead to failure
- Errors in assembly arising out of inaccurate/ inadequate specifications
- Misalignment of parts such as shafts, couplings, gears, bearings, seals etc.

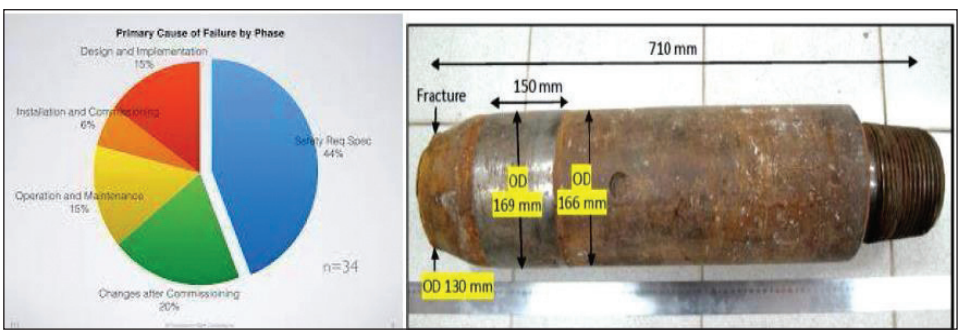


***Fig. 1 : Causes & Failures of Metals.**

- Improper service conditions in terms of temperature, pressure, speed, loading, chemical environment etc.
- Improper startup and shutdown procedure.

Why Failure Analysis?

Failure analysis helps in improvising the product reliability by suggesting changes in the design, manufacturing process and materials and also assists in extending the useful life of system or structure.

Legal reasons for failure analysis are equally compelling. This is in context with the product reliability laws. The pattern of failure can be compared to that of human life characteristics.

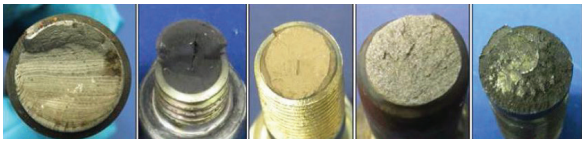


Fig. 2: Different failure modes form different fracture features.

Failure Analysis Steps:

The following guidelines help the investigator in a systematic manner to reach the root cause of the failures :

- Background information which provides what happened prior to and at the time of failure, the manufacturing history of the part and also the data collected from the discussions with the eye witness.
- Visual examination includes a visit to the scene of failure, making sketches and taking measurements, notes and photographs. It helps to select parts to be taken to the investigation agency for prima facie examination and understanding.
- Non-destructive examination to obtain defect-information on the surface as well as the core of the failed part.
- Fracto-graphic examination to identify the type and nature of fracture.
- Destructive test to ensure soundness of the material in conformity with the specification in respect of chemistry, properties of microstructure etc
- Examination of all data to arrive at a conclusion of the cause of failure and recommendations for its prevention.

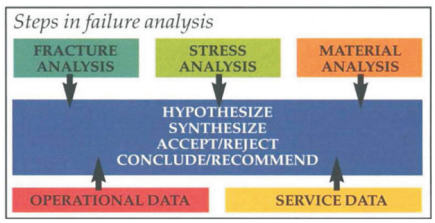


Fig. 3 : Steps in Failure Analysis.

Tools and Techniques of Failure Analysis:

The principal stages that comprise the investigation and analysis of a failure are as follows:

- Collection of background data and selection of samples
- Preliminary examination of the failed part
- Selection, identification, cleaning and preservation of samples
- Chemical analysis
- Non-destructive testing
- Mechanical testing
- Selection and preparation of samples for metallographic examination
- Examination and analysis of metallographic samples
- Analysis of fracture mechanism
- Determination of failure analysis

Non-Destructive testing (NDT)

Non-Destructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed, the part can still be used.

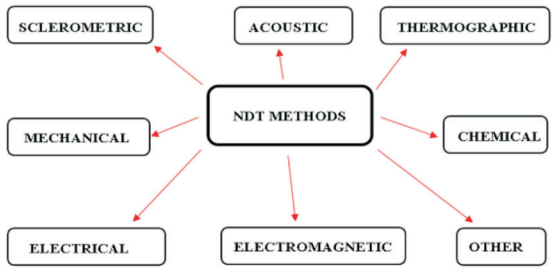


Fig. 4 : Different Methods of NDT.

NDT is carried out on failed part(s) to evaluate surface as well as internal defects in the material. Surface defects are evaluated using techniques such as

- Dye penetration test
- Magnetic practical test
- Eddy current test
- Ultrasonic test

Internal defects are evaluated by tests like

- Ultrasonic test
- Radiography
- Acoustic emission test
- Experimental stress analysis is special NDT method which may be employed for determining machine loads and component stress that can cause failure.

Fig. 5 : Equipment for different kinds of NDT.

- Use of strain-gauges to estimate acting stresses and use of x-ray diffraction method for residual stresses are fairly common.
- Commonly employed mechanical tests during failure analysis are the Hardness test, Tensile test and Impact test.

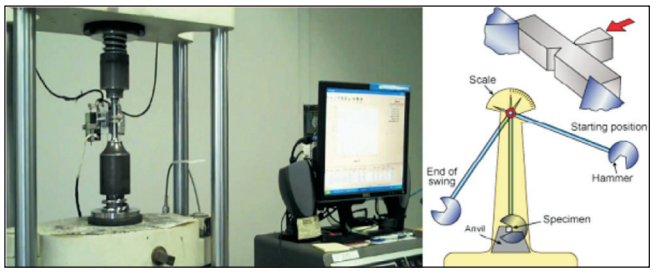
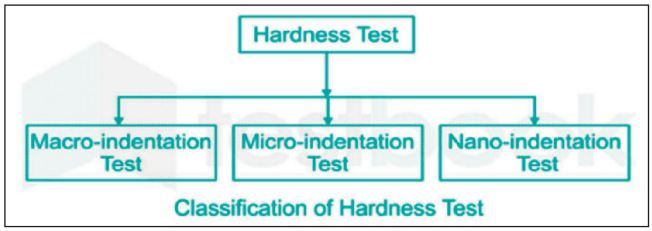


Fig. 6 : Tensile Testing and Impact Testing Machines.

Hardness test is classified into following three types as given below :



Hardness test is used for three major purposes:

- To assist in evaluating the heat treatment that the part has undergone
- To provide an approximate idea about the tensile strength of the material using standard monographs
- To determine the work hardening or softening that the part has undergone during service.

Tensile test gives an idea about the yield strength, ultimate tensile strength, ductility and toughness of material. It gives a general idea about the load bearing capacity of the material.

Impact test indicate the material's resistance to brittle fracture and also provide information regarding ductile-to-brittle transition of material with respect to temperatures.

Microscopic Examinations:

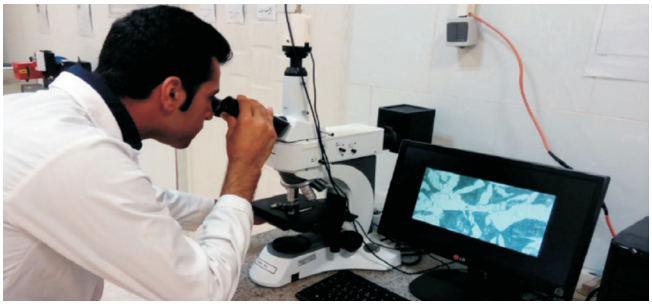


Fig. 7 : Testing with Optical Microscope.

The information gathered from such observation is valuable in analyzing the cause of failure and throws light on the following aspects.

Engineering materials are often placed in various service conditions, such as different status of mechanical stresses and temperatures, resulting in different types of mechanical failures.

