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GD Birla Gold Medal Lecture

Research and Development in Materials for Indian Space Programs (1st part)

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Trivandrum - 695 547

Abstract

It is often said that, the success in new materials development is directly related to advancements made in aerospace science and technology. In view of the complexity involved with large number of processing variables, products shapes and sizes, there could be certain deviations in materials from the specifications that need to be probed and understood before their actual application. In this article (which is based on the IIM's GD Birla Memorial Lecture – 2022 that the author had delivered at the ATM-2022, Hyderabad) a few and select major contributions made by the author are given in gist with adequate examples of deviations in processing, fabrication, storage that resulted in failures are described initially to highlight the importance of materials processing. Further a few more interesting developments in new materials as well as case studies on testing and characterization for qualifying flight hardware/new processes for the Indian Space Programme are elucidated and they include: (i) Premium melt practices (such as vacuum induction melting, vacuum arc re-melting, electro slag refining, electron beam melting, often through double or triple melt practices) for strict control of impurities and gas contents; (ii) Optimised thermo-mechanical processing and heat treatment schedules to produce defect-free materials; and, (iii) Monitoring of the process with end-to-end traceability, detailed material testing and characterisation, extensive non-destructive testing and qualification, careful handling and storage – all in the cases of many a materials that have now become integral to many Indian aerospace systems.

1. Introduction

Understanding the effects of strain, strain rate and temperature on the flow behaviour of materials, obtaining defect-free products with desired microstructures and mechanical properties meeting the quality control norms is the essence of aerospace materials research and production activities. Unlimited opportunities and practical exposure to the fundamental problems are encountered normally during materials processing, hardware fabrication, testing, qualification, storage and service. Further, probing the material behavior in depth provides solutions to several materials related issues and such an effort adds significant value for the materials development to systems engineering. The author's own research at Liquid Propulsion Systems Centre, ISRO, Trivandrum provided several new, performance critical, exotic material solutions for liquid, cryogenic and semi-cryogenic engines. This special article provides some of these exciting results obtained from several studies conducted as a part of aerospace materials development program in Indian Space Research Organization [1-60]. While this article provides the gist of these studies, another one that would appear in the subsequent issues of Metal News provides many more intricate details.

2. Aerospace materials and how they are a different class

As space systems are airborne, for every kilogram of weight saved in dry mass, i.e. structural mass of launch vehicle, there will be an advantage of an increase in payload (satellite or cargo in the case of a rocket and passenger or cargo in the case of an aircraft), albeit in different ratios for different stages. The lower stage structures of a launch vehicle, for example offer lesser returns whereas in upper stage structures, every kilogram of weight saved results in an equivalent payload gain. Therefore, there is

a sustained interest in developing high specific strength (ratio of strength to density of the material) materials that can cater to this segment. However, the materials choice is limited to high strength steels, Ti, Al and Mg alloys as these materials have higher strengths and lower densities among the structural materials. Further, many of the structural aerospace alloys are used in their peak aged temper conditions to obtain maximum strength potential of the alloy, provided adequate damage tolerance properties are met. It may be noted that high strength steels (>1250 MPa) are prone for embrittlement and high strength aluminum alloys in their peak aged temper (T6) have problems related to stress corrosion cracking. All the three requirements are important to avoid catastrophic failures in materials systems.

Fig. 1 shows the progress in Indian satellite launch vehicle development program during the past five decades. As can be seen from this figure, the technology demonstrators SLV-3 and ASLV used predominantly carbon steels for external structures. With the introduction of PSLV, high strength Aluminum alloys were introduced for the earth storable propellant tanks and titanium alloys for upper stage propellant tanks and high pressure gas bottles. GSLV MkII and MkIII (LVM3) use aluminum alloy AA2219 for both earth storable and cryogenic propellant tanks. This clearly indicates progressive improvements in the successful usage of advanced materials over the years [1].

Further, the space missions are expensive and time taking and therefore reliability is the key. This critical requirement of enhanced reliability has resulted in the development of a number of international aerospace quality standards such as AMS, ASTM, MIL against which the materials are processed and qualified. Many materials are monitored from cradle to grave, which means that they are protected right from the cast house to the launch pad and during the launch. Another important point to note that in space systems there is no possibility of ground testing of pyro devices, igniters and initiators etc., that account for about 70% components of the fabricated systems, improved reliability is ensured by special design and testing methodologies. Hence, most of the structural hardware after fabrication goes for extensive testing at component stages.

