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PRESIDENTIAL SPEECH

Mr. T. V. Narendran
CEO & Managing Director, Tata Steel Limited
President, Indian Institute of Metals

PRESIDENT (IIM)'s Speech during the inaugural function of IIM ATM 2021

This is the platinum jubilee year of the Indian Institute of Metals and it is my privilege to welcome you all to this inaugural programme of the 75th annual technical meet of IIM. It is a landmark for any professional body to have a journey of 75 years and I'm sure IIM will have many more successful years ahead. I congratulate the members, fellows, past presidents, and all the contributors and well-wishers of the IIM for nurturing, guiding, and leading the organisation through 75 years of glorious contribution to the nation and to the professional fields that it represents. Celebration of the platinum Jubilee started in February 2021. Several competitions and webinars have been held. Most of the chapters have actively participated. A special edition of the Transactions of IIM has been published and several other books commemorating the 75th year are at various stages of publication.

Materials are fundamental to the progress of civilization. Consumption of materials is seen as a yardstick of extent of development of nations. In the last decade or so, India's production and consumption of steel has risen consistently and is now among the top 2 in the world. Use and production of other metallic materials is gradually increasing. Advanced structural materials such as polymer matrix composites are finding increasing use in infrastructure (e. g., pipes), mobility (e. g., railways), aerospace and industrial applications. India has a large (more than Rs 50,000 crores) market for medical materials and devices. Pretty much all of it is imported. The Indian Institute of Metals provides a common platform for academics, researchers, industrialists, and policy makers who are involved in the entire gamut of materials to interact, exchange views, and formulate future action plans for the country which is at a very critical stage of development. The ATM is the annual event that the fraternity looks forward to meeting each other.

I hope the elaborate arrangement made for on-line technical session, poster and metallographic contests, exhibitions, and meeting rooms will provide a conducive environment for fruitful meetings. Yesterday's International Conference aptly covered advanced characterisation, use of digital in product development, perspectives of customer industries and a panel discussion on various aspects of sustainability. That was an appropriate build up to today's inauguration of the 75th Annual Technical Meet. The ATM has received an overwhelming response from both the industry and the academia. I am happy to announce that there are 47 technical sessions in the ATM on eight different themes. The themes include safety, raw materials, products, ferrous process metallurgy, non-ferrous metals, energy environment and waste utilization, Industry 4.0 and advances in materials science and technology. I am happy to see IIM playing its role in providing platform for interaction, exchange of views and discussion on the role of materials in society.

Going forward, I see IIM playing a prominent role in the emerging eco-system of start-ups. There is a lot of innovating work being driven in this ecosystem and IIM could provide a platform where young, energetic entrepreneurs with bright ideas would meet industries that would provide mentorship and opportunities to scale up.

Peer recognition is a vital part of enthusing and motivating professionals and creating pull among youngsters. The IIM ATM will acknowledge the pioneering work of distinguished metallurgists through various awards. I congratulate all the awardees for the year 2021 for their contribution and I am confident these accolades will spur them to scale greater heights in their chosen fields. I offer my compliments and appreciation to everyone involved with the IIM including the participants, IIM-members, sponsors, the collaborating Chapters of Jamshedpur and Kolkata, and volunteers and wish the ATM a grand success. Thank you!

PRESIDENT (IIM)'s Speech during the award function of IIM ATM 2021

This is the platinum jubilee year of the Indian Institute of Metals and it is my privilege to IIM traditionally recognises the contributions of individual metallurgists and materials scientists as well as organisations towards industrial, academic brilliance and societal well-being. At the inaugural function, the organizational awards have already been conferred. In this session we will confer the honorary memberships and fellowship awards, and ten individual awards under various categories.

The metallurgical and materials fraternity of India is carrying out leading-edge work both in research and manufacturing. It is satisfying to see the constructive role IIM is playing in strengthening this eco-system spanning across industry and academia. The industry, be in ferrous or non-ferrous or non-metallic materials, is developing products and solutions for our nation. The R&D institutions and the centres of excellence are assisting in building capability. I am glad to see that IIM is encouraging excellence as it should. The IIM awards are highly competitive, and the winners are selected through a stringent screening process. I am happy to note that IIM is continuing this rich tradition of felicitation. This is even more important on the backdrop of a difficult year that all of us have had due to the pandemic.

I congratulate all the award-winners and I am sure the examples will be emulated, and the next generation will be motivated to keep India at the forefront of metallurgy and materials science.

Looking forward, there is a lot to be done towards making India self-reliant and world-leading in manufacturing of metals and materials, in waste to wealth initiatives and in addressing climate change. I look forward to seeing cutting-edge research and commercial implementations of new technologies and ventures in these areas. I also encourage involvement of start-ups. I congratulate all the winners again on achieving their personal milestones and wish them all the best in their careers.

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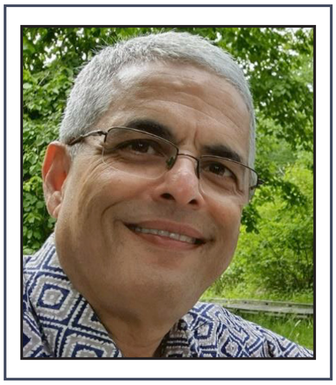
Joys and Challenges along a Fascinating Journey through Surface Engineering



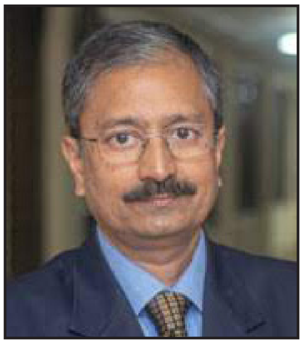
Shrikant Joshi
Professor, University West
Sweden

Abstract

Surface engineering refers to tailoring properties of a component to impart performance which cannot be realized either by the bulk material or the surface-layer alone. The portfolio of associated technologies that enables this has remarkably expanded over the years and today spans mechanical treatments and surface modifications without any extraneous material addition, changes in composition and chemical treatments in the near-surface region, and deposition of appropriate overlay coatings. Adopting such an approach is increasingly inevitable for a vast majority of industrial applications as well as in every-day life, as the bulk-property requirements and surface functionality demands are often distinct and a single material that fulfils both is usually unavailable. Today, use of a suitable surface-modification methodology extends to protection of industrial parts that are prone to premature degradation due to phenomena such as wear, oxidation, corrosion, high thermal load etc., enhancing performance of parts routinely exposed to harsh operating environments, and even for aesthetic purpose. Acknowledging the technological need, excited by the associated opportunities and allured by potential commercial benefits, surface engineering has made enormous advances in recent years. Evolution of new techniques for surface-modification and innovations in prevailing methods have ensured immense versatility and an ever-growing application spectrum that already covers nearly every known industry segment.

In this talk, I will attempt to provide a bird's eye view of the interesting canvas offered by surface engineering for pursuing cutting-edge multidisciplinary research and realizing novel applications. Along the way, an insight will be provided into the vast portfolio of surfacing options available today to a designer to deliver more durable, versatile, and cost-effective solutions. I will rely on numerous illustrative examples based on my experience to highlight the considerable potential of surface engineering as well as some extant challenges.

Metal Casting 4.0: Closing the Loop between Design and Manufacturing



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Abstract

Product quality depends upon symbiotic inter-dependency among material, design, tooling and process parameters. Such diverse relationships make it very difficult to avoid defects in metal casting – still the most economical process to produce large parts with intricate features. To get the quality 'right first time and every time', we need to transform this art into science by leveraging the latest information technologies. Four relevant R&D works carried out by the author and associates over the last three decades are described in this article: (i) user-friendly simulation-software to predict casting defects; (ii) intelligent design and optimization of methods and tooling; (iii) Cloud-based utilities for universal access; and (iv) smart foundry for process data capture and analytics. These are laying the path for new technologies to reduce the difference between designed and manufactured products. Such advanced and inter-disciplinary projects are also changing the mind-set about metal casting and attracting the next generation of researchers.

Keywords : Metal Casting, Design for Manufacturability, Process Simulation, Industry 4.0, Smart Manufacturing.

1. Metal Casting

Metal casting is a major milestone in the long history of humankind. The *Rigveda* mentions casting equipment such as *dhamatri* (cupola) and *bhastri* (blower). The bronze dancing girl found at Mohen-jo-daro, iron pillar in Delhi and *pancha-dhatu* (five-metal) statues in Chola temples stand testimony to this fine art practiced over millennia [1].

Today, India is among the top three countries in the world producing a large variety of cast parts for various sectors (Fig. 1). These include transport (automobile, aerospace, railways and shipping), heavy equipment (construction and mining), farming (tractor, irrigation, harvester, dryer), machine tools for various manufacturing processes, plant machinery (chemical, petroleum, paper, sugar, textile, steel and thermal power), defence (vehicles, artillery, munitions, storage and support), electrical machines (motors, generators, pumps, compressors, transmission and distribution), sanitary (pipes, joints, valves and fittings), household (appliances, kitchen, gardening and fittings), art works (metal sculpture, furniture, lamp-stands and decorations) and medical (diagnostics equipment, surgical instruments and implants).

The examples above establish the versatility of casting process. A variety of metals and alloys (ferrous or non-ferrous) can be melted and led under gravity, pressure or vacuum into appropriate moulds (dispensable or permanent) to obtain near-net shape parts. This continues to be the most economical way to obtain intricate shapes in a wide range of size and weight (few grams to hundreds of tonnes). The order quantity can vary from one-off to millions. Large parts with complex external and internal features can be cast with much less skill, energy and material (wastage) compared to machining.

Despite the long history and widespread application, cast parts are considered unreliable due to the presence of various defects (Fig. 2): these include external defects (shape, dimensions, features, roughness), internal defects (misrun, cold shut, inclusion, blow hole, gas porosity, shrinkage porosity, hot tear, crack and others) and property defects (physical, mechanical, metallurgical and chemical). These are difficult to avoid due to the multi-physics phenomena (melting, pouring, filling, solidification, cooling and stresses) involving multiple materials (casting, mould, core, etc.) [2]. Metal temperature and mould opacity make it difficult to observe, measure and control the process parameters. As a result, about 5% castings are rejected and recycled in production foundries; the rejection rate goes upin jobbing foundries. This is a far cry from the parts per million rejections targeted in other manufacturing processes. It is not surprising that metal casting is considered an art, relying on the intuition and skill of experienced foundry engineers.