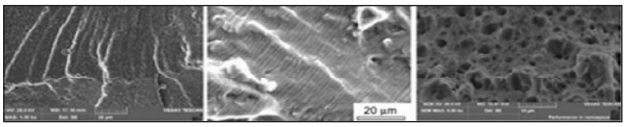


Figure : Three types of mechanical failure surfaces under electron microscope
Figure shows three fracture surfaces of metallic materials obtained using a scanning electron microscope. Describe the main features appearing at three fracture surfaces and discuss the corresponding crack propagation mechanisms with the detailed explanation.

Fig. 8 : Resulting Surfaces from Electron Microscope.

- Nature of origin of failure
- Location of contributing stress concentration
- Deviation of crack propagation and sequence of failure.
- Failure mode and mechanism
- Orientation and magnitude of stresses.
- Imperfections contributing to the failure.
- Presence of relevant contaminants on the fracture surface, e.g. scale, paint, corrosion products etc.
- Dimension and important physical data.

Common Metallography:

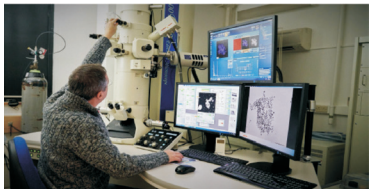


Fig. 9 : Testing with Electron (SEM) Microscope.

Metallography can be precisely defined as the scientific discipline of observing and determining the chemical and atomic structure and spatial distribution of the grains, constituents, inclusions or phases in metallic alloys. Metallographic microscopes are used to identify defects in metal surfaces, to determine the crystal grain boundaries in metal alloys, and to study rocks and minerals.

Fracture & Steps in fracture:

Separation of a body into pieces due to stress, at temperatures below the melting point.

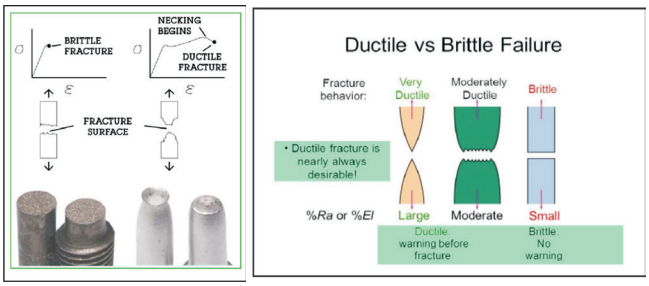


Fig. 10 : Different types Fracture.

Scope of Crack formation in material

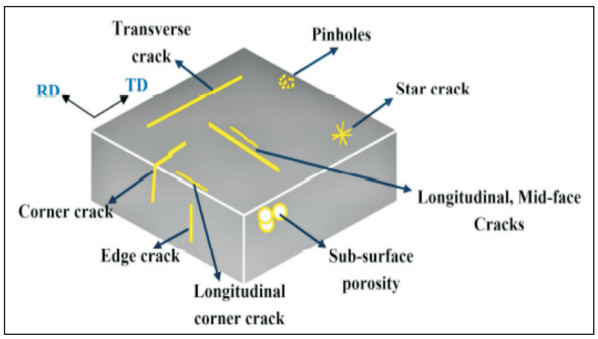


Fig. 11 : Scope of Crack formation.

Steps:

• Crack formation

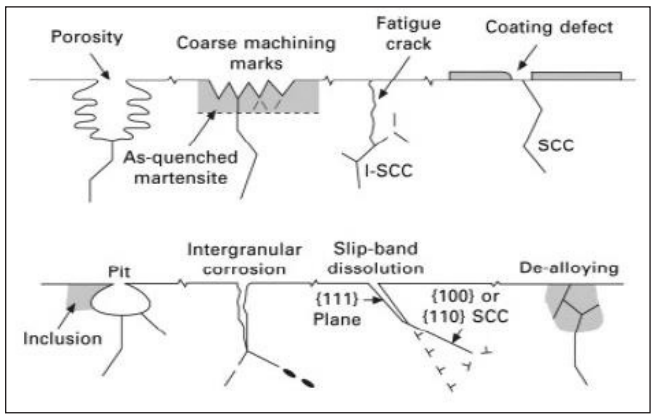


Fig. 12 : Causes of Crack formation.

• Crack propagation

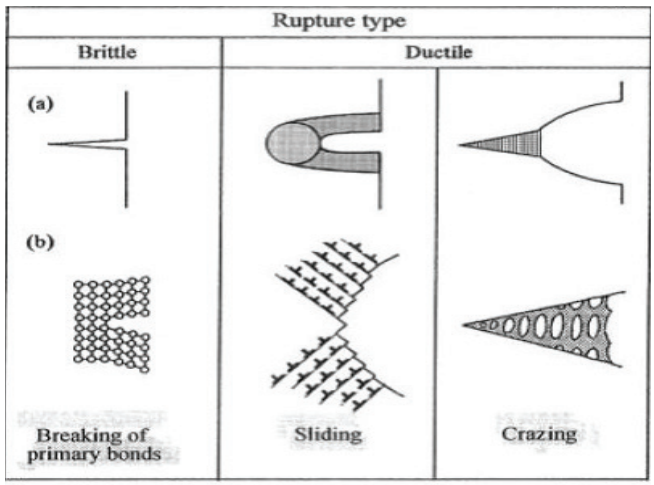


Fig. 13 : Crack Propagation in Brittle and Ductile Material.

• Depending on the ability of material to undergo plastic deformation before the fracture, two fracture modes can be defined -ductile or brittle

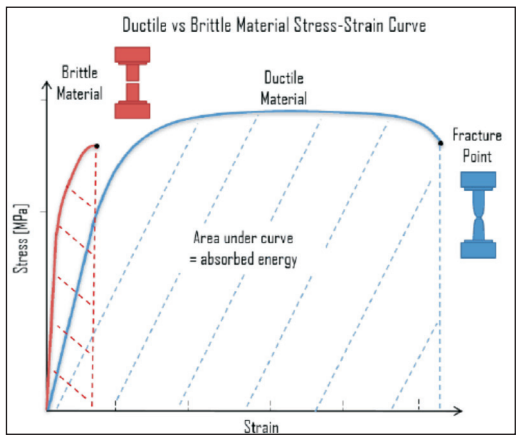


Fig. 14 : Stress-Strain Curve for Ductile and Brittle Material.

• Ductile fracture -most metals

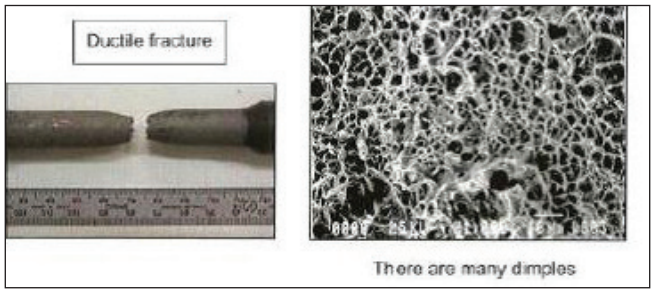


Fig. 15 : Fracture in Ductile Material.