Fig. 1: Progress in ISRO's satellite launch vehicle development program during the past five decades. Both SLV-3 and ASLV used predominantly steels for their construction and are based on solid propellants. PSLV second stage and GSLV, both Mk-II and Mk-III versions extensively use Aluminum alloys for earth-storable and cryogenic propellant tanks. The far right picture shows the GSLV MkIII (LVM3) with Gaganyaan configuration. The complexity of materials technologies increases from left to right.

3. Materials Selection for Aerospace Systems :

Usually structural designers choose the materials based on stress analysis and other performance requirements/operating conditions. Strength is an important parameter for design, but stiffness of the structure should ensure that it will not buckle under the loading conditions. Once the material is finalized, the onus lies with the metallurgists to produce and supply the materials to the required specifications, desired melt practices, chemical composition (including the control of impurities such as inclusions and gas content), thermo-mechanical processing, heat treatment schedules, mechanical properties and most importantly, the microstructural requirements (such as inclusion rating, grain size, phase fraction and their distribution), Non-destructive test requirements for the acceptance of materials before they are certified for usage; the sequence and processing steps to obtain the products meeting all the requirements as per the specification; producing materials in a manufacturing environment that provides economically adequate yield; study and suggest deviations from the specifications, wherever required, based on the impact of deviations on the performance of the product under operating conditions – all of these need to be studied and understood before their acceptance for flight usage. The following section provides some critical examples of materials related issues which resulted in failures to highlight the importance of metallurgical processing, their usage and storage.

4. Practical issues in materials processing

4.1. Metallurgical Processing

Fig. 2 presents the photograph of large diameter as-cast ingot of Ti-6Al-4V and macrostructures of maraging steel and nickel based superalloy In- 718. The highly heterogeneous, as-cast microstructure needs to be converted to a homogeneous, near isotropic, defect-free wrought material with balanced strength-ductility- toughness amenable for performance critical, damage-tolerant, engineering applications. For this to achieve, they need to be processed to the required reduction ratios with well optimised process parameters in the sequence of operations that will avoid any alignment of second phases to achieve bi-directional properties as per the desired specifications. The following sub-sections highlight practical case studies on materials limiting the performance of products, when used in service and how to overcome the shortcomings noticed. Such an understanding on the relationship between microstructure and product performance will help in improved processing schedules and to obtain materials with desired characteristics.

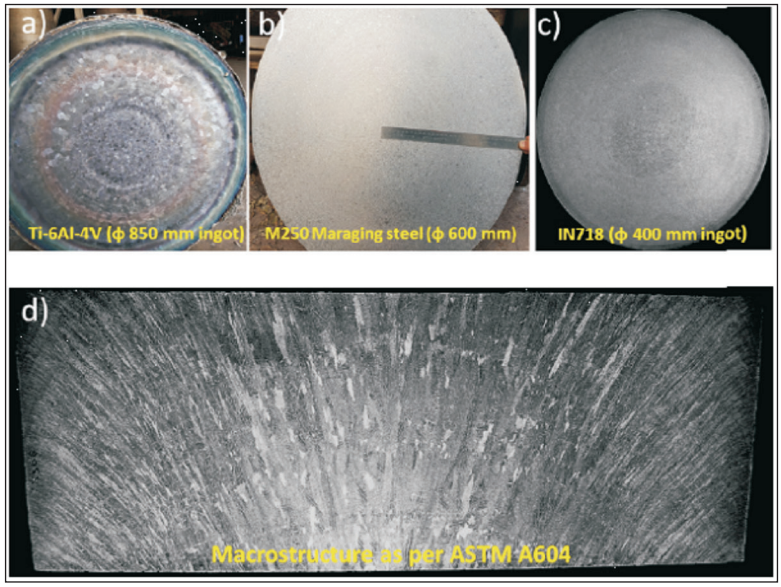

Fig. 2 : Photograph of (a) as-cast ingots of Ti-6Al-4V (Dia. 850 mm), and macrostructures of (b) Dia. 600 mm M250 grade maraging steel and (c) Dia. 400 mm Inconel alloy In-718 and (d) showing highly inhomogeneous structure of In-718.