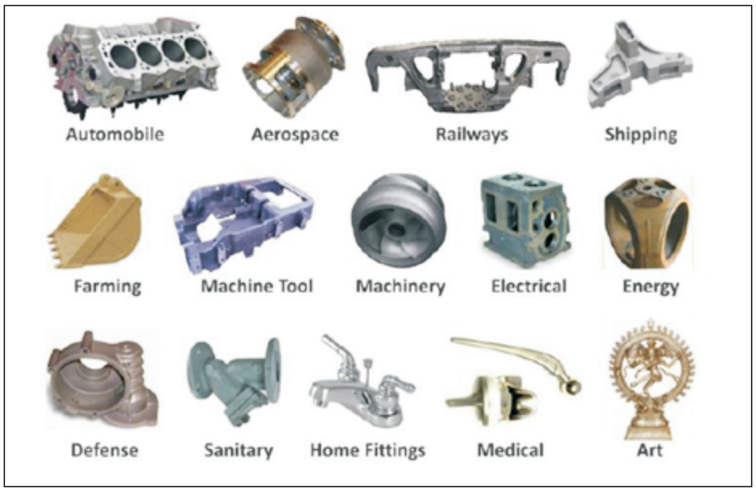

Fig. 1 : Cast metallic components used in various sectors

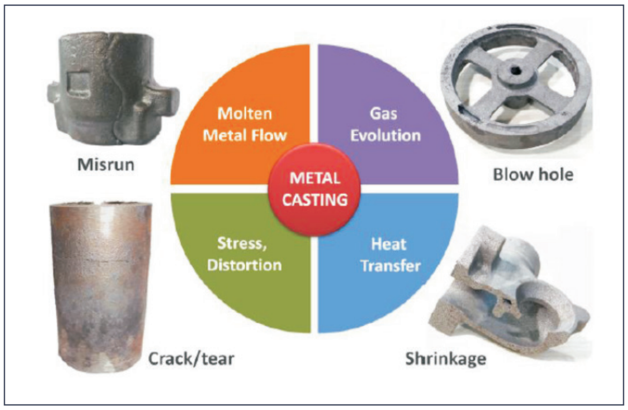

Fig. 2 : Major casting defects related to process

There is another impairing factor. Casting lifecycle has four major stages, which are usually carried out in separate organizations: component design at original equipment manufacturer (OEM); pattern development in tool-room; process planning, casting and fettling in foundry; and component machining in another organization. Process planning (also called methoding) includes the design of the gating system to lead molten metal into the mould cavity and feeding system to compensate solidification shrinkage (Fig. 3). The component design is modified during tooling and methoding to improve its manufacturability. This can increase its weight (typically by 5%–15%), which has to be either accepted by the OEM or machined off, implying higher cost. These factors along with metal and process also affect the overall yield – the ratio of component weight to poured weight, which can range from 40% to 80%. While remelting and recycling is an integral part of metal casting, it also leads to preventable loss of energy and productivity.

Most foundries in India are small and medium enterprises at the bottom of the manufacturing value chain as tier-2 or tier-3 suppliers. Their operating margins have been squeezed to single digits due to OEMs demanding continuous reduction in price, coupled with rising costs of manufacturing resources – materials, manpower, energy and logistics. This has limited the inflow of capital and human resources required for exploring and implementing new technologies to achieve high quality and optimal yield along with minimal impact on the environment.

Since 1980s, 3D CAD/CAE/CAM technologies have been adapted in the industry, initially by OEMs, followed by others in the value chain. The foundry industry has been rather slow in this regard. A survey carried out during 2000-2010 involving over 150 Indian foundries showed that only 75% used CAD/CAM and even fewer (25%) used simulation software [3]. Most of them were aware of the benefits of these technologies to minimize internal resources as well as to enhance customer value through higher quality assurance and tighter delivery schedules. However, the high cost and difficulty of using the technologies limited their widespread application, particularly in small and medium foundries.

This article describes four relevant R&D works carried out over the last three decades at IIT Bombay and partner organizations. They developed, disseminated and deployed computer-aided technologies for design, simulation, automation and optimization, to successively improve product quality and process efficiency. It started in 1990 with the Gradient Vector method to quickly predict the location of shrinkage porosity defects. Later, coupled simulation of mould filling and casting solidification enabled predicting many other defects such as blow hole, cold shut and hard zone. The simulation software was integrated with methoding to optimize

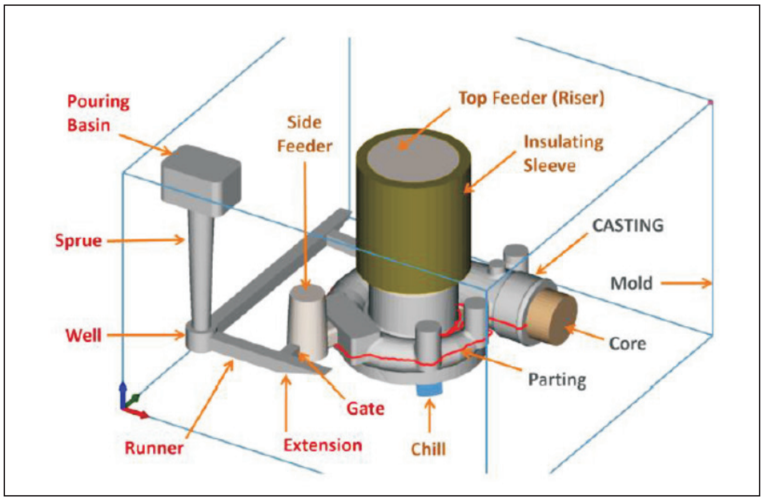

Fig. 3 : Casting, mold and methoding (gating and feeding)

the design of feeding and gating systems, and later with tooling design to obtain patterns and core-box models. The basic simulation tool was incorporated in Cloud-based E-Foundry, making it accessible to many people across the world. The latest project currently underway involves embedding sensors in pattern printing, mould-making, melting & pouring and sand-reclamation units to create SMART Foundry. This allows streaming process data to the Cloud, for analysis with respect to product design in terms of quality. These initiatives and their outcomes are described in the following sections.

2. Casting Process Simulation

Among the various casting defects mentioned earlier, solidification shrinkage (in the form of porosity, cavity or sink mark) can account for up to half of the rejections. These occur due to the volume difference between liquid and solid phases of cast metal (up to 7% for aluminium and steel). The shrinkage accumulates at the hot spots, which internally feed adjacent regions that solidify earlier. The defects can be avoided by shifting hot spots into attached feeders, which are later cut-off and recycled (Fig. 4). Small or incorrectly placed feeders can increase the shrinkage defect, whereas very large feeders reduce the overall yield. For optimizing the feeder design, it is necessary to identify the location and magnitude of hot spots.

The progressive solidification of casting can be simulated using finite difference or finite element methods. The computational domain of casting and mould is divided into many tiny elements; thermo-physical properties (density, thermal conductivity, specific heat and latent heat) are assigned to each element; and boundary conditions, such as the interfacial heat transfer coefficients (at casting-mould, mould-air and other interfaces) are applied. The results are computed by an iterative numerical procedure over a large number of small time-steps. By early 1990s, several simulation programs were available in Europe and USA, adapted by leading foundries [4]. However, input preparation and temperature computation usually took much more time than the actual casting solidification. Moreover, the programs were expensive and required high level of technical skills, limiting their penetration.

By serendipity, a novel method for hot-spot location was discovered in 1988, triggering a chain of technological developments described in this paper. It was based on tracing the directional solidification (the reverse of feed paths), to reach the hot spot [5]. The direction G of maximum solidification at any point P inside the casting is perpendicular to the isothermal contour passing through P and is proportional to the resultant of the thermal flux vectors g_i around P (Fig. 5). The Gradient Vector method was validated on many shapes from literature, demonstrated for feeder design optimization [6], and successfully applied to industrial castings [7]. The method was continuously improved to handle various boundary conditions such as feeder insulation and casting chill [8].

Metal casting is, however, a multi-physics process. The liquid metal starts solidifying even before the mould is completely filled. Around late 1990s, an all-women team at CSIR-NIIST Thiruvananthapuram started developing the relevant algorithms and created a software called Virtual Casting [9]. The governing equations were based on the conservation of mass, energy and momentum.

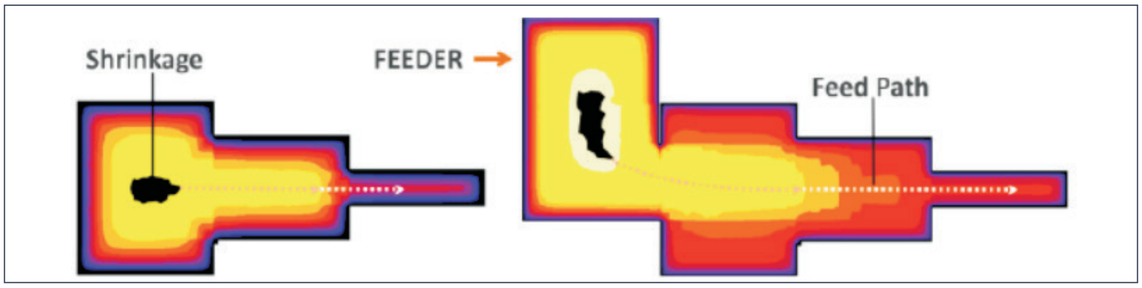

Fig. 4 : Shrinkage defect at hotspot, shifted to feeder

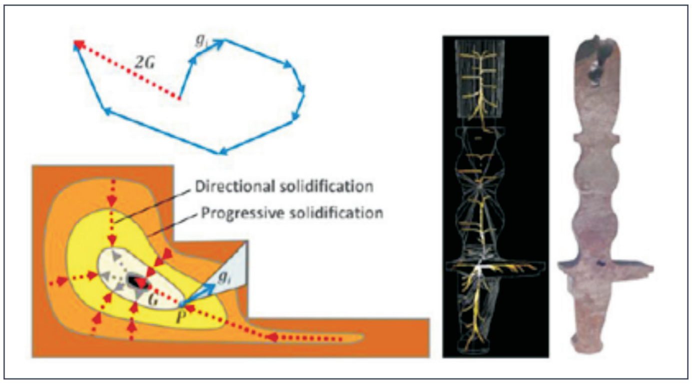

Fig. 5 : Gradient Vector Method for feed path simulation

Additional equations were solved for fluid fraction and boundary conditions at the free surface (its location also being a part of the procedure). The variation of solid fraction between the liquidus and solidus temperatures was handled using Scheil's equation complemented by experimental measurements. The governing equations along with initial and boundary conditions were solved using finite volume method using a structured grid. Explicit time integration scheme for transient simulation was employed, and the time-step for solver computations was automatically selected based on stability criteria. The metal pouring temperature is one of the inputs for mould-filling simulation. The computed temperature at the end of filling serves as the initial temperature for solidification simulation.