• Extensive plastic deformation ahead of crack

• Crack is stable : resists further extension unless the applied stress is increased

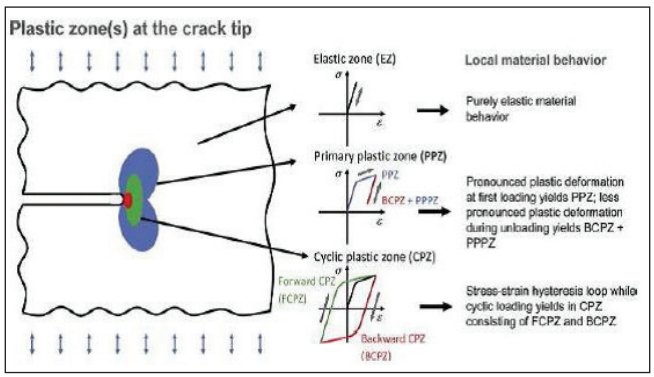


Fig. 16 : Plastic Deformation in Ductile Material.

• Brittle fracture -ceramics, ice, cold metals:

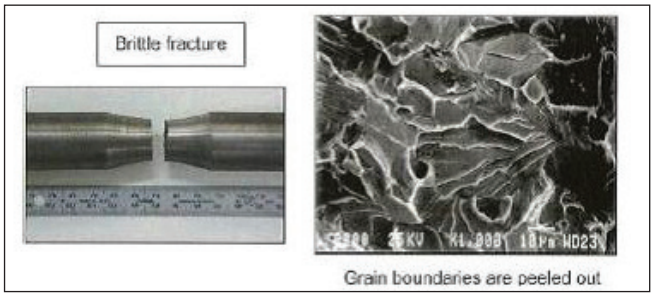


Fig. 17 : Fracture in Brittle Material.

- Relatively little plastic deformation
- Crack is *unstable:* propagates rapidly without increase in applied stress

Hence, ductile fracture is preferred in most applications.

Conclusion

The purpose of failure analysis is to determine the primary causes leading to failure, develop ways to prevent future failure occurrences and modify the design and manufacturing procedures in order to develop a product or system that is robust against potential failures.

The goal of failure analysis is to determine what can be done to correct or prevent failure, and also outline any potential product liabilities.

Failure analysis can be used in the development of new and the refinement of existing products as a tool for both prevention and troubleshooting.

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Report IIM-ATM 2022 from 13 – 16 November 2022

Every year, the Indian Institute of Metals (IIM) organises the Annual Technical Meeting (ATM), which is a flagship event for the Indian metallurgical and materials science community. The 76th Annual Technical Meeting of the Indian Institute of Metals was held from 14th to 16th November, 2022 at Ramoji Film City (RFC), Hyderabad, Telangana. This was preceded, on 13th November 2022, by an International Symposium on "Accelerated Materials Development and Additive Manufacturing: Scientific and Technological Perspectives (AMDAM)", which was held in hybrid (Online + Physical) mode. The International Symposium and the 76th ATM of IIM were organized by the IIM Hyderabad Chapter, its associated student affiliate chapters and the IIM Visakhapatnam Chapter, in association with leading institutions in and around Hyderabad. The latter included Defence Metallurgical Research Laboratory (DMRL); School of Engineering Sciences and Technology (SEST),University of Hyderabad; Mishra Dhatu Nigam Limited (MIDHANI); Nuclear Fuel Complex (NFC); International Advanced Research Centre for Powder, Metallurgy and New Materials (ARCI); National Mineral Development Corporation, (NMDC), Hyderabad, and the Indian Institute of Technology, Hyderabad (IITH).

Eight eminent speakers from around the world delivered their plenary lectures at the International Symposium, AMDAM, on 13th November, which was held in hybrid mode. The entire symposium was designed to reflect the current global trends in materials and manufacturing process development and was well received by the participants. The physical event was held in the main convention hall in RFC and was attended by about 600 people. In addition, several people also participated online. The Symposium was inaugurated by Dr. Samir V Kamat, IIM President and Chairman, Defence Research and Development Organization (DRDO) and Secretary, Department of Defence R&D. In his Inaugural Address, Dr. Kamat appreciated the organizers on the contemporary relevance of the chosen topic. He emphasized the importance of developing new materials and processes in an accelerated manner and at reduced cost if the country's needs are to be met in an effective and timely manner. Delivering his lecture online, Prof. Bernard Rolfe of Deakin University, Australia spoke about "Developing Benchmarks for Process Window Discovery for Laser-Based Powder Bed Fusion". Prof. Upadrasta Ramamurty of Nanyang Technological University, Singapore gave the second online talk, which focussed on the "Structural Integrity of Additively Manufactured Alloys". The next two talks were delivered in person by Prof. Shiro Torizuka, University of Hyogo, Japan ("In-Situ Synchrotron Radiation Diffraction Study in Characterizing the Dislocation Density of Additively Manufactured Metallic Materials") and Dr. Sanjay Sondhi of GE Global Research - Bangalore ("Materials Modeling – An Industrial Perspective"). Prof. Dirk Helm, Fraunhofer Institute for Mechanics of Materials IWM, Germany delivered an online lecture on the "Progress in Modeling, Simulation and Digitalization for Material and Process Design". Dr. Hui Jiang, of Oxford Instruments Nanoanalysis, UK ("The Complete Characterisation of Additive Manufacturing Powders") and Prof. Ankit Agrawal, of Northwestern University, USA ("Artificial Intelligence and High-Performance Data Mining for Accelerating Materials Science and Engineering") delivered the other two online talks. Prof. Surya Kalidindi, Georgia Institute of Technology, USA, attended the event in person and spoke about "A New AI/ML Framework for Materials Innovation".

The Inaugural Function of the 76th ATM was held on 14th November, 2022. The function was graced by Shri Faggan Singh Kulaste, Hon'ble Minister of State for Steel and Rural Development, Government of India as the Chief Guest. The Guest of Honour for the event was Prof. Basuthkar Jagadeeshwar Rao, Vice-Chancellor, University of Hyderabad. The Function commenced with the traditional lighting of the lamp accompanied by an invocation song. Subsequently, the welcome address was delivered by Dr. G Madhusudhan Reddy, Director, Defence Metallurgical Research Laboratory, Hyderabad in his capacity as the Chairman, Core Organising

Committee of IIM-ATM 2022 and Chairman, IIM Hyderabad Chapter and he welcomed the galaxy of luminaries present in the event and also the participants from the academia, industry, research laboratories and students to the event and wished them a pleasant stay in Hyderabad and also hoped that they have an enriching experience. Dr. Amit Bhattacharjee, Convener of the Conference, presented the details about the conference. The Senior Vice President & Chairman of Non Ferrous Division, IIM, Shri Satish Pai gave the Presidential Address on behalf of Dr. Samir V Kamat, the IIM President who had to rush to Delhi on urgent official commitment. The Guest of Honour, Prof. BJ Rao addressed the gathering next. He said that he is a ring side viewer of the world of metals and urged that brick by brick research method of discovering metal alloys is slow and has to be replaced by more scientific understanding and much faster discoveries and in a cost effective manner is the need of the hour and hence this conference is very relevant. He also pointed out that since it is the 76th ATM, the ATM is sailing with India after it's independence. This was followed by the address by the Chief Guest, Shri Faggan Singh Kulaste, Hon'ble Minister. In his address he said that it is very heartening to note that IIM has been conducting these event and the technical discussions in them certainly will help in taking India forward as metals play a vital role in the advancement of a country. Following his address, the Chief Guest formally released the IIM ATM 2022 souvenir. This was followed by the presentation of the various IIM organisational awards. The list of the IIM award winners is given at the IIM HO site. The function ended with a vote of thanks by the convener, Dr. Amit Bhattacharjee. The honourable minister inaugurated the technical exhibition. He showed keen interest in visiting the different stalls and interacting with the exhibitors and the participants.