4.2. Carbide banding in AISI-440C :

Wrought components show improved mechanical properties under both static and dynamic conditions against their cast counterparts. This is basically attributed to the homogeneous and fine microstructure introduced by the thermo-mechanical processing. However, thermo-mechanical processing also leads to anisotropy in mechanical properties especially when the microstructural heterogeneities (second phase and inclusions) are not randomly distributed and get oriented preferentially. This usually occurs due to the nature of the thermo-mechanical processing adopted to fabricate the products. The microstructural heterogeneities can be both metallic (such as delta ferrite stringers in steels) and non-metallic (such as MnS inclusions in steel) in nature. Physical orientation of grains and the crystallographic orientation due to thermo-mechanical processing also add to the woes of heterogeneities in these materials. Figure-3 presents a case study [2] on the failure of AISI- 440C ball screws due to the highly oriented chromium carbides along the direction of thermo-mechanical processing that resulted in banding. The aligned carbides under the application of load resulted in cracks in the ball screws fabricated. It was suggested to have a multi-directional deformation to break the coarse carbides and distribute them uniformly in the matrix.

4.3. Inclusions in AISI304L Tubes :

Inclusions are unwanted, but are unavoidable as metallic materials are melted in crucibles with refractory lining. As the crucibles are used, they get eroded and the particles of refractory lining get in to the melt. During subsequent re-melting operations such as electro slag refining, some of them can get removed, but few of them will still be present. These get broken, dispersed and get aligned along the direction of rolling. There are specifications for various types of inclusions as per ASTM E8 and are stringently controlled. However, when materials with non-metallic inclusions are subjected to large plastic deformation, such as wire drawing and are used for applications such as springs (which are subjected to dynamic loading), failures can occur in these components due to the propagation of cracks from the incoherent interface between inclusion and matrix. Similarly, when these materials are subjected to secondary fabrication processes such as cold swaging or high strain rate deformation, failures can occur due to the propagation of cracks along the interface of the second phase with the matrix.

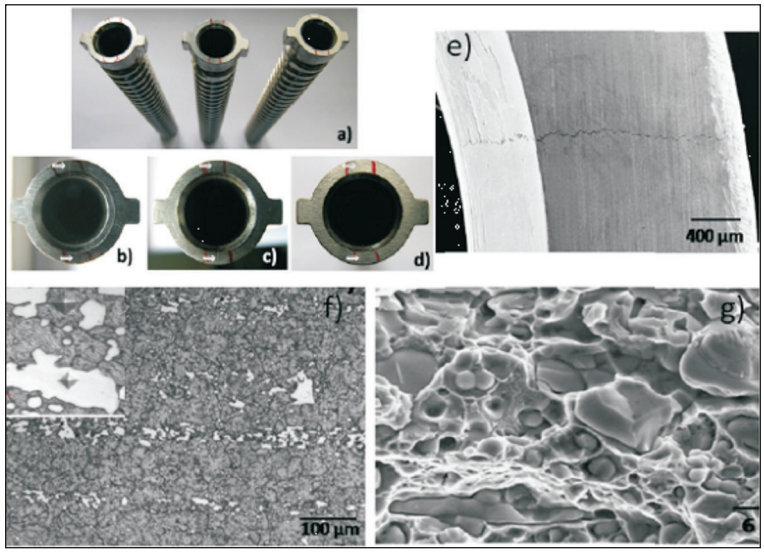

Fig. 3 : Failure of AISI-440C ball screws (a) global picture with red markings on ball screws showing the location of failure, (b-d) close up view of the cracks on opposite sides shown with white arrows (e) higher magnification photograph of the crack noticed, (f) aligned chromium carbide particles along the working direction with an inset showing the microhardness indents on carbides and matrix and (g) fracture surface of the failed ball screw showing coarse oriented carbides [2].

Here is an example on the effect of inclusions in a AISI 304L stainless steel tubes with Ø6 and Ø4 mm used in pressurization system module of a liquid engine of a satellite launch vehicle were found to crack after the qualification level random vibration test [3]. The failed tubes were subjected to detailed metallurgical analysis to understand the reasons for failure. The location of failure in both tubes was at the cross-section change area in the nipple (Figure-4). The presence of sharp-cornered inclusions in the material helped easy crack initiation. Smaller radius and angle at the weld-parent interface resulted in additional stress concentration. The presence of striations on the fracture surface and slip bands near to the fracture edge confirm that the failure of tubes to be due to vibration induced fatigue.