In 2011, the NIIST team joined hands with IIT Bombay and an industry partner (3D Foundry Tech) to develop an advanced simulation module called FLOW+ with improved features, user interface and computational performance (Fig. 6). The default inputs including thermo-physical properties and interface heat transfer coefficients are taken from a comprehensive database to minimize user inputs [10]. The mesh generation is also automatic, though the user can control the desired speed and accuracy of results. The software computes the mould filling velocity, liquid fraction, solidification temperature and cooling rate at various points inside the casting. These computations take only a few hours for even large and complex castings. The 3D-visualization and analysis of results enable accurate prediction of defects related to filling (blow hole, misrun, cold shut), solidification (shrinkage cavity/porosity) and cooling (hard zone). This was successfully validated on several industrial case studies [11].

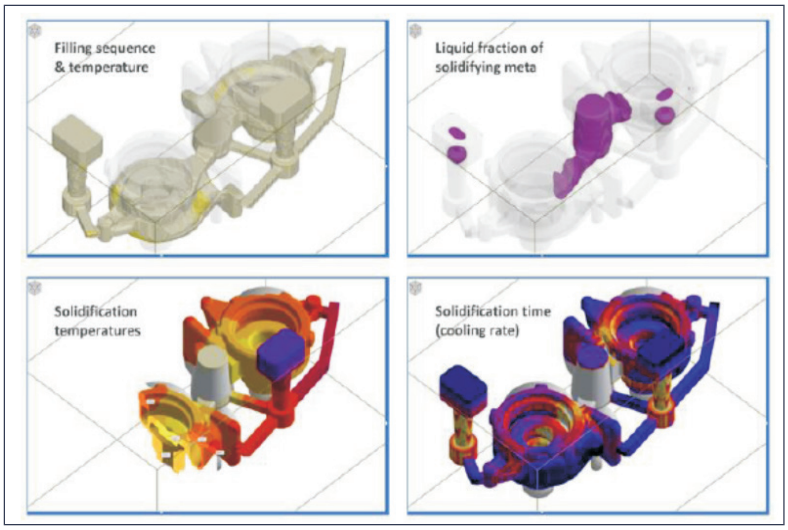

Fig. 6 : Coupled simulation of mould filling and solidification

3. Methoding & Tooling Design

Defect-prediction alone is of limited use to foundry engineers. They also need to modify the methoding design in a CAD program, transfer the casting model (along with mold, core, feeding and gating elements) to a simulation program, compute the results, visualize the defects, check if they are still present inside the casting and repeat the steps till the desired quality and optimal yield are achieved. This is cumbersome for those who have limited knowledge, skills and patience for complex software programs. The obvious solution is to integrate the casting design and simulation in a single system and incorporate intelligent algorithms to quickly accomplish the job with minimal user inputs.

Methoding of castings is, however, complex. It includes many inter-connected decisions regarding mould cavities, gating and feeding (Fig. 3). The number and layout of cavities are optimized to achieve maximum productivity (ratio of cast metal to mould material per cycle) while minimizing mould damage and casting defects [12]. The gating system comprises pouring basin, sprue, well, runner, extension, gates and filters. Their number, location, shape and dimensions, along with pouring parameters (temperature, pressure, time and rate) are designed to ensure complete, uniform and smooth filling of mould cavity with clean metal. For this purpose, experimental studies with water in transparent moulds [13] provide good insights. The elements of feeding system include feeder, neck (connection to casting), sleeve (insulating or exothermic), chill and padding. Feeders can be blind or open to atmosphere; they can be connected to casting top or side. Top feeders have more feeding pressure, but shorter solidification time compared to side feeders. Feeder efficiency can be improved using sleeves or by connecting to multiple castings, as long as there is sufficient capacity (liquid metal in the feeder). Chills can eliminate small local hot spots. The number, location, shape and dimensions of various feeding elements are designed to ensure controlled progressive directional solidification from thin or end regions toward the feeders.

Gating and feeding systems influence each other in many ways. For example, gates connected to side feeders can improve feeding efficiency and reduce fettling effort. On the other hand, thick gates connected to thin sections of casting can lead to local hot spots that may need additional feeders. It is quite common in foundries to experiment with a dozen or more methoding layouts and select the best one after casting experiments (real or virtual). Since the relevant knowledge available in technical literature is limited to simple shapes, the methoding of real-life complex castings remains a practical challenge in foundry industry.

The problem was tackled by systematically collecting and collating the relevant methoding knowledge through deep interactions with senior foundry experts and encapsulating it in rules [14]. One such rule suggests the feeder location (connection point with casting): flat and vertical casting face that is close to hot-spot and mould parting. The feeder dimensions are suggested based on modulus principle: the square of the modulus (ratio of heat content volume to heat transfer area) is proportional to the solidification time of the shape. If the feeder height is close to the mould top, it can be converted into an open feeder. The neck is designed with an intermediate modulus value compared to casting (hot-spot region) and feeder, to ensure directional solidification. All these rules can be incorporated in software algorithms; the user only needs to confirm or fine-tune the suggested values. Then 3D models of the feeder and neck can be generated and attached to the casting. Similarly, gating design would only require the location of gate and sprue by the user; the runner layout, dimensions of all gating elements and generation of their 3D models can be automated [15].

The above approach based on practical methoding knowledge and intelligent geometric reasoning was implemented for the first time in 1998 in a software program called AutoCAST [16]. It empowered even fresh engineers (who lack foundry experience) and senior engineers (who may have limited computer skills), to effectively and efficiently use it without elaborate training. Their feedback helped in improving successive

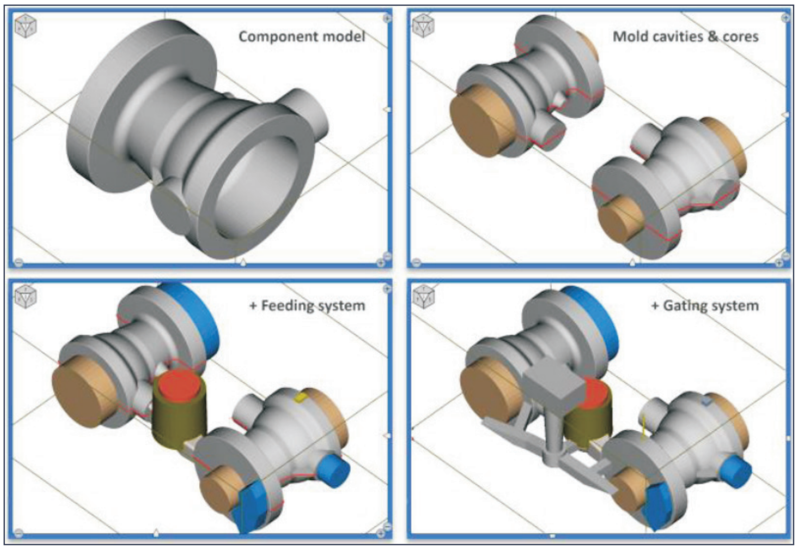

Fig. 7 : Semi-automatic design of feeding & gating systems

versions of the software. Over the next ten years, the software was also employed to train several hundred foundry engineers in casting design and simulation through continuing education programs organized at IIT Bombay.

The tenth version of the software was developed with an entirely new user interface, additional features, more automation and expanded alloy database (Fig. 7). It was named AutoCAST-X and launched at the World Foundry Congress at Chennai in 2008. Five years later, an advanced version of the software (AutoCAST-X1) incorporated the FLOW+ module mentioned earlier, which was launched at the Indian Foundry Congress in Ahmedabad. Till date, it has been implemented at about 200 organizations. Most of them are foundries; others include OEMs, R&D institutes and consultants providing simulation services. The end-users reported good matching of simulated and observed results, as well as ease of optimizing the methoding, leading to overall improvement in casting quality, yield and energy utilization.

The next major item on the 'wish-list' of foundries was automated tooling design. This had become a bottleneck due to the limited number of tool-rooms and long lead time (often several weeks) for pattern development. Further, poor coordination between tooling and methoding engineers led to many quality issues and increased casting weight, which was unacceptable to OEMs. The activities had to be integrated.

Tooling design has several critical steps. The first is the suppression of drilled holes and other machined features, followed by the twin decisions of casting orientation and mould parting that affect all other steps in tooling and methoding design. Parting line divides the casting surface into non-overlapping regions, each produced by a separate segment of mould – cope, drag or core [17]. It is marked by flash that has to be trimmed later and leaves a visual mark. Cores are designed for through holes and undercuts, which obstruct the withdrawal of the pattern from dispensable mould or casting from permanent mould. Such features can be automatically identified through geometric reasoning [18]. Core supports or prints must be designed for stress as well as transfer of heat and gases. Draft is applied to surfaces perpendicular to the parting (for ease of withdrawal of pattern or casting); more on internal surfaces since they grip the mould. Sharp corners are filleted to facilitate moulding and metal flow. Other allowances include contraction, distortion and machining. Their values depend on the casting metal, shape, location and process; they must also follow the standard practices of geometric dimensioning and tolerancing. The allowances can be combined and optimized to reduce the total increase in weight and machining required to obtain the desired component.

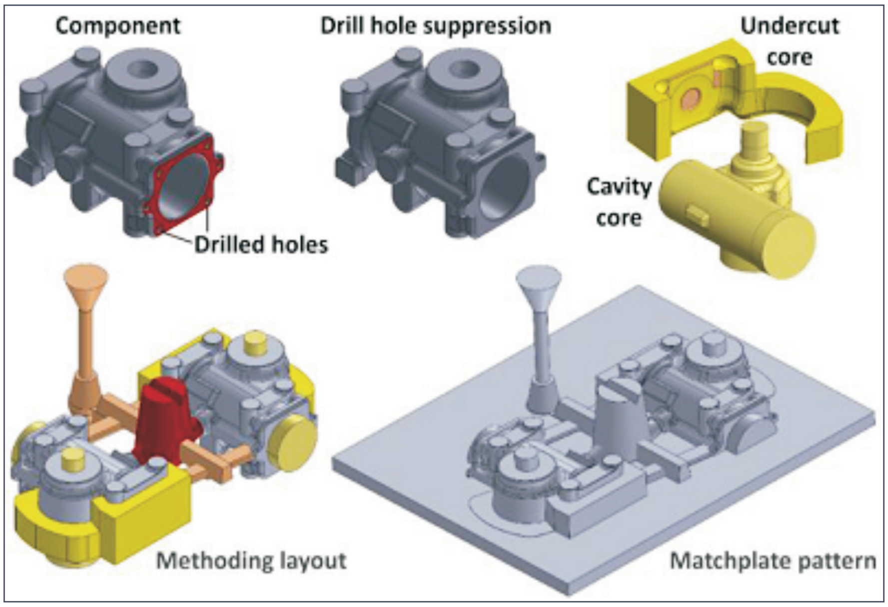

Fig. 8 : Tooling (pattern/core) design in CAD environment

The above routines required a regular CAD program. For this purpose, the team selected SolidWorks, since it was widely used and preferred by foundries owing to its user-friendly features for 3D modelling. Using the basic routines of the software, a new module called AX-Tooling was developed during 2015-2020, to semi-automatically convert a component model into corresponding tooling models (Fig. 8).