The IIM Awards Function was next. Prof. B S Murty, Vice President and Chairman, Metal Science Division of IIM addressed the gathering. Shri Somnath Guha, Honorary Treasurer, IIM HO, announced the various award winners and read out the citations. Shri Satish Pai, Senior VP and Prof. B S Murty, VP presented the awards. The list of the award winners is given in the IIM HO site. Then Dr. U Kamachi Mudali, Vice Chancellor, VIT Bhopal and Editor-in-Chief, IIM Book Series & Former IIM President was invited on the stage to release books published by Springer as part of the IIM book series. Three books were released on the occasion. These are: "Treatise on Corrosion Science, Engineering and Technology", "New Horizons in Metallurgy, Materials and Manufacturing", and "Microstructural Characterisation Techniques". The function concluded with a vote of thanks proposed by Shri Kushal Saha, Secretary General of IIM, followed by the national anthem.

The Awards function was followed by the IIM Prof. NP Gandhi memorial lecture was delivered by Prof. Rajiv Shekhar, Director, IIT (ISM), Dhanbad, entitled "Hydrometallurgy and Electrochemistry: Keys to a Sustainable, Secure Indian Economy". The Dr. Daya Swaroop memorial lecture was delivered by Prof. K Baba Pai, Director, Institute of Technology & Management Universe, Dean School of Technology & Engineering, Vadodara entitled "Failure Investigation & analysis – A Powerful Metallurgical Tool". The Binani gold medal award lecture was delivered by Dr. S.V.S. Narayana Murty, General Manager, Materials Development and Production Group, Liquid Propulsion Systems Centre, VSSC, Trivandrum and the topic was "Research and Development in Materials for Indian Space Program".

The first plenary lecture entitled "Opportunities in New Materials in India" by Dr. Debashish Bhattacharjee Vice President (Technology and New Materials Business), Tata Steel and the second lecture was delivered by Prof. B S Murty, Director IIT Hyderabad entitled "High Entropy Alloys: A Physical Metallurgist's Delight".

There were two panel discussions, the first Topic was "Role of Innovation and R&D in Indian Industries: Roadmap to AatmaNirbhar Bharat and Beyond, to Global Leader". It was moderated by Shri S S Mohanty, CEO & MD Essar Minnet Ltd and Ex Director (Technical), SAIL, & Former President IIM. The honourable panelists who participated and deliberated on the topic were Shri Satish Pai, VP, IIM and MD Hindalco, Ms. Soma Mandal, Chairman, SAIL, Shri T V Narendran, CEO and MD, Tata Steel Ltd, Shri Atanu Mukherjee, President and CEO, MN Dastur & Co. Pvt. Ltd., and Shri Pranav Bharadwaj,

MD, Sunflag Steel. The second panel discussion was on "Strategic Materials Security: Technological & Geopolitical Perspective" and it was moderated by Dr. U Kamachi Mudali, Ex IIM President and VC, VIT, Bhopal, and the panelists were Shri M Narayan Rao, Former President IIM, President-EU, The KCP Ltd., Dr. S Basu, Director, IIMT, Bhubhaneswar, Prof. Amol A Gokhale, Former President IIM, Ex Director, DMRL & Prof. IIT, Mumbai, Dr. D Singh, C&MD, IREL and Shri Ranjit Mathure, GM, Jindal Power and Steel.

This was followed by two industry sessions, the first was entitled "New Characterisation Tools" and the presenters were, Mr. Alex Bright, who spoke about Spectra 300: Optimized microscope design for atomic resolution imaging & analysis. Mr. Yimeng Chen of CAMECA Instruments Inc. spoke about atom probe applications for materials design and additive manufacturing and Mr. Nagaarjun Sridhar of ZEISS, India spoke on "Unlocking new opportunities in engineering materials research with ZEISS 3D-Xray Microscopy Solutions. The industry session entitled Novel Processing Methods was held parallelly and the participants were, Qiang Wu of ALD Vacuum Technology GmbH who described Advanced Gas Atomization Systems - VIGA and EIGA for High-Quality Metal. Shri P babu of MIDHANI Hyderabad spoke about special melting techniques and then Shri Alok Agarwal of PTC Industries, Lucknow spoke of investemnet casting of Titanium and Nickel base superalloys and the Shri M Thejo Vardhan of Sunflag spoke about processing of special steels.

After this there was cultural program at the Mughal Garden, followed by gala dinner.

Dr. Samir V Kamat visited the exhibition stalls both in the morning and also later in the afternoon and interacted with the company represntatives. The technical sessions started the next day, 15th November with two parallel keynote lecture sessions as detailed out in the program by various experts. This was followed by inauguration of the poster and the metallography sessions by IIM President, Dr. Samir V Kamat. All the parallel technical sessions were held after that. The technical sessions were spread over two days ie 15th and 16th November, 2022 and over 47 sessions consisting of 111 invited talks and 312 contributed talks. Similarly, more than 400 posters and about 50 metallographs were displayed by various participants. The total registrations for the event was about 1308, out of which 326 were students, 381 were industrial delegates and sponsors and 34 spouses. There was a Ramoji film city tour that was organised for all the ladies. On the 15th November there was also cultural program and banquet dinner that was organised in the sun fountain park in Ramoji Film city.

The valedictory session was organised on 16th November after lunch and was very well attended. The address was given by Dr. G Madhusudhan Reddy, Chairman Local Organising Committee and Director, DMRL. Prof. BS Murty, VP Metal Science Division and Director, IIT Hyderabad also was on the dias along with Dr. R Balamuralikrishnan, Head of the Technical organising committee, IIM ATM 2022 and Dr. Partha Ghosal, Head of the Fund raising and registration committee ATM 2022. After the address by Prof. BS Murty, Dr. Amit Bhattacharjee, Convener IIM ATM 2022 conducted the feedback session. Most of the feedback was positive. After the feedback session, best paper, best poster and metllography awards in various categories were given away by Prof. BS Murty and Dr. G Madhusudhan Reddy to the various awardees. The vote of thanks was proposed by Dr. Partha Ghosal in the end. The IIM ATM 2022 ended with a group photograph and then high tea was served.

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रक्षा अनुसंधान एवं विकास संगठन
रक्षा मंत्रालय, भारत सरकार
DEFENCE RESEARCH & DEVELOPMENT ORGANISATION
Ministry of Defence, Government of India

Aeronautics Research & Development Board

Vision

Make India technologically strong by establishing world class cutting edge aeronautical science and technology base to provide our Defence, Space and Civil Aviation sectors a decisive edge by equipping them with internationally competitive systems and solutions.

Mission

To encourage and fund basic and applied research in pertinent scientific disciplines directly relevant to our aeronautical systems needed for future by enabling and supporting emerging talents, particularly in academic and research institutions to create and evolve a potential knowledge-base system applicable to future aeronautics needs of the country.

Charter

•To formulate research, design and development programmes in aeronautics and allied sciences, keeping in view future needs of the country specifically with respect to aircraft, helicopter, missiles and all other airborne vehicles.
•To implement such programmes through appropriate institutions and individuals by sponsoring research, design and development projects, creating/ improving infrastructure facilities deemed necessary, while ensuring that they are suitably monitored.
•To promote in all possible ways such educational and training programmes as may be considered necessary for ensuring that adequate manpower of requisite quality becomes available to various aeronautical organizations in the country.
•To promote all relevant R&D activities in the country through appropriate scientific meetings, provisions of support for participation of Indian and foreign scientists in such meetings, conduct of relevant competitions as well as other training and visiting programmes within India and abroad as may fall within the scope of the programmes mentioned at sub para (a) above.
•Dissemination of appropriate technical information through journals and documents, encouragement of individual and collective efforts and nurturing of young talent by institutions with suitable awards, scholarships etc. Organization of necessary centralized services related documentation, software, data-link etc. and in all such other ways that the Board may determine from time to time.