4.4. Delta Ferrite Stringers in 17-4PH Stainless Steel:

Precipitation hardenable stainless steels are widely used in aerospace applications because of their excellent combination of superior strength and corrosion resistance. In view of this advantage, Fe-17Cr-4Ni (17-4 PH) stainless steel is used in pyro bolts in space ordnance systems for stage separation in a satellite launch vehicle [4]. These systems typically consist of a pyro-charge to sever a given material resulting in stage separation, and these materials are exposed to high strain rates. In one such application, although perfect severance took place, secondary cracks were noticed longitudinally, which are not desirable. This steel, in view of its composition, has delta ferrite in a martensitic matrix in the hardened and tempered condition. In wrought products worked unidirectionally, delta ferrite gets oriented along the direction of thermo mechanical processing. The effect of delta ferrite orientation on the impact properties of 17-4 PH stainless steel was studied in various heat- treatment conditions with a view to understand the effect of microstructure on impact properties (Figure-5). It was found that the transverse impact properties are severely affected by the presence of highly oriented delta ferrite stringers for any given heat-treatment condition. This has been attributed to the weak delta ferrite-martensite interface, which facilitates easy crack propagation. Finally, it was suggested that the anisotropy in impact properties need to be carefully considered in the design of components for applications that involve high strain rates during service.

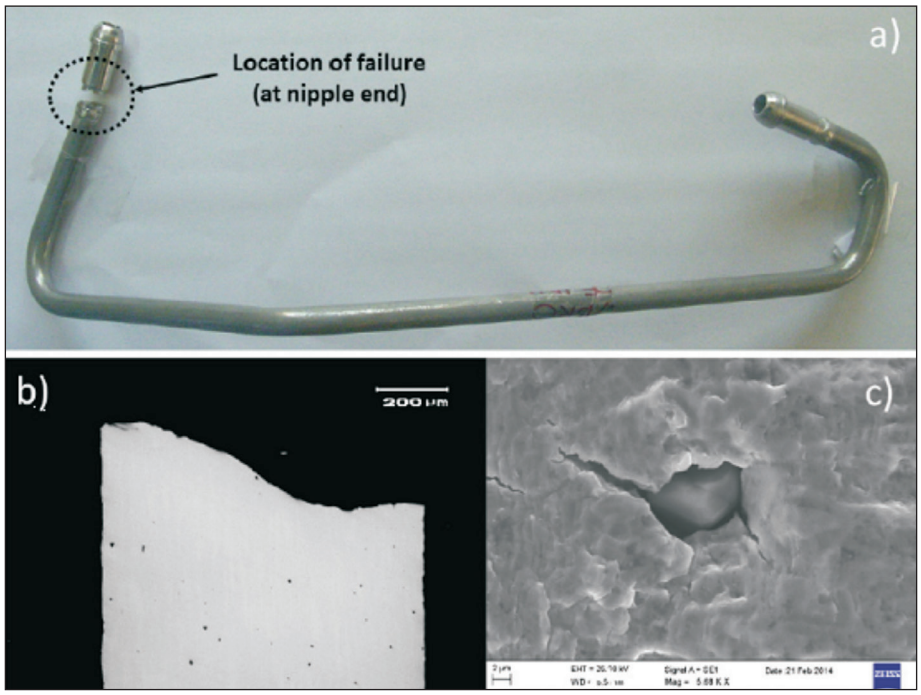

Fig. 4 : (a) Failure of a weld joint at the nipple end where it is welded to a tube containing large number of sharp cornered inclusions (b) and an inclusion with an incoherent interface leading to the formation of microcracks [3].