Some features of the methoding design and casting simulation mentioned earlier were also included in the module. This was meant for product designers in OEMs to quickly assess and improve the design for castability [19]. For example, they could minimize the hot-spots by redesigning the thick junctions, leading to improved quality and yield, as well as reduced weight and machining cost. This was enabled by algorithms for automatic computation of wall thickness [20] and classification of junctions [21]. The availability of tooling, methoding and simulation data made it possible to estimate the tooling cost [22] and casting cost [23]. This enabled early identification and modification of critical features at the product design stage itself, to optimize the overall cost.

4. Cloud-based Simulation

Indigenous development of technologies brought them within the reach of even small and medium foundries. They were, however, constrained by the lack of trained human resources to utilize the software technologies. Most of the engineering and polytechnic institutes had limited resources (teachers and labs) for metal casting theory and experiments. There was a dire need of high-quality learning content in casting design and simulation that could be freely accessed by anyone, anytime, anywhere, using any computing device (desktop, laptop, tablet or smartphone) [24].

This led to the development of a Cloud-based simulation system called E-Foundry during 2012-2015 (Fig. 9). The user can upload a 3D-model to the Cloud, and select the cast metal, mould material and mesh size (coarse or fine). The online system computes the solidification results using Gradient Vector method and sends colour-coded temperature images to the user's device within minutes (Fig. 10). Foundry engineers can identify hot spots (prone to shrinkage porosity), cold spots (prone to cold shuts) and high gradient regions (prone to hot tears); then modify the design, upload the new model and verify by simulation [25]. Product engineers can check and modify the part design (wall thickness, tapers, ribs, fillets) to ensure directional solidification and ease of feeding. Tooling engineers also find it useful to find casting orientations that are easy to feed and fettle.

The system includes several learning resources. 'Classroom' comprises 45 lessons, each with a short video, downloadable slides and online quiz. These are optimized for low Internet bandwidth and smartphone viewing. 'Library' contains process animations, abstracts of over 1000 selected technical papers published worldwide, industrial case studies and defects museum. 'Tutorial' includes 18 exercises in methoding design with immediate feedback. The 'Projects' page provides ideas for research in metal casting field. 'Hub' enables discussion threads. All utilities can be freely accessed by the users.

Till date, E-Foundry has been utilized by over 9000 members worldwide, who have carried out more than 25,000 simulations. The learning resources were utilized for short training programs at many institutes, benefitting several hundred teachers and students. Some of these institutes later set up dedicated cells for research, training and consulting, leading to closer ties with the local industry.

Fig. 9 : Cloud-based casting simulation and learning

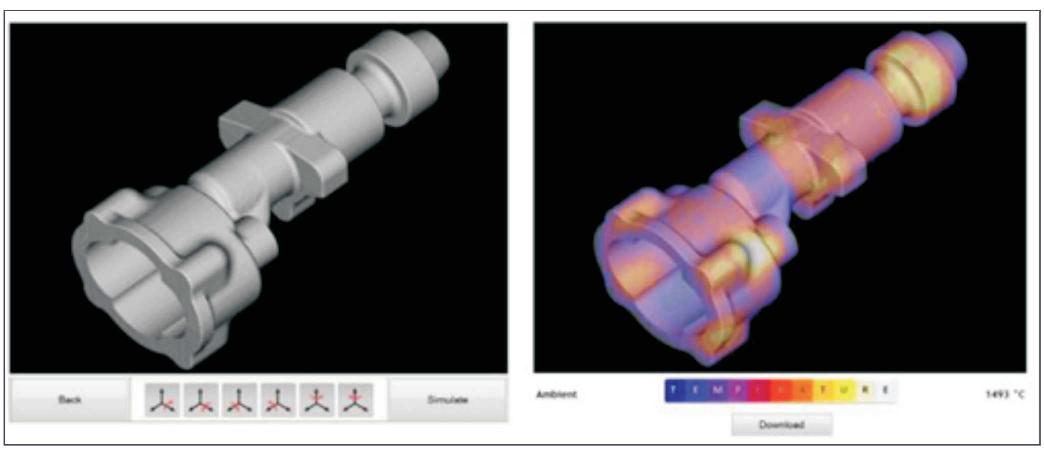

Fig. 10 : E-Foundry simulation input and output

5. Smart Manufacturing

The first three industrial revolutions enabled mass production of complex engineering products (such as automobiles) at low cost, making them affordable to large sections of society. However, they concentrated the activities in clusters, and caused significant damage to the environment. The world started looking for alternative systems of production that are distributed, flexible, smart and sustainable.

The fourth industrial revolution (Industry 4.0) was born out of the convergence of digitization and connectivity. The enabling technologies include automation, simulation, Internet of Things (IoT), Cloud computing, Big data and analytics [26]. The factories of the future will have sensors embedded in all manufacturing equipment that stream data to the Cloud, making it possible to remotely control, visualize, analyse and optimize the process. This would be a great leap forward for countries like India, who already have the necessary IT infrastructure in place.

Industry 4.0 applied to metal casting would enable rapid manufacture of small intricate metal parts with high quality even for a single or tiny order quantity, and at a much lower cost than conventional casting or metal 3D printing. Driven by this vision, the researchers and industry partners associated with the E-Foundry project conceived SMART Foundry in 2015. They started developing four compact automated units for patternmaking, no-bake moulding, melting & pouring and sand reclamation (Fig. 11), with embedded sensors for capturing real-time process data such as temperature and pressure [27].

Pattern-making unit includes a 3D- printer developed at College of Engineering, Pune, based on fused-deposition modelling process using polymer (ABS or PLA), and a vapour-polishing setup to smoothen the surface of the fabricated patterns. Sensors pick up the real-time temperatures of the printer nozzle, bed and chamber.

No-bake moulding unit was developed by CMERI Durgapur and CMTI Bangalore. It comprises containers for sand and resin, mixing chamber, ramming station, adjustable mould box for match-plate patterns and various actuators. Sensors include load cell for sand discharge quantity, speed sensor for mixer RPM, proximity sensors for ramming station, limit sensor for mould box movement and force sensor for ramming force.

Melting & pouring unit was developed at CHARUSAT, Changa. It combines the two functions to reduce energy loss and improve casting quality.

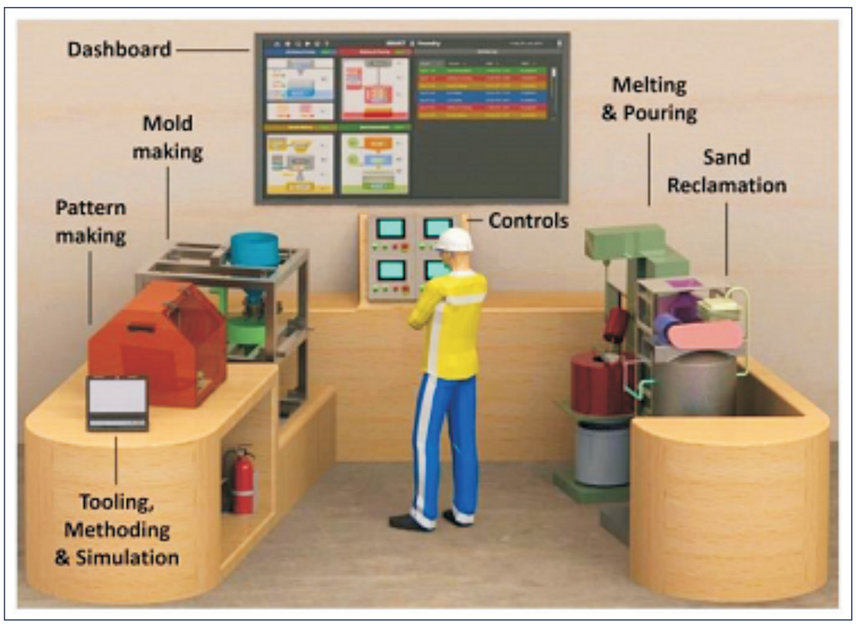

Fig. 11. SMART Foundry units, layout and dashboard

Optional attachments include particle stirring and vacuum pouring. Sensors pick up the furnace temperature, pouring temperature, stirrer speed, metal quantity and vacuum chamber pressure.

Sand reclamation unit was developed at DKTE, Ichalkaranji. It comprises lump breaker, vibrating screen, fluidized bed combustor, cooler and sand siever, and sensors for temperature and other parameters. It can recover 85-90% of no-bake mould sand for reuse in the moulding unit.

Micro-controllers placed in all four units collect data from various sensors in real-time and stream it to the Cloud, where they are stored in spreadsheets. A graphical dashboard displays the overall status of the four units and allows the user to view the instantaneous value of any selected parameter or its variation over time. The dashboard is also used for setting the desired values of selected parameters and to switch any unit on or off.

The integrated SMART Foundry (Fig. 12) combines all the technologies developed so far including the software programs for tooling design, methoding design and process simulation; hardware units for pattern-making, no-bake moulding, melting & pouring and sand reclamation; as well as process data sensing and monitoring. The first version of the integrated system was put together in 2020 at CMTI Bangalore.

6. Closing the Loop

Quality is defined as the conformance between designed and manufactured components. The difference between the two cannot be eliminated just by improving the manufacturing process alone using conventional techniques such as statistical process control. It also requires the component design to be compatible with the general capabilities of a selected manufacturing process as well as the specific capabilities of a particular facility or equipment [28].

Product design for manufacturing is an open loop approach; it needs to be replaced by product design for manufacturability, which is a closed loop approach. This requires a comprehensive knowledge-base about the effect of a given combination of component geometry, material composition, equipment specifications and process parameters on various aspects of product quality. Measuring and analysing the difference between the designed and manufactured components is the first step in building such a knowledge-base. This is enabled by the 'digital twin' encompassing the detailed information related to a product and its process.