Panels & Chairman	
Aerodynamics Panel **Dr S Pandian** Prof. Vikram Sarabhai Distinguished Professor & Ex- Director & DS, SHAR	**Propulsion Panel** **Dr V Ramanujachari** National Centre for Combustion Research & Development (NCCRD), IIT Madras, Chennai
Aerospace Resources Panel **Dr N Eswara Prasad** OS & Ex-Director, DMSRDE (DRDO), Knp.-13	**UNMANNED AERO SYSTEMS PANEL** **Shri PS Krishnan** DS & Ex-Director, ADE, Bangalore-560075
Materials & Manufacturing Panel **Dr DK Das, Scientist H** Group Head (DSG), DMRL (DRDO) Hyd. - 58	**Structures Panel** **Dr Makarand Joshi** Scientist G, R&DE (E), DRDO, Pune-411015
GTMAP **Prof. Amol A Gokhale, IITB, Chairman**	**Systems / Systems Engineering Panel** **Shri APVS Prasad** Scientist H, CE, CEMILAC, DRDO, Bangalore

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Chapters' Conclave — CRC Meeting

The Chapter's Conclave was hosted in hybrid mode on November 13, 2022 at 1615 hrs, chaired by Mr. S. S. Mohanty, Chairman, Chapter Relations Committee (CRC). Representatives from CRC, IIM Chapters and Head Office were present.

A. The Chairman, Chapter Relations Committee (CRC) welcomed all members and initiated the proceedings with the points arose in the previous CRC meeting held in July-2022 and actions taken thereof. These were presented by Shri Tamal Goswami from Head office. Dr. Sudhanshu Shekhar Singh (Co-chairman, CRC) briefed about the number of chapters presenting in the CRC meeting and the overview of the chapters representation for last few years. A total nos. of 17 chapters (8: Large, 5: Medium, 4: Small) attended and presented their activities report in the CRC Meeting.

- ✓ Regarding membership drive, HO informed that it has been suggested to the chapters to conduct membership drive in a regular interval and encourage the professionals to become the IIM Member. In recent years, IIM HO has visited 36 chapters for membership drive. The total number of members in IIM (as on 30th Sep) is 7243 (life member: 6340). A total of 248 members have been inducted in IIM from April 22 – Sep 22.
- ✓ Regarding short-term course continuation, a short-term course on "Metal Coating Processes & their application" is going to be conducted on 28th – 30th November 2022.
- ✓ Four chapters (Baroda, Chennai, Ranchi and Vizag) have not paid their GST amount which is due to IIM HO till date.

B. Chapters presentations and Deliberation

- ✓ Each chapter presented on six headings, namely, (i) Activities completed, (ii) Financials, (iii) IT / networking strategies, (iv) Future plans and long-term vision, (v) major success and (vi) area in which excellence is wished to be attained. Most of the attending chapters have done lots of activities and were observed to be sound in terms of finances.
- ✓ A few chapters talked about problems in enhancing IIM membership, especially student members. A few suggestions that came out during the discussion are as follows:
  - IIM HO was suggested to circulate IIM brochure mentioning about the benefits of becoming IIM member.
  - Chapters should conduct regular activities
  - Discussion with nearby industries and MSMEs and bring them into the gambit of IIM
  - Dr. Mudali suggested that each chapter should conduct "Metallurgist for Non-Metallurgist" workshop, which has been proven to be successful for some of the chapters.
  - It was suggested that IIM HO can use the VC facility and conduct online meetings with the chapters for communicating the benefits of becoming IIM members to those
- ✓ A few events, such as MMMM in Delhi and IIM-ATM will be organised in 2024 as well. Chairman CRC suggested that all chapters should help in organising these events. Furthermore, the large chapters were suggested to coordinate with small chapters – Vijayanagar chapter can coordinate with Salem and Sambalpur Chapters.
- ✓ Jamshedpur Chapter informed about the issue faced by one of the members during registration. Shri Kushal Saha apprised the members that suggestions are being incorporated.
- ✓ Mr. Tamal from HO informed that IIM Roorkee chapter has been revived and a student affiliated chapter in Hyderabad has been formed. A total of 36 chapters are registered for GST (two in 2022-2023). In addition, Mr. Tamal informed about IIM publication, IIM examinations, e-library (As on 30th Sept'22, 8.46 L pages have been uploaded to the internal server)

C. Suggestions from the Chairman, CRC

The major suggestions from the chairman included the involvement of each chapter in increasing the IIM membership. The chapters were advised to conduct activities which will enhance number of IIM Members.

Mr. Mohanty, Chairman CRC concluded the meeting by thanking members for their active participation.

Chapters' Conclave - Participants

CRC: *Mr. S. S. Mohanty, Dr. S. S. Singh, Mr. P. Ganesh, Dr. J. Krishnamoorthi, Mr. Kushal Saha*

Former Presidents: *Dr. U. Kamachi Mudali*

Participating Chapters: *Bhubneshwar, Kalpakkam, Durgapur, Delhi, Jamshedpur, Mumbai, Kolkata, Hyderabad, Coimbator, Sambalpur, Varanasi, Vijayanagar, Chennai, Hazira, Keonjhar, Nagpur, Kanpur*

IIM Head Office: *Mr. Tamal Goswami, Mr. Somnath Guha*

IIM Awards 2022 — The flagship event of The Indian Institute of Metals

IIM National Sustainability Awards : IRON & STEEL

The Ferrous Division of the Indian Institute of Metals has been organising the National Quality Competition since 1991 to encourage and recognise Quality Assurance aspects in the Steel Sector. The award has been re-named as National Sustainability Award from 2007.

The Awards for the year 2022 are presented to:

(a) Category I : **Integrated Steel Plants**
First Prize : **JSW Steel Ltd., Vidyanagar**
Second Prize : **Tata Steel Ltd., Jamshedpur**

(b) Category II : **Secondary Steel and Alloy Steel Plants**
First Prize : **JSW Steel Ltd, Salem Works, Salem**
Second Prize : **Salem Steel Plant, SAIL**

(c) Category III : **Pig-Iron Plants / DRI Plants/ Major Re-rolling units**
Winner : **L&T Special Steels Heavy Forging Ltd, Hazira**

IIM Non–Ferrous Best Performance Award

The Non-Ferrous Division of the Indian Institute of Metals has been organising the National Quality Competition since 2002 to encourage and recognise Quality Control aspects in the Non–ferrous sector.

The Awards for the year 2022 are presented to:

(a) Category I : **Large Integrated Production Organisations**
First Prize : **Hindalco, Birla Copper, Dahej**
Second Prize : **NALCO, Angul**

(b) Category II : **Secondary Processing / Fabrication Plants**
Winner : **Hindalco, Alupurum Extrusion Unit, Kerala**

(c) Category III : **Casting & Forging**
Winner : **Hindalco Almex Aerospace Ltd., Maharashtra**

IIM Honorary Membership

The **Honorary Membership** of IIM is conferred on **Mr. TV Narendran,** Former President, IIM [2021-22] and CEO & Managing Director, Tata Steel Ltd.

Mr. T V Narendran is a Mechanical Engineer from the National Institute of Technology (NIT) Trichy and did his MBA from the Indian Institute of Management (IIM) Calcutta. He is a recipient of Distinguished Alumnus Awards from both NIT Trichy and IIM Calcutta. He is a Chevening Scholar and has also attended the Advanced Management Programme in INSEAD, France.