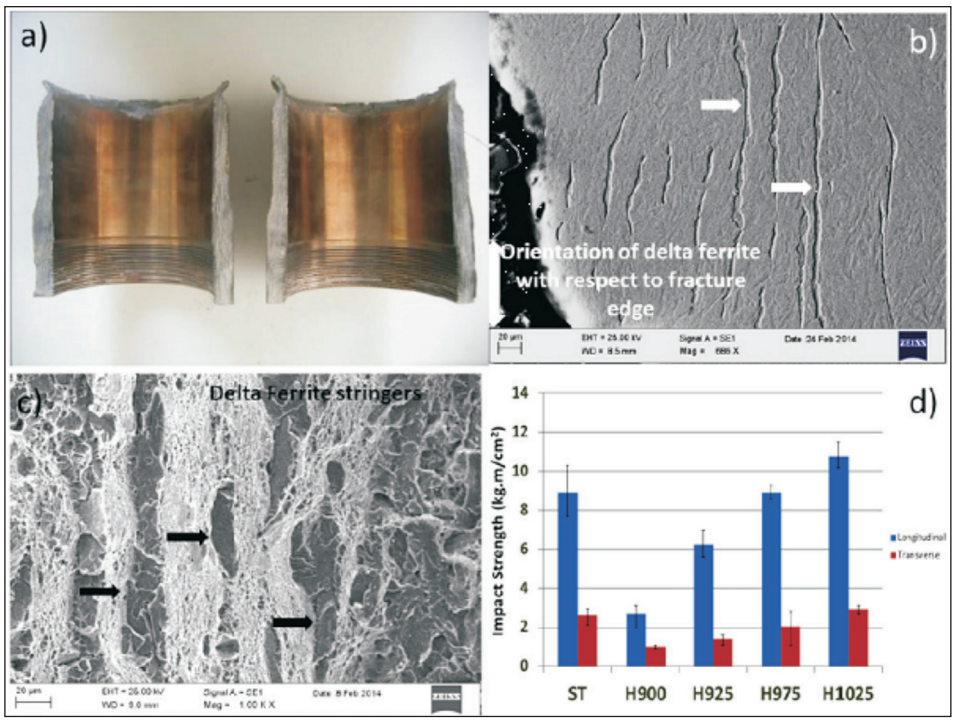

Fig. 5 : Pyro bolt used for separation system made of 17-4 PH steel (a) with two vertical halves instead of a clean flat separation, (b) stringers of delta ferrite oriented along the bar rolling direction, (c) fractographic analysis of the fracture surface showing ductile dimples at the location of martensitic matrix and clean flat features at the delta ferrite regions and (d) impact strength of the material in longitudinal and transverse directions in different heat treatment conditions [4].

4.5. Embrittlement in Ti-5Al-2.5Sn-ELI :

Thermo mechanical processing of titanium alloys is very challenging. An example of embrittlement of Ti-5Al-2.5Sn-ELI alloy that has resulted in a catastrophic failure during proof pressure testing at cryogenic temperature (77K) is presented in Fig. 6 [5]. The optical microstructures, inverse pole figures and the fractographs of the failed domes reveal significant differences among the two welded domes. While one dome exhibited an equiaxed grain structure that resulted in a ductile fracture, the other half of the electron beam welded dome revealed lamellar microstructure with micro-cracks that resulted in brittle cleavage failure. The failure was attributed to higher hydrogen content (specification for hydrogen content <125 ppm) present in the material that was picked up during the thermo-mechanical processing stage, than permissible for a product to be used at the lower operating temperature. A vacuum annealing step introduced subsequently to limit the hydrogen content was proved to be successful in mitigating the problem.

Apart from the aforementioned, the author had made several major contributions on (A). Deformation processing and developed a simple, but extremely effective instability criterion [6-30]; (B). Development and characterization of 3rd Generation Al-Cu-Li alloys [31-39]; (C). Development of Copper alloys for thrust chambers [40-50]; (D). Development of Boron added titanium alloys [51-53]; (E). Mechanical properties of Aerospace materials at low temperatures [54-60] – Salient findings from all these studies will be discussed separately in a different article that would appear in one of the future issues of this journal.

5. Technological Implications & Remarks: A Few Closing Thoughts

Performance of structural materials is governed by a large number of factors that include strength, toughness and susceptibility to environmental factors. These parameters are considered during the design stage of a component or a structure. Designers choose materials that meet the mechanical property