In metal casting, the component geometry in terms of overall shape, individual features and dimensions is transformed during tooling and methoding design. The manufacturing process

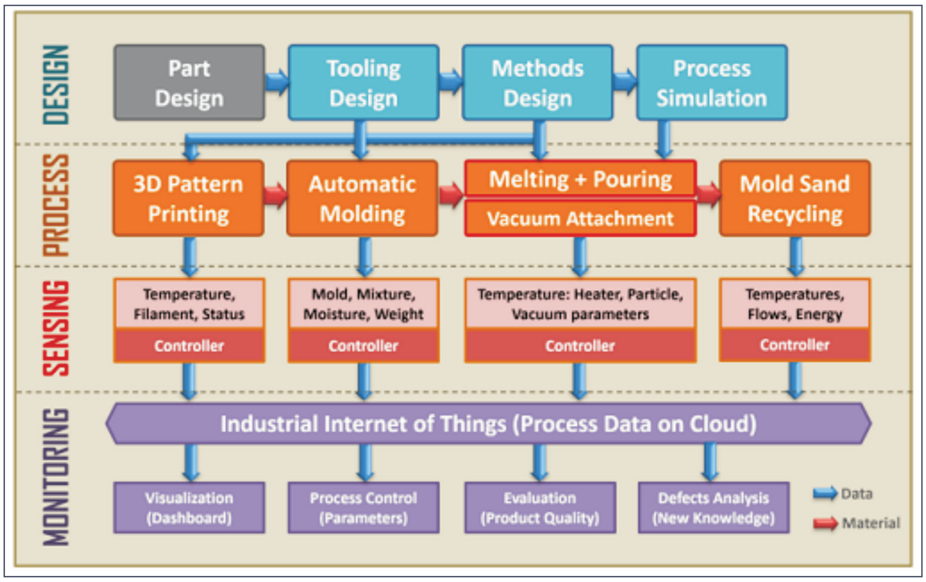

Fig. 12. Integrated software, hardware and IoT for casting

(moulding, melting, pouring and cooling) creates further divergence in terms of composition, surface quality, internal integrity and mechanical properties. The geometric differences can be visualized by superimposing the 3D-scanned model of the cast component over 3D-CAD model of the designed component (Fig. 12). The colour mapping of positive and negative deviations provides valuable insights [29].

Such experiments with different combination of component shapes, casting alloys, mould materials and process parameters can help in creating a useful knowledge-base to predict the shape and dimensions of new components having a similar combination. The knowledge-base incorporated in CAD software will enable fine-tuning the methoding and tooling design (such as distortion and machining allowances) to bring the cast component closer to the designed geometry without shop-floor trials.

The above method can be extended to all other aspects of quality. The large amount of process data recorded by sensors embedded in equipment can be mined for useful knowledge. The values of process parameters along with observed defects and mechanical properties can be analysed to identify the parameters (along with their specific range of values) responsible for causing the deviations. For this purpose, AI techniques such as artificial neural networks and Bayesian inference methodology have been found to be useful [30]. The resulting knowledge-base will enable optimizing the process parameters to achieve the desired internal quality and mechanical properties for similar castings in the future.

7. Conclusion

Metal casting continues to be an essential manufacturing process, even after millennia. This apparently simple process belies complex multi-physics phenomena that defy clear insights, as it is difficult to produce high quality castings on the shopfloor without trial and error experiments. The digital technologies described in this paper are helping unravel the mystery by allowing the visualization and analysis of the component, tooling, methoding, moulding, filling, solidification and various process parameters on computer before actual casting. The 'digital twin' produced by such virtual engineering enables comparing the geometric, material and quality parameters of designed and manufactured components. The resulting knowledge-base is useful for reducing the defects and deviations in future.

Closing the loop between design and manufacturing is still a work in progress. The paper has provided a glimpse of the many challenges and opportunities at the intersection of

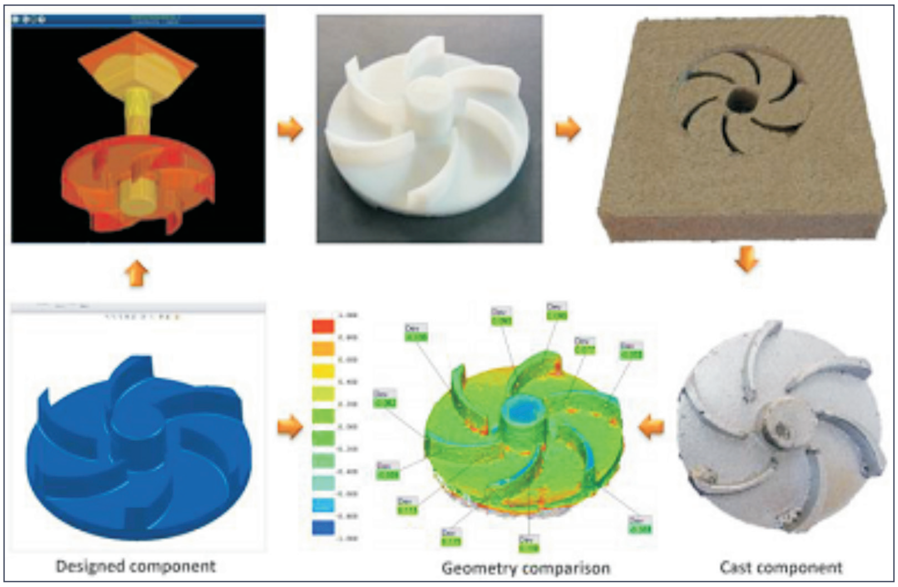

Fig. 13 : Geometry comparison of designed and cast parts

metal casting and information technology fields. Many new avenues have opened up for inter-disciplinary research, knowledge-integration and technology development projects that will benefit the industry as well as the society at large. Long perceived as difficult and dirty, metal casting appears to have crossed the inflection point on the way to becoming smart and sustainable.

Acknowledgements

The research work described in this paper spanned three decades and involved more than one hundred researchers, engineers and industry experts from multiple disciplines and organizations. Those who led the projects or made significant contributions deserve special mention. It includes Ramesh Dommeti, who developed the first version of AutoCAST, and Kaustubh Moharir, who developed AutoCAST-X. The tooling design module was created by 3D Foundry Tech team led by BabaPrasad Lanka. The FLOW+ software was developed by Dr. Roschen Sasikumar, Dr. Savithri Sivaraman and Dr. Elizabeth Jacob at CSIR-NIIST, Thiruvananthapuram. Relevant experimental studies were carried out by Dr. MM Akarte, Dr. RG Chougule, Dr. Dinesh Pal, Dr. K. Subburaj, Dr. KH Renukananda and Dr. Himanshu Khandelwal. The E-Foundry project involved Dr. Durgesh Joshi from Indore (who sadly passed away in a road accident), Dr. Mayur Sutaria from Changa, Dr. Amit Sata from Rajkot, and Dr. Vasudev Shinde from Icchalkaranji. The SMART Foundry project brought in additional researchers including Prof. A.M. Kuthe from Nagpur, Prof. Goutam Sutradhar from Kolkata (later Manipur), Dr. Nagahanumaiah from Durgapur (later Bangalore) and Dr. Arati Mulay from Pune. The support of government agencies – National Knowledge Network for E-Foundry project, Department of Science & Technology for the SMART Foundry project, and industry (mainly 3D Foundry Tech) for software development is gratefully acknowledged. The technologies were refined with valuable inputs from many casting experts. The implicit support of the parent institutions of the researchers in sustaining the above projects over many years helped in crossing the 'valleys of death' from scientific concepts to practical applications.

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TATA STEEL
#WeAlsoMakeTomorrow
TATA
#SteelFact
Recycling 1 tonne of steel scrap saves
1.5 tonnes of CO2,
1.4 tonnes of Iron Ore, 740 Kg of Coal and 120 Kg of Limestone.
Source: World Steel Association
RECYCLING STEEL
FOR A BETTER TOMORROW
Steel Production through Electric Arc Furnace (EAF) uses scrap as an input & Tata Steel has set up India's first state-of-the-art scrap processing centre at Rohtak, Haryana. The scrap is sourced from market segments like End-of-Life Vehicle scrap, Obsolete Household Scrap, Industrial Scrap etc through Digital FerroHaat App.
Sure we make steel.
But #WeAlsoMakeTomorrow.
Responsible Steel standards & certification
Tata Steel is now a part of ResponsibleSteel™, the industry's first global multi-stakeholder standard and certification initiative.
www.wealsomaketomorrow.com | | www.tatasteel.com

This year, the Indian Institute of Metals (IIM) is celebrating its 75 years of glorious service to the Nation. The International Conference and 75th Annual Technical Meeting (ATM) of IIM, was organised virtually, from November 13-15, 2021 to celebrate the legacy of the Institution.

The IIM ATM 2021 began with the poster competition, metallography and technical exhibition on 13th Nov'21. On the same day, the international conference on 'Advanced Materials and manufacturing for sustainable future' was inaugurated by **Mr. T V Narendran (CEO & MD, TATA Steel and President IIM)**. In his speech, he elucidated the role played by IIM as a nation-building institution. He invited all the stakeholders to collaborate and contribute for new frontiers in manufacturing, sustainability and innovation. Mr. Narendran had stressed that going forward IIM should play a prominent role in the emerging eco-system of start-ups and also could provide a platform where young, energetic entrepreneurs with bright ideas would meet industries that would provide the mentorship and opportunities to scale up.

On this occasion, the chief guest **Dr. K Vijay Raghawan, Principal Scientific Advisor, Government of India** delivered the keynote lecture. He stressed on the role of energy usage on climate change and urged the fraternity to bring in changes to make manufacturing processes energy-efficient and use energy sourced in a green way. He urged the fraternity to use advanced computational techniques e. g., artificial intelligence, machine learning and robotics to shorten the innovation time line. People from all walks of life came together to tackle the issues faced during the COVID-pandemic. Dr. Raghawan insisted materials science and metallurgy fraternity to resemble that and adopt decentralized and personalized production methods leveraging digital technologies instead of making generic products. He suggested co-partnering to move out of silos for economic gain while addressing the imminent environmental crises. Energy inputs being a crucial lever, he illustrated how the national hydrogen mission will make H_2-generation technologies cheaper.

There were two technical sessions with invited presentations and one panel discussion by world-renowned academicians, professionals and industry leaders from all over the world. The theme of the conference will revolve around the topic of sustainability with a focus on the development and application of advanced materials and manufacturing technology.

A broad outline of the conference was as follows:

Session I : Material synthesis/development/ design

i. ICME and Material Genome in process technology by **Mr Ananth Krishnan**, CTO, TCS

ii. Emerging Technology in 2D and FGM development by **Dr G U Kulkarni**, President, JNCAR & CeNS

iii. Advancing materials towards a sustainable society by **Prof Philip Withers,** University of Manchester

Session II : Modern application development and trends

iv. Light weighting and safety in mobility and e-mobility by **Andrew Foster**, Chief Engr Body Component and **Rebecca Hitch**, Senior Manager for Materials Engineering and Product Sustainability, JLR, UK

v. Power to the people democratisation driven by coated steel products by **Prof David Worsley**, University of Swansea

vi. Additive's Future in Manufacturing by **Dr. Kirk Rogers**, The Barnes Groups Advisors (TBGA)

Session III : Panel Discussion on Sustainability (Cradle to Grave) :

Session Moderator was Prof Rangan Banerjee, IIT Bombay. Panel members was **Dr. Pinakin Chaubal**, VP & CTO, ArcelorMittal, **Ms Deeksha Vats**, Chief Sustainability Officer, Aditya Birla Group, **Dr. N Kalaiselvi**, Director CSIR-CECRI.