Mr. Narendran has overseen the organic and inorganic growth of Tata Steel over the last few years. This includes the Kalinganagar greenfield expansion and the acquisition of Bhushan steel and the steel business of Usha Martin. He has over 34 years of experience in the Mining and Metals industry. Mr. Narendran is currently on the Board of Tata Steel Limited. He is the Chairman of Tata Steel Europe and Tata Steel Long Products Limited. He is also the Chairman of the Board of Governors of XLRI Jamshedpur, a member of the Executive Committee and the Board of the World Steel Association, a fellow of the INAE. He served as the President of the Indian Institute of Metals from 2021 to 2022. During his tenure, Mr. Narendran has led by examples. His contributions & interventions in various facets helped the Institute sail through trying times.

IIM Honorary Membership

The **Honorary Membership** of IIM is conferred on **Dr. Debashish Bhattacharjee,** Vice President Technology & New Materials Business, Tata Steel Ltd.

Dr. Debashish Bhattacharjee completed B.E. in Metallurgical Engineering from Jadavpur University in 1986, M. Tech in Metallurgy from IIT Kanpur in 1989 and PhD in Materials Science & Metallurgy from University of Cambridge, UK in 1993. He joined Tata Steel in the R&D function in 1996 and headed the function as Chief Research & Development and Scientific Services between 2002 and 2009. In 2009, he was seconded to Tata Steel Europe as Group Director Research, Development & Technology for Tata Steel Group. Dr. Bhattacharjee is an expert in development of materials and associated technologies. He has more than 50 international peer reviewed journal publications and 20 patents.

IIM Platinum Medal

The **IIM Platinum Medal** for the year 2022 is awarded to **Dr. Amol A Gokhale,** Former President, IIM [2020-21] and Professor, Dept. of Mechanical Engg., IIT Bombay.

Dr. Gokhale is a B Tech from IIT Bombay and Ph D from University of Pittsburgh in Metallurgical Engineering. He served in the Defence Metallurgical Research Laboratory from 1985 till July 2015, and was a Distinguished Scientist and Director of the Laboratory. There he led research on aluminium alloy wrought products and castings for aerospace and naval applications, crashworthy aluminium foams, additive manufacturing, and high temperature materials for hypersonics. In August 2015, he became a Professor in the Department of Mechanical Engineering in IIT Bombay, where he is teaching and conducting research on aerospace materials. He has two patents, has co-edited two books and published over 100 papers.

IIM Tata Gold Medal

The **Tata Gold Medal** for the year 2022 is awarded to **Mr. Vinay Vasant Mahashabde,** Chief R&D and Product Technology, Tata Steel Ltd.

Mr. Mahashabde has led Tata Steel to scale new heights under his leadership. Among several new product developments, notable include tapping market in API segment by successful commercialisation of J55 for OCTG application, development of X42 and X60 with stringent sour performance guarantee. With government focus on self-reliance, he played a significant role in developing S700MC with guaranteed toughness at -40°C. It was under his leadership that R&D demonstrated continuous injection of Coal Bed Methane in blast-furnace, operationalization of 5 tpd CO_2 capture plant, removal of cyanide from coke-oven wastewater by UV oxidation. He has led Tata Steel to make strides towards efficient utilization of raw materials - projects worth highlighting include increased use of non-coking coal, producing high value products from low-grade Mn-ore.

IIM G D Birla Gold Medal

The **G D Birla Gold Medal** for the year 2022 is awarded to **Dr. SVS Narayana Murty,** General Manager, Materials Development and Production Group, Liquid Propulsion Systems Centre, VSSC, Trivandrum.

He joined VSSC, Trivandrum in 1993 and has worked on materials processing, testing characterisation of various grades of aerospace materials and failure analysis investigation of launch vehicle hardware. The specific contributions of Dr. Murty include (i) improving mechanical properties, reliability and productivity of Aluminium Alloy AA2219-T87 propellant tanks through friction stir welding; (ii) understanding the dynamic strain aging and embrittlement behaviour of IN718 during high-temperature deformation; (iii) studying effect of ternary additions of Cu and Fe on the hot deformation behaviour of NiTi shape memory alloy.

IIM Hindustan Zinc Gold Medal

The **Hindustan Zinc Gold Medal** for the year 2022 is awarded to **Mr. Arbind Kumar,** Scientist G & Head, Refractory Metals Division and Project Manager, Hafnium Project, Centre for Materials for Electronics Technology (C-MET), Hyderabad.

Mr. Arbind Kumar has been working as Scientist G & Head, Refractory Metals Division & Hafnium Plant at Centre for Materials for Electronics Technology (C-MET), Hyderabad since 1991. During this time, he has undertaken several key projects in the areas of refractory metals extraction, metals purification, E-waste recycling and powder metallurgy. As leader of a VSSC sponsored project, he has developed process technology and established the first Hafnium plant in India, which was awarded the Indian Chemical Council award for Excellent in Chemical Plant Design and Engineering.

IIM TSL New Millennium Award

The **IIM TSL New Millennium Award** for the year 2022 is awarded to **Mr. Atanu Bhowmick,** Director In-Charge Rourkela Steel Plant, SAIL Rourkela.

Mr. Atanu Bhowmick, a doyen of Blast Furnace Technology, spent over three decades in Steel Industry. From 2019 -21 Shri Bhowmick led Bokaro Steel Plant as ED(Works) when his plant recorded the highest production from Blast Furnaces and consequently record profits among SAIL Units for two successive years. Under his leadership as Director In-Charge of RSP, SAIL, the organisation achieved all time highest production, productivity, profit and best-ever Techno-economic parameters during 2021-22.

IIM SMS-Demag Excellence Award

The **IIM SMS-Demag Excellence Award** for the year 2022 is awarded to **Mr. Manasa Prasad Mishra,** Director (Project & Technical), NALCO.

Mr. Manasa Prasad Mishra graduated in Mechanical Engineering with Honours from the Vir Surendra Sai University of Technology (VSSUT) Odisha and joined NALCO in 1984. Prior to occupying the present position as Director (Project & Technical), he has successfully worked various functions at different capacities in O&M, Business Development, Head of Smelter as well as Head of Smelter & Power complex. He was instrumental in adaptation of latest technologies with lower environmental footprint in the projects under execution.

IIM NALCO Gold Medal

The **NALCO Gold Medal** for 2022 is awarded to **Mr. Ambika Prasad Panda,** Executive Director [Smelter & Power Complex], NALCO.

Mr. Ambika Prasad Panda has vast experience in different capacities of Operation & Maintenance in Smelter & Power plants of NALCO. He was instrumental in commissioning of all units of CPP at Angul. He has spear-headed implementation of computerized maintenance, Energy Management, Total Quality Management (TQM), Total Productive Maintenance (TPM) & Environment Management System (EMS) across NALCO. His decisive leadership was pivotal in enabling the company to achieve full capacity operation of Smelter plant i.e. operation of all 960 pots in FY 2021-22- a record in the company with record annual aluminium metal production of 4.6 lakh Mt.

IIM OP Jindal Gold Medal

The **IIM OP Jindal Award** for 2022 is awarded to **Mr. Devasish Mishra,** Executive Vice President, JSW Steel Ltd.

Mr. Devasish Mishra is an outstanding metallurgist & strategic leader, with over 30 years of multi-disciplinary experience in Operation, Product & Technology. His major contribution is towards "Make in India & Green Steel Technology", where multiple products were developed first time in India with lower carbon footprint. Mr. Mishra, piloted the Product Development of JSW Steel to meet strategic need of market, such as Debottleneck and developed international benchmark and import substitute AHSS grades 1180 MPa DP steel, 780 MPa coated steel, High end Electrical steel up-to 2.5 watt/kg, Sub-zero & Sour line API grades, Steel for EV (Electrical Vehicle).