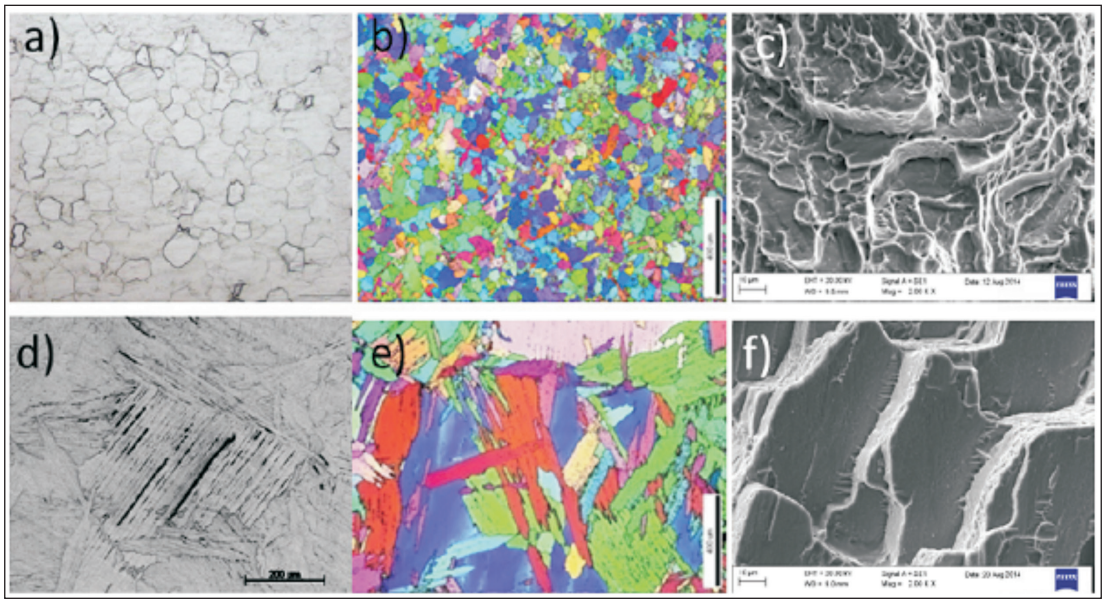

Fig. 6 : Photographs of catastrophically failed Ti-5Al-2.5Sn gas bottle showing separation of top and bottom domes in to near equal halves. The optical microstructures (a,d), inverse pole figures (b,e) and the fractographs (c,f) of the failed domes reveal significant differences among the two welded domes. While one dome has an equiaxed grain structure that resulted in a ductile fracture, the other half of the electron beam welded dome has lamellar microstructure with micro-cracks that results in brittle cleavage failure [5].

requirements for the intended applications. The specifications of the materials for the intended applications are finalized based on the nature of application whether conventional or strategic. The strategic areas include aerospace, nuclear and defense applications. While specifications for conventional applications are regular in nature, materials for strategic applications demand certain additional requirements with respect to quality, reliability and testing. This is to ensure their satisfactory performance under extreme conditions at which materials are expected to function. Specifications of materials for strategic applications include ASTM, AMS, and MIL. These specifications are for the acceptance of materials and they do not suggest how further secondary processing of these materials is to be carried out or on how to use the materials for a given application. The process designers have to select suitable raw material for the fabrication of components/structures based on test data or experience. Improper selection of raw materials which undergo extensive secondary working/forming operation or materials that are subjected to fatigue/high strain rate loading need to be selected carefully. Specific attention should be paid to the microstructural cleanliness of the material (inclusion content) and second phase that has an incoherent interface. Satisfactory functioning of a material under static loading conditions does not assure reliable performance under dynamic loading conditions, if the material is not microstructurally clean.

The challenges posed by the aerospace structural engineers to develop materials that can successfully perform under highly stressed conditions in extremely hostile environments prompted metallurgists to develop technologies to produce materials meeting all desired specifications, against a given standard. The inherent requirements of materials for aerospace applications are high specific strength and specific stiffness, easy fabricability with simple heat treatment, high reliability, with low lead times for realization. In order to meet these requirements, high strength steels, age hardenable aluminum alloys, titanium alloys and magnesium alloys are used extensively, mostly in their peak aged tempers, wherever applicable. However, these materials should be handled carefully as they could pose several challenges during service under hostile environments.

While it might look simple to process the materials, meeting the specified quality on a repeatable basis, in a manufacturing environment with high yield, in practice it is a challenge, as there are many variables affecting the product quality. Occasionally, during the development of new products forms or during process changes, there can be deviations from the specifications. Care must be taken to assess the location and orientation of the component fabricated out of the semi-finished product for realistic analysis with respect to desired properties, quality and suitability assessment. Residual stresses as a result of extensive machining or other processes should be studied and their role, well understood. The effects of any deviations on the performance of the parts need to be studied and understood thoroughly before their acceptance. Optimization of process parameters at each and every stage of processing and their strict control during production can only ensure quality and repeatability of properties.

New materials development and their introduction in to space systems is a long lead time activity. Most of the high volume grades used in aerospace were developed more than five or six decades back, for example aluminum alloys AA2014, AA2219, AA6061, AA7075, titanium alloys Ti-5Al-2.5Sn-ELI, Ti-6Al-4V, Maraging steels, Stainless steels AISI304, AISI316, AISI321, magnesium alloy AZ31B, AZ91 and their applications are proven, heritage established and extensive database generated over a long time is available. For critical applications, It is not unusual to have a desired chemical composition range narrower than specified standard and tolerable gas contents lower than permitted as per standards and these are usually not shared. Therefore, improvements in existing processes and development of new materials for superior performance need to be pursued wherever benefits are attractive for their introduction in space systems. Newer disruptive processing technologies are