Concluding remarks and vote of thanks were given by Joint Convener Dr. A N Bhagat, Tata Steel.

On 14th November'21, IIM ATM inaugural and award programme were conducted. **Mr Sudhansu Pathak, Chairman COC and former VP- Steel Manufacturing, TATA Steel** welcomed the august gathering and expressed his happiness and thanked the mentors, sponsors, IIM-members, volunteers for their contribution in organizing the IIM ATM'2021. He gave an overview of the agenda of IIM ATM'21.

Dr. S V Kamath (VP-IIM) in his address invited to leverage all the stakeholders including industry, R&D institutions and academia to address the issues faced by the nation.

Mr. T V Narendran (CEO & MD, TATA Steel and President IIM) urged the gathering to collaborate more with the start-up companies and talked highly of IIM's rich tradition of rewarding individual and organizational excellence.

The chief guest of the occasion, **Shri Tripathy, Secretary Steel Ministry** congratulated IIM for its service to the nation over seven and half decades and was happy to note that along with IIM's Platinum Jubilee Year, 75 years of India's independence is also celebrated through 'Azadi Ka Amrit Mahotsav'. He stressed on the importance of energy security in an environment constrained world. He told that the 21st Century is the century of Materials Science and it poses a big opportunity to the Material scientists and metallurgists on the backdrop of a low per capita steel consumption (1/3rd of the global average). He acknowledged that COVID changed the skill-set required and digital skill has become essential and we, as a fraternity need to overcome the challenges related to the skill gap. It is essential to have a collaborative effort to harness the talent pool that the country has. He illustrated how the policies related to the sector will help in 'Atma Nirbhar Bharat Nirman'.

The organizational and individual awards were then conferred by the President, IIM. He congratulated all the award winners with the confidence that the younger generation will be motivated to make India a world leader in all endeavours related to manufacturing, Metallurgy and Materials Science. This was followed by launching of 3 books under the IIM-Springer Book series.

The memorial lectures were then chaired and delivered by eminent professionals across the globe.

The plenary lecture-1, chaired by Dr. Indranil Chattoraj, was delivered by Dr. Anil Kakodkar, Chancellor, Homi Bhabha National Institute & Former Chairman, Atomic Energy Commission. Dr Kakodkar outlined that to achieve a Human Development Index of 0.5, energy consumption needs to increase by 5-fold and energy supply by 120-140 times. He said that to achieve the net-zero goals taken by Indian government at the COP26, we need to use H_2 in the industry and increase our share of electricity in the energy-mix. He reiterated that, going forward, CCS (Carbon Capture and Sequestration) is inevitable. He suggested to accelerate nuclear programmes to achieve the net-zero targets in an effective manner.

Dr Debashish Bhattacharjee, VP- Technology and New Materials Business, TATA Steel introduced Professor HKDH Bhadeshia (Emeritus Tata Steel Professor of Metallurgy, University of Cambridge, UK) as the speaker for the plenary lecture-2. Professor Bhadeshia deliberated on the fundamental aspects of hexagonal close packed iron and how the polymorph can be moderated to leverage its properties.

Post that **parallel sessions** were conducted for oral presentations on eight different themes.

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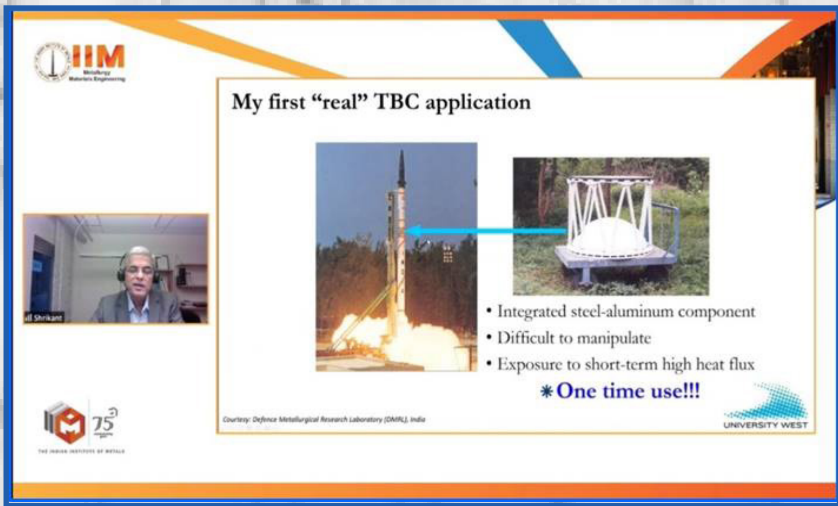
GLIMPSES OF IIM AWARDS 2021


IIM ATM 2021
IIM Certificate of Honour
Recipient of
IIM
IIM Certificate of Honor
2021
Dr. Chiradeep Ghosh
Secretary, IIM Jamshedpur Chapter
In recognition of his commendable work in overall membership development of the Chapter, interaction with students/colleges and organising technical conferences.
THE INDIAN INSTITUTE OF METALS
T V Narendran Tata Steel
S V Kamath

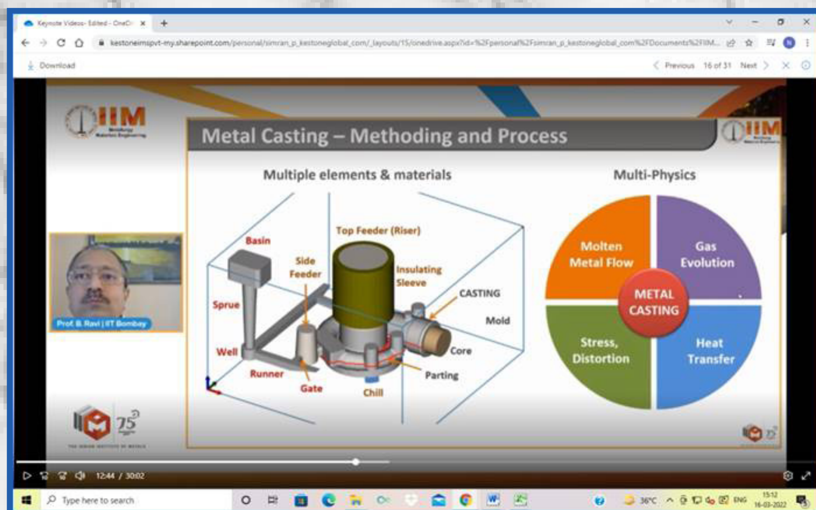

IIM ATM 2021
IIM Honorary Membership
Conferment of
Honorary Membership
2021
Dr. Amol A Gokhale
Professor, Department of Mechanical Engineering, IIT Bombay &
Immediate Former President, IIM
THE INDIAN INSTITUTE OF METALS
T V Narendran Tata Steel
S V Kamath


IIM ATM 2021
Category II
Secondary Steel and Alloy Steels Plants
Winner
JSW Steel Ltd., Salem
Sustainability Award
THE INDIAN INSTITUTE OF METALS
T V Narendran Tata Steel

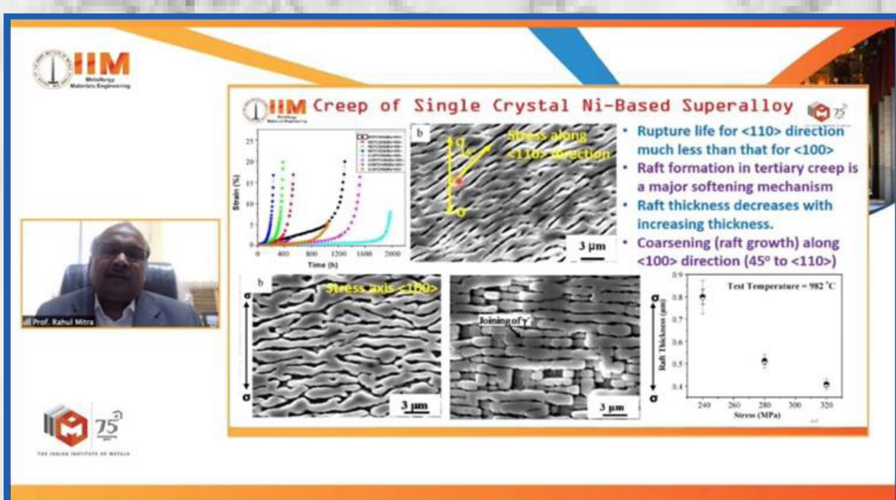
IIM MEMORIAL & AWARD LECTURES 2021



PROF NP GANDHI MEMORIAL LECTURE
by Professor Shrikant Joshi



DR DAYA SWARUP MEMORIAL LECTURE
by Professor B Ravi



G D BIRLA GOLD MEDAL LECTURE
by Professor Rahul Mitra

China's production cuts paving way for accelerated growth of Indian steel industry: TV Narendran

As China undergoes stringent production cuts, its share of the world's steel market is dropping paving the way for accelerated growth of the Indian steel industry, said Tata Steel's managing director TV Narendran in an interaction with ET.

"The forecast is that Chinese consumption will stay flat and consumption outside China will grow...the growth in consumption will be driven more by markets outside China, and I'm more positive about this industry in India," Narendran said.

The company has plans to grow its capacity by at least 35-40 million tonnes by 2030 and is considering setting up 'more scrap-based facilities' in the coming years with a capacity of at least a billion tonnes by 2025.

"The ambition is to go to 40 million tonnes by 2030. And I think between now and 2025, we would have made the plans for Kalinganagar third phase of expansion as well as the Angul expansion," Narendran said.

The Economic Times

JSW Steel gains after November 2021 crude steel production spurts 10% Y-o-Y

JSW Steel rose 1.21% to Rs. 669 after the company's standalone crude steel production for the month of November 2021 grew 10% to 14.60 lakh tonnes as against 13.32 lakh tonnes in November 2020.

On a sequential basis, crude steel production rose by 2% in November 2021 from 14.25 lakh tonnes produced in October 2021.

While the production of flat rolled products increased by 4% to 9.99 lakh tonnes, production of long rolled products jumped 13% to 3.32 lakh tonnes in November 2021 over November 2020. Sequentially, production of flat rolled products and that of long rolled products fell by 4% and 1%, respectively.

Business Standard

Top aluminium and steelmakers witness a rise in thermal coal stock, secondary players still under pressure

Top steel and aluminium makers are witnessing a rise in thermal coal stock levels even as some secondary players are still reeling under supply constraints of solid fuel from the state-owned Coal India Ltd.

"In between, there was a period where we were really worried. Stocks were low; it came down to 4-5 days for us, but now things have improved," said T.V.Narendran, Tata Steel's managing director.

While Tata Steel also imports thermal coal from countries such as South Africa, Narendran said that the company went lean on stocks during the month of October.