IIM Distinguished Educator Award

The **IIM Distinguished Educator Award** for 2022 is awarded to **Prof. Bikramjit Basu,** Professor, Materials Research Centre, IISC Bangalore Executive Vice President, JSW Steel Ltd., Jointly with Prof. **M Kamaraj,** E.G. Ramachandran Institute Chair Professor, Dept. of MME, IIT Madras.

Prof. Bikramjit Basu is widely regarded as a 'teacher in a true sense' in a much broader perspective. In terms of scientific talent mentoring in the field of Engineering Ceramics and Biomaterials, he has been a primary advisor of 31 PhD students (including ten female students and eight ongoing), 25 MTech/MS, 52 research interns, including 32 undergraduates, and 20 post-doctoral research fellows/Project Scientists; 2 PhD students are Prime Minister Research Fellows at IISc. Apart from teaching several Institute core and departmental core courses in last one decade, Dr Basu designed and taught a number of new graduate level courses, e.g. Materials for Biomedical Applications, Design and selection of Materials, Tribology of Materials as well as Nanomaterials.

Prof. M Kamaraj worked as Research Engineer at EWAC Alloys Ltd (L&T Ltd.), Mumbai (1990-94) where he was involved in the development of new wear-resistant coating materials for various applications. Subsequent to this, he continued as Research Fellow on high temperature fretting fatigue of advanced materials at Nagaoka University of Technology, Japan (1994-96), and as STA Fellow at National Institute of Industrial Safety, Tokyo, Japan (1996-97). During this stay he took keen interest in teaching and mentoring Japanese research scholars in the field of high temperature materials. Later he joined as Guest Scientist at Ruhr-Universität Bochum, Bochum, Germany (1997-99) where he has contributed to the identification of basics of high-temperature micro-deformation mechanisms of high temperature materials.

IIM Distinguished Contributor Award

The **IIM Distinguished Contributor Award** for 2022 is awarded to **Dr. Tanmay Bhattacharyya,** Chief- Khopoli Project Composites, Tata Steel Ltd.

Dr. Tanmay Bhattacharyya played the pivotal role for setting up of the composite business of Tata Steel leading the Partnerships, Supply Chain & Railway Business and contributed for growth to INR 120 Cr revenue from its ideation stage. Currently, he is responsible for setting up a project for the state-of-the-art components of alternative materials for global railways having resemblance with the AtmaNirbhar Bharat. Towards the growth of alternative materials in the country and having the favourable ecosystem, he has been contributing significantly in collaboration with industry, academia and professional bodies such as CII, BIS and The Indian Institute of Metals [IIM]. Dr Bhattacharyya, a PhD in metallurgy from IIT, Kharagapur, and Graduate and Post Graduate from Bengal Engineering College, Shibpur (currently known as IIEST) has been associated with the activities of the Indian Institute of Metals from his student days.

IIM Distinguished Service Award

The **IIM Distinguished Service Award** 2022 is awarded to **Ms. Atashi Saha,** Deputy General Manager, The Indian Institute of Metals.

Ms. Atashi Saha has shouldered up varied responsibilities at IIM HO in her stint of 9 years with the Institute. She has managed facilitation for all NMD-IIM Awards Ceremony during her tenure in an impeccable manner, supporting the Organisers in all possible endeavour. She has been effective in undertaking crucial responsibilities time and again. As an employee, Ms. Saha contributed towards the digitisation process as implemented at IIM HO and also towards effective administration & employee relations at workplace.

IIM Certificate of Honour Award

The 2022 **'Certificate of Honour'** (introduced in 2008) is presented to **Ms. Arthita Dey,** Sr Manager Technical Services, LD#3TSCR, Tata Steel Ltd.

Ms. Arthita Dey is a metallurgist with fourteen years of experiences in the field of material characterization, component and product failure investigation, product and process design. She is currently working as Sr Manager Technical Services LD#3 TSCR Tata Steel. She has a wide association with Jamshedpur Chapter of IIM and represented the chapter in various forums.

IIM Dr. A. K. Bose Gold Medal

The **Dr. A. K. Bose Gold Medal,** established in 1972 to perpetuate the memory of Late Dr. A. K. Bose, is awarded to honour a student whose M E Thesis is adjudged as the best.

For the year 2022 it is awarded to **Mr. Hari Narayanan Vasavan,** Dept. of Metallurgy Engineering & Materials. Sc., IIT Indore in recognition of his ME Thesis on "STRUCTURALLY ENGINEERED HIGH PERFORMANCE LAYERED OXIDE CATHODES FOR Na-ION BATTERIES" submitted and defended during the year 2021-22.

IIM Vidya Bharathi Prize

The **Vidya Bharathi Prize** established in 1978, is presented to a student for securing highest grade in order of merit in the final B.Tech./ B.E./ B.Sc. (Met. Engineering) Examinations held in the last academic session among all Indian Institutes of Technologies in India.

Sonakshi Gupta

The Vidya Bharathi Prize for the year 2022 is awarded jointly to **Ms Aayushi Chauhan,** Dept. of Materials Sc. & Engineering, IIT, Kanpur and **Ms Sonakshi Gupta,** Dept. of Metallurgy Engineering & Materials. Sc., IIT Indore.

IIM Students' Prize

IIM Students' Prize, established in 2001, is presented to three students for securing highest marks in order of merit in the final B.Tech. / B.E ./ B.Sc. (Met. Engineering) Examination during 2021-2022 academic session among all National Institutes of Technology / Indian Universities / Engineering Colleges.

The IIM Students' Prize for the year 2022 is awarded to **Mr. Syed Abdur Rahman,** Dept. of Metallurgy Engineering & Materials Sc., NIT Durgapur for securing the highest marks in order of merit in the final B Tech examination during 2021-22 academic session among all National Institutes of Technology / Indian Universities/ Engineering colleges, **Mr. Shivansh,** Dept. of Metallurgical & Materials


Sarathi Dey

Engineering, VNIT, Nagpur, for securing the second highest marks in order of merit in the final B Tech examination during 2021-22 academic session among all National Institutes of Technology / Indian Universities/ Engineering colleges, **Mr. Sarathi Dey,** Dept. of Metallurgy Engineering & Materials Sc., NIT Durgapur, for securing the third highest marks in order of merit in the final B Tech examination during 2021-22 academic session among all National Institutes of Technology / Indian Universities/ Engineering colleges.

IIM Best Chapter Award

The **Best Chapter Award** Plaques are awarded to encourage Chapters for overall performance.

The following Chapters in various categories are felicitated with the IIM Best Chapter Award :

Large Category

First Prize : IIM Kalpakkam Chapter

Second Prize: IIM Jamshedpur Chapter

Medium Category

Winner: IIM Coimbatore Chapter

Prof Brahm Prakash Memorial Quiz Award

The Prof Brahm Prakash Memorial Quiz is aimed to create awareness among school students and to motivate them to choose their career in Materials Science and Engineering.

Winners:

Mr Arjoe Basak

&

Mr Prateek Kumar Behera

Delhi Public School, Ruby Park, Kolkata

Runners-Up:

Mr Suketu Patni

&

Mr Jairam Suresh Ayyar

Delhi Public School, Navi Mumbai

IIM Fellowship

The Fellowship is conferred on members in recognition of their services to the Institute and to the Metallurgy Profession.

The 2022 Fellowship is conferred on :

Dr. Arup Dasgupta, Scientific Officer G and Head, Physical Metallurgy Division, Metallurgy Materials Group, Indira Gandhi Centre for Atomic Research.

Prof. Rahul Mitra, Professor, Dept. of Met & Mat Engg, IIT Kharagpur.

Mr. RV Ramna, Former Chief Technology Officer (Process), Tata Steel Ltd.

Dr. Ramen Datta, EX.-GM, RDCIS, SAIL.

Dr. Partha Ghosal, Scientist G & Head- Electron Microscopy Group & Advanced Materials Characterization Centre, DMRL.

IIM ASM Lectureship 2021 & 2022

The program, established in 1979 between ASM and The Indian Institute of Metals [IIM], is intended to promote international co-operation and provide useful service to ASM and IIM Members.

The IIM-ASM Lectureship for 2021 is conferred on

Prof. Pinaki Prasad Bhattacharjee, Professor, Dept. of Materials Sc. & Metallurgy Engineering, IIT Hyderabad. Prof Bhattacharjee pioneered the study on the texture analysis of HEAs after heavy deformation and annealing.

Prof. Sudhanshu Sekhar Singh, Assistant Professor, Dept. of Materials Sc. & Engineering IIT Kanpur. The broad area of his research includes mechanical behaviour of materials at different length scales, 3D/4D materials science and laser assisted processing of materials.

The IIM-ASM Lectureship for 2022 is conferred on

Prof. Subhasis Sinha, Assistant Professor, Dept. of Metallurgical Engineering, IIT BHU. Prof. Sinha completed his doctoral thesis on "Effect of twinning on tensile and cyclic deformation behaviour of hexagonal close packed titanium". Then, he worked as a postdoc for 2 years at the Department of Materials Science and Engineering, University of North Texas, Denton, USA, in the field of friction stir processing of transformative high entropy alloys and copper based immiscible alloys.

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India's finished steel imports from Russia hit 4-year high in April-October

India's finished steel imports from Russia during April-October rose to their highest in at least four years, government data compiled by Reuters showed, underscoring Moscow's bid to divert shipments in the wake of Western sanctions.

Russia's steel exports to India reached 149,000 tonnes in the first seven months of the current fiscal year that began in April, up from around 34,000 tonnes shipped a year earlier. Russia accounted for just about 5% of India's total steel imports but was among the top five exporters.

India's total steel imports between April and October stood at 3.2 million tonnes, up 14.5% from a year earlier. South Korea exported 1.3 million tonnes to India, accounting for a 41% share of the country's total purchase.

Between April and October, India emerged as a net exporter of steel, even as overall shipments more than halved due to an export tax and a slowdown in global demand. Earlier this month, India scrapped the export tax levied on some steel intermediates, reviving expectations of a turnaround in exports.

Business Standard

How India can decarbonise the steel industry

The steel industry is responsible for 2% of the country's GDP, and about 7% of its greenhouse gas emissions. Steel production currently accounts for around 242 Mt of carbon dioxide (CO_2) emissions annually and this is expected to double by 2030 (and triple by 2050), with increased production for meeting domestic and global demands.

While the government of India's National Policy for steel has projections of double steel production by 2030, production processes are still coal intensive with most steel still made using coal to reduce iron ore. This process emits roughly two tonnes of CO_2 for every tonne of steel produced. The evaluated exposure to climate-related risks and opportunities over a range of time horizons allows for the assessment of an internal strategy for the transition to a net-zero carbon economy. The steel companies disclosing to CDP India (2022 data) have reported climate-related issues such as water scarcity, changes in precipitation patterns, enhanced emissions-reporting obligations, and increased cost of raw materials all of which could cost them approx. Rs 194.4 billion. However, the cost of action for private players to decarbonise is 21% (Rs 161.3 billion) lower than the cost of inaction. This provides adequate reasoning for prompt action to leverage a transition to clean production and energy in operations.

Additionally, the total identified opportunity was estimated at Rs 1334 billion and the estimated cost to realise the opportunity is Rs 186 billion. This means that the financial impact on the sector due to climate transition is estimated to be seven folds in comparison to the cost of realising the opportunity; indicating that there is a good opportunity for realising high returns. Such a robust climate-related risk assessment process in place would help companies identify the likelihood and magnitude of present and future climate-related impacts not only on the environment but also on business performance.

The Economic Times

Export duty removal will boost business sentiments of steel industry: Faggan Kulaste

Duty-related measures taken by the government will boost the business sentiments of the domestic steel industry, Union Minister Faggan Singh Kulaste said. Six months after the imposition of the export duty on May 21, the government has removed the levy on steel items to nil with effect from November 19, 2022.

"The move will boost business sentiments of the steel makers. It will also boost the demand and investments in the sector," the Minister of State (MoS) for Steel told PTI.

Kulaste, who is also the MoS for Rural Development, said the players will now utilise their capex (capex expenditure) without any "fear" as they have opportunities in the local and global markets.

The minister recently directed the steel companies to invest in research and development activities to

make new special-grade products in the country. The move will help boost the domestic consumption of various grades of steel, he added. Value-added steel or special grade steel is used in segments like power, ship, rail, metro, defence, auto etc. The demand for steel used by these industries is being met through imports.

The Economic Times

Govt invites bids for privatisation of NMDC's Nagarnar Steel Plant

The government invited preliminary bids for strategic sale of NMDC's Nagarnar Steel Plant. The last date for submitting bids for NMDC Steel Ltd is January 27, 2023, while the last date for submitting queries is December 29, 2022, the Department of Investment and Public Asset Management (DIPAM) said.

NISP is in the process of being demerged from NMDC into a separate company NMDC Steel Ltd (NSL). Subsequent to demerger, shares of NSL will be listed on BSE, National Stock Exchange of India Limited and Calcutta Stock Exchange.

NSL will have mirror shareholding to NMDC i.e. government of India (GoI) shareholding of 60.79 per cent and public shareholding of 39.21 per cent. Thereafter, GoI, via DIPAM, shall divest its 50.79 per cent shareholding in NSL along with management control to a strategic buyer through a two-stage competitive bidding process.

The Economic Times

India has great opportunity to make steel for domestic, global needs: T V Narendran

Welcoming the government's move to remove export duty on steel, Tata Steel CEO T V Narendran said India has a great opportunity to make steel for domestic consumption as well as to meet global needs. "We welcome the government's decision to roll back the export duty on steel products and iron ore, imposed to deal with the inflationary situation, and we acknowledge the same," Narendran told PTI.

India, being richly endowed with iron ore, has a great opportunity to make steel in India, for India, and for the world, he said. China, Japan, and South Korea, together export around 150 million tonne of steel annually despite importing most of their iron ore needs, Narendran noted.

Six months after imposition of the levy on May 21, the government removed the export duty on steel items and iron ore to nil effective from November 19, 2022.

The Economic Times

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Member in the News Dr. K. Srinivasan

Dr. K. Srinivasan, Former Professor, NITK, Surathkal and a Life member of The Indian Institute of Metals, has authored a textbook on, 'Electron Theories and Properties of Solid Materials' which describes the electrical, magnetic, thermal and optical properties of various materials. The book is published by Cleverfox publishers, Bangalore and Chennai and it is priced at Rs. 349/- and number of pages is 224. It is available in paperback edition.

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Conferment of IIM Sustainability Award 2022 by the Hon'ble Minister of State for Steel

Conferment of IIM Non–Ferrous Best Performance Award2022 by the Hon'ble Minister of State for Steel

Valedictory Session

Cultural Programme

IIM TSL New Millennium Award is awarded to Mr Atanu Bhowmick

IIM Distinguished Service Award is awarded to Ms. Atashi Saha

Releasing of IIM ATM 2022 souvenir