Naveen-Jindal led Jindal Steel and Power that faced supply constraints of thermal coal during the month of October said that the situation is getting back to normalcy.

The aluminium industry was also struggling to sustain operations due to alarmingly depleted coal stocks that would last for only 1.5-3 days in the months of October and the beginning of November.

However, one of the top Aluminium makers, Hindalco said that the situation is easing.

"We were in fact much better prepared, we had built up an inventory of coal and raw material expecting some glitches. We also see this issue slowly easing out," said Satish Pai, Hindalco's managing director.

Some MSME aluminium makers are witnessing a slight improvement but supplies are not fully restored.

The Economic Times

India's top steelmakers hike prices by Rs 3,000 - Rs 3,500 a tonne due to rising cost inflation

India's leading steel makers have raised prices of the benchmark hot-rolled coil by up to Rs 3,500 a tonne on the back of rising cost inflation due to soaring coal prices.

"This was an expected move by the Industry. The cost inflation is too high. Our fuel costs have gone up by more than 70% yoy and a fall in iron ore price is minimal," said an executive at one of India's top steelmakers.

Industry sources said that JSW Steel, ArcelorMittal Nippon Steel and Jindal Steel and Power have raised prices by around Rs 3,000 - Rs 3,500 a tonne. Other steelmakers are expected to follow suit.

The Economic Times

IIM Awards 2021

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 recognize Quality Assurance aspects in the Steel Sector. The award has been re-named as National Sustainability Award from 2007.

The Awards for the year 2021 are presented to:

(a) Category I : **Integrated Steel Plants**
Joint Winners : **Tata Steel Ltd., Jamshedpur** & **JSW Steel Ltd., Bellary, Vidyanagar**

(b) Category II : **Secondary Steel and Alloy Steel Plants**
Winner : **JSW Steel Ltd, Salem Works, Salem**

(c) Category III : **Forging Units/ DRI Plants**
Winner : **Tata Steel BSL Ltd., Angul, Odisha**

IIM NON–FERROUS BEST PERFORMANCE AWARD

The Non-Ferrous Division of the Indian Institute of Metals has been organizing the National Quality Competition since 2002 to encourage and recognize Quality Control aspects in the Non–ferrous sector. The Awards for the year 2021 are presented to :

(a) Category I : **Large Integrated Production Organizations:**
Joint Winners : **NALCO, Angul** & **HINDALCO Aluminium, Sambalpur**

(b) Category II : **Secondary Processing / Fabrication Plants of Non-Ferrous Products:**
Winner : **MIDHANI, Hyderabad**

IIM HONORARY MEMBERSHIP

The **Honorary Membership** of IIM is conferred on **Dr. Amol A Gokhale**, Former President, IIM [2020-21] & Professor, Mechanical Engg. Dept., IITB.

Dr. Amol A Gokhale did his B Tech in Metallurgical Engineering from IIT Bombay in 1978, and MS and Ph D in Metallurgical Engineering from University of Pittsburgh, USA in 1980 and 1985, respectively. He served in DRDO for 30 years, retiring as Distinguished Scientist and Director, Defence Metallurgical Research Laboratory, Hyderabad in July 2015. At DMRL, he led research on aluminium lithium alloys for aerospace applications, aluminium alloy components for torpedoes, crash resistant aluminium foams, additive manufacturing of Ni based superalloys, and other very high temperature materials for hypersonic vehicles. In August 2015, he was re-employed as Professor in the Department of Mechanical Engineering in IIT Bombay, where he teaches courses on "Processing of Aerospace Materials" and "Structural Materials". He is pursuing research in processing and oxidation behaviour of high temperature niobium alloys for rocket applications; studies on shock loaded foams, honeycombs and sandwich structures; damage assisted machining of Ni base superalloys, etc.

He has been a Life Member of IIM from 1993 and has taken part in the organisation of many IIM events at the Chapter level and at the national level. He was a member of the examination committee for 4 years in the 1990s. He was the Convener of NMD ATM 2011 held at Hyderabad. He was Vice Chairman and Chairman of IIM Hyderabad Chapter for four and two years, respectively. He was the Chairman of the International Symposium on Light Weighting held at BITS Goa as part of NMD ATM 2017 and edited a book on the same subject published by Springer Publishers. Leading a team of six, he played a crucial role in the creation of a package of 10 short term courses to be offered by the Institute. As President of the IIM during 2020-21, Dr. Gokhale has put commendable efforts and driven many initiatives in achieving greater heights. During unprecedented times due to the outbreak of Covid-19, the monumental success of the flagship event has raised the bar for the future Organizers.

IIM HONORARY MEMBERSHIP

The **Honorary Membership** of IIM is conferred on **Dr. Vinod Nowal**, Deputy Managing Director, JSW Steel Ltd.

As the Deputy Managing Director of JSW Steel Limited, Dr. Nowal heads the Steel vertical across the three major manufacturing sites viz., Vijayanagar (India's largest integrated Steel Plant), Dolvi, and Salem. These units cumulatively have a capacity of 14.3 Mtpa and are on track to achieve 18 Mtpa by the end of this calendar year. As in-charge of these 3 units, the CEOs of these units report to him. As a Wholetime Director of the JSW Steel Board, Dr. Nowal is responsible for the development and execution of JSW Steel's long term growth strategy.

Dr. Nowal headed the Acquisitions of Bhushan Power & Steel Ltd., Asian Colour Coated Ltd., PCMD Division of Welspun Corp., Vallabh Tinplate; Iron ore mines in Odisha and Karnataka having reserves of 1.20BnT. He led the expansion on JSW Steel, Dolvi form 5 Mtpa to 10 Mtpa. Under his supervision increased usage of iron ores from JSW captive mines from 15% (2019-20) to 35% (2020-21) was achieved.

Dr. Vinod Nowal is currently the Chairman of the IIM Vijayanagar Chapter since 2010 and has contributed immensely for the growth of the Chapter. Under his mentorship & guidance, Shri OP Jindal Memorial Lecture series was started in 2018.

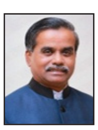
IIM HONORARY MEMBERSHIP

The **Honorary Membership** of IIM is conferred on **Mr. K K Mehrotra,** Formerly CMD, MECON Ltd. & Presently Chairman, IIM Delhi Chapter.

Mr. K K Mehrotra's significant contributions in advising Andhra Pradesh Government in selection of best process route & capacity as well as evaluation of offer submitted by investors for installation of 3.0 Mt capacity green field integrated steel plant in A.P have been noteworthy.

Mr. Mehrotra has been a very active member of The Indian Institute of Metals since 1990 & associated for organizing many seminars at Ranchi. Being the chairman of IIM, Delhi Chapter, he is currently working on further enhancing the visibility & activities through several steps such as associating small & medium scale industries in & around NCR for conducting webinars / seminars.

IIM PLATINUM MEDAL



The **IIM Platinum Medal** for the year 2021 is awarded to **Dr. Uthandi Kamachi Mudali**, [FNAE, FIIM, FNASc., FIIChE, FNACE, FASM, FAPAM, FIE, HFECSI, HMUDCTAA, HMIIM, FASch, FICS] Vice Chancellor, VIT Bhopal University and Former President, The Indian Institute of Metals.

Currently the Vice Chancellor of VIT Bhopal University Dr. U. Kamachi Mudali is formerly the Distinguished Scientist of Department of Atomic Energy, and Chief Executive & Chairman of Heavy Water Board, a flagship industrial unit of DAE. Dr. Mudali has made pioneering individual contributions to advanced materials & coating technology development; corrosion science, engineering and technology; materials, process and equipment development for reprocessing applications; failure analysis, consultancy and societal contributions; for more than three decades during his service at DAE. Dr. U. Kamachi Mudali is an internationally recognized scientist and technologist with outstanding contributions in advanced materials, corrosion science and engineering and coating technologies, and has put in remarkable efforts for implementing many R&D projects of immense value to the country. The hallmarks of his work are high level of originality, focus and innovation, and direct application for field and industry. Dr. Mudali's R&D contributions in the areas of advanced & specialty materials, coatings and corrosion science and technology have been widely cited by peers and other scientists which can be seen with high citations (~8900) and h-index (43).

Dr. Mudali is a Member of IIM since 1984 and has been Chairman of IIM Kalpakkam Chapter and IIM National Council Member, and made significant contributions to the growth of IIM at Chapter and national level. He is the Founder-Convener of Prof. Brahm Prakash Memorial Materials Quiz at IIM Kalpakkam, and has organised many national and international conference/symposia of high relevance to advanced materials, coatings and processes under IIM Kalpakkam Chapter.

IIM TATA GOLD MEDAL

The **Tata Gold Medal** for the year 2021 is awarded to **Dr. Debashish Bhattacharjee,** Vice President Technology & New Materials Business, Tata Steel Ltd., Kolkata.

Dr. Debashish Bhattacharjee is a technocrat having more than 35 years of experience working with one of the largest conglomerates in the world. During his current tenure, Dr. Bhattacharjee established technology roadmap for Tata Steel to achieve technology leadership in specific areas and associated capabilities, identifying Seven Technology Leadership Areas (TLAs), including CO2 capture & utilization (CCU), green hydrogen generation, low grade raw materials utilization, future mobility, water, coatings, AI in process control. For monetization of intellectual Venture was created; Innoventure was initiated to engage with start-up ecosystem. Under his supervision, alliances were established for institutional collaboration with academia, Government and industry. Dr. Bhattacharjee's commendable contributions helped in setting up the Tata Steel Industrial Consultancy to monetize knowledge; New Materials Business has grown significantly to 150 Crs in the last three years and Medical Materials and Devices has been added; The Ventures commercialized one IP "yellow gypsum" – a modified version of steelmaking slag; Necessary certification for this has been received for use as soil conditioner, Currently, 500 tons produced and is being test-marketed. His recent accomplishments also include CcU pilot plant being installed at Tata Steel's Jamshedpur and Kalinganagar plants, for the first time in India.

IIM G D BIRLA GOLD MEDAL

The **G D Birla Gold Medal** for the year 2021 is awarded to **Prof. Rahul Mitra**, Professor (HAG) and Head, Department of Metallurgical & Materials Engineering, IIT Kharagpur.

Prof. Rahul Mitra's research has contributed significantly to understanding the structure-property relations of high temperature materials including Mo or Nb-Silicide based multicomponent alloys, ZrB2-based ultra-high temperature ceramic composites, Ni-based superalloys and Cf-SiC composites. A major achievement includes development of Nb-silicide based refractory intermetallic alloys with desirable fracture toughness, high temperature strength and oxidation resistance, for use beyond the limit of Nibased superalloys through alloying. Novel contributions also include pressure-less sintering for near-net shaping, and understanding mechanisms of densification, creep, oxidation and ablation behavior of UHTCs, along with study of oxidation mechanisms of multiphase Mo-Si-B alloys in dry/moist air, and strategies for improving high temperature performance. Furthermore, Al-based composites with refined microstructure and superior mechanical properties have been developed by mushy-state rolling.

Prof. Mitra is presently the Chairman of the IIM Kharagpur Chapter, and Convenor of Swarna Jayanti Endowment Fellowship. Earlier, he has served as member of the Editorial Board of Transactions of IIM. He has so far 180 journal publications, 8 book chapters, and two patents. Furthermore, he has authored a book, "Structural Intermetallics and Intermetallic Matrix Composites" (CRC Press), and edited another with title, "Intermetallic Matrix Composites: Properties and Applications," (Woodhead Publishers - Elsevier).

IIM HINDUSTAN ZINC GOLD MEDAL

The **Hindustan Zinc Gold Medal** for the year 2021 is awarded to **Dr. Vilas Tathavadkar**, Senior Vice President & Function Head Technology (Metals & Mining), Aditya Birla Science & Technology Pvt. Ltd.

As a Head of Metals & Mining Technology Function at Corporate R&D centre of Aditya Birla Group (ABSTC), Dr. Tathavadkar leads the strategic Research & Development programs for Metals & Mining businesses of Aditya Birla Group. Main focus areas are raw material sustainability, reduction in specific energy consumption, new product development & quality improvement, and environment sustainability. Successful development & implementation of technology solutions at various production plants of Hindalco was acknowledged at Aditya Birla Group level. Dr. Tathavadkar was felicitated with the prestigious Innovation Award "Leader in Action - Smart and Sustainable Manufacturing" in the Bizlab-Digital and AI Conclave of Aditya Birla Group, 2021.

IIM TSL NEW MILLENNIUM AWARD

The **IIM TSL New Millennium Award** for the year 2021 is awarded to **Mr. AVRP Dasu**, Associate Vice President (AVP), JSW, Vidyanagar.

The incumbent with his strong Technical, Operational and Managerial Expertise have made significant and outstanding contribution in the growth story of JSW Steel Ltd. His innovative approach, Global understanding of process requirement, excellent statistical and conceptual skills have contributed in Standardisation and Optimisation of Corex technology at JSW Steel and the achievement of high productivity levels in Blast Furnace Iron Making.

IIM MECON AWARD

The **MECON Award for 2021** is awarded to **Mr. Ravindra Sangwai,** Chief, Steel Making & LCP, TATA Steel Kalinganagar.

Amongst Mr. Sangwai's exemplary work it is worth mentioning that, he has reengineered CASOB (Composition Adjustment by Sealed argon bubbling – Oxygen Blowing) operation A Success- Cost Effective Steel Making for range of value-added steel. With his contribution as steelmaking team lead, Tata Steel Kalinganagar has achieved the fastest ramp up in production with rated capacity of 3 Mt in a short span which is new benchmark in the country.

Mr R. Sangwai, is an active member of IIM Kalinganagar Chapter and has contributed immensely towards the development of the chapter. He has organized IIM events of Kalinganagar Chapter for IIM Activities.

IIM NALCO GOLD MEDAL

The **NALCO Gold Medal** for 2021 is awarded to **Mr. Bijay Kumar Das,** Director [Production] & Director [Commercial], Additional Charge, NALCO.

Mr. Das has 36 years of experience working with NALCO in various capacities. Amongst his laudable contributions, the following are worth mentioning :

- Contributed significantly in execution of various projects including diversification & opening of new vista in Renewable Energy Projects (Wind Energy & Solar)
- Conceptualisation & optimal sizing of 4x350MW super critical thermal power plant for brownfield expansion of Nalco.
- Finalisation of 0.6 Million Ton Brownfield Expansion programme at Nalco Smelter with due financial appraisal & DPR.
- Steering addition of Aluminium Alloy Wire Rod Mill of 40000MT/Y to existing Value-added products portfolio of Nalco
- Prepared a long-term goal for Nalco through a Corporate Plan (2017-2032) including improvements in functional efficiency.
- Development and implementation of online automated MIS Dashboard including capital expenditure monitoring system
- Providing strategic inputs for Management and Ministry decisions.

IIM-Angul Chapter from strength of 30 members has grown to Large Chapter with present strength of 308 members from different disciplines. Mr. Das was associated with the Chapter from formative days and associated with many deliberations through Seminars, Technical & non-technical lectures and Conferences over the years.

IIM ESSAR GOLD MEDAL

The **Essar Gold Medal for 2021** is awarded to **Mr. Sokkuraj Kanakanand**, President & Unit Head, Hindalco, Birla Copper.

Mr. Kanakanand has an exceptional contribution of 30+ years in manufacturing with his last 10 years in the field of non-ferrous metal. He is a Production Engineer and spent his earlier years with Hindustan Unilever. He joined the Aditya Birla Group in 2009 and has handled important portfolios like Unit Head-Alumina-Muri, Smelter Head- Mahan, CPP Head- Mahan and currently Unit Heat- Birla Copper. He is known for his technical know-how, meticulously getting into details, great managerial expertise and a focused leader for Quality, Safety and Sustainability.

His achievements and contributions in the field of metallurgy have been exemplary which includes project like Usage of Low Density AlF_3 for cost reduction, Copper Insert Cu Cathode for Energy Reduction, Throughput improvement in Copper Smelter, Redesign of ESP for better heat utilisation, Redesign of Shaft Furnace and anode furnace#5 refractory for better life, coke blending facility at Mahan etc. He is also spearheading the digitization drive for a Smart Birla Copper.

IIM DISTINGUISHED SERVICE AWARD

The **IIM Distinguished Service Award 2021** is awarded to **Mr. Viswanath** MNV, Scientific Officer 'G' (retd.), NFC, Hyderabad. Mr. Viswanath's prolonged and dedicated services to the Institute, and IIM Hyderabad Chapter in particular: initiatives taken in organizing seminars, workshops, and technical lectures, disseminate and update the metallurgical fraternity have been praiseworthy. He served in various capacities, as Secretary, Treasurer and Joint Secretary of the Institute's Chapter, and immensely contributed towards the betterment of the Chapter, in all aspects, since the last 25 years.

CERTIFICATE OF HONOUR

The **2021 'Certificate of Honour'** (introduced in 2008) is presented to **Dr. Chiradeep Ghosh**, Principal Researcher, Tata Steel Ltd. & Secretary, IIM Jamshedpur Chapter, in recognition for his commendable work in overall membership development of the Chapter, interaction with students / colleges, co-ordination with IIM Head Quarters and office bearers.

Dr. Chiradeeep Ghosh graduated from IIEST, Shibpur (Formerly known as B.E. College, Shibpur) in the year 2001 and subsequently obtained his M.Tech from IIT, Kanpur in 2003. Then he joined the R&D Division of Tata Steel, India and worked there for 7 years. In 2010, he went to McGill University, Montreal, Canada for pursuing his Ph.D. degree. In 2013 after completing his Ph.D. he came back and joined the same department of Tata Steel. Till date he has published more than 50 scientific papers in international peer reviewed journals which include Progress in Materials Science, International Materials Review, Metallurgical and Materials Transactions A, Acta Materialia, Scripta Materialia, ISIJ International etc. According to 'Google Scholar' his current h-index is 17. He has also 9 granted patents to his credit. He was the recipient of 'Leon and Suzanne Fattal' Graduate Fellowships in

McGill University for carrying out Ph.D. research. This is awarded annually by the Faculty of Engineering to recruit outstanding students into the faculty's graduate degree programs. He is also the recipient of the '2018 ASM-IIM Visiting Lecturer' from an industrial R&D in India.

CERTIFICATE OF HONOUR

The **IIM Certificate of Honor Award 2021** is awarded to **Mr. Lohitendu Badu,** GM [RCL], MSM & Mills, Durgapur Steel Plant & Secretary, IIM Durgapur Chapter.

An alumnus from NIT Rourkela in Metallurgical Engg in the year 1992 and life member of IIM since 2001, Mr. Badu started his career in research RRL, CSIR at Bhubaneswar and subsequently joined Ispat Alloys Ltd Balasore for hands-on production experience in the ferro alloy industry. In 1993 he joined SAIL DSP at Durgapur unit as Management Trainee (Technical) and worked in sinter making, iron making and raw material handling. He served as technical advisor to Executive Director (works) and gradually moved up the corporate ladder and currently designated as the General Manager overseeing the Quality aspects of the rolling mills areas of Durgapur Steel Plant.

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 2021 it is awarded to **Mr Raineesh Babu** KP, Dept. of Metallurgy Engineering and Materials Science, IIT Indore in recognition of his ME Thesis on "'UNDERSTANDING DEFORMATION BEHAVIOR OF MAGNESIUM UNDER NANOINDENTATION " submitted and defended during the year 2020-21.

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 2020-21 academic session among all Indian Institutes of Technology and Institutes of Technology.

The Vidya Bharathi Prize for the year 2021 is awarded to **Mr. Aneesh Amarendra Namjoshi**, Dept of Metallurgical Engineering, IIT, BHU.

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 2019-2021 academic session among all National Institutes of Technology / Indian Universities / Engineering Colleges.

The IIM Students' Prize for the year 2021 is awarded to

Ms Swathilakshmi
NIT Surathkal

Ms Poojitha Durgamahanti
VNIT Nagpur

Mr Vinayak Gawande
VNIT Nagpur

for jointly securing the highest marks in order of merit in the final B Tech examination during 2020-21 academic session among all National Institutes of Technology / Indian Universities/ Engineering colleges.

Miss Atchutanna Vidyaadhari, VNIT Nagpur

for securing the second highest marks in order of merit in the final B Tech examination during 2020-21 academic session among all National Institutes of Technology / Indian Universities/ Engineering colleges.

Ms Archita Sajjan, NIT Surathkal

for securing the third highest marks in order of merit in the final B Tech examination during 2020-21 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 :

Category	:	**Large Chapters**
Winners	:	**Jamshedpur** & **Kalpakkam**

IIM FELLOWS

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

The 2021 Fellowship is conferred on :

Mr. Sudhansu Pathak, Vice President, Steel Manufacturing, Tata Steel Ltd.

Dr. M Vasudevan, SO/H, Head, Materials Development & Technology Division, IGCAR, Kalpakkam.

Dr. Uday Chakkingal, Professor [HAG], IIT Madras.

Dr. G Appa Rao, Scientist 'G', DMRL, Hyderabad.

Dr. Raghavendra Bhat, Addl. General Manager (Lab & Qr), Central Mat & Proc Lab., Foundry & Forge Divn. Hindustan Aeronautics Ltd.


STEEL FACTS
The industry is working together on many initiatives to develop breakthrough steelmaking technologies that could reduce CO_2 emissions by more than
50%
potentially revolutionising the way steel is made.
worldsteel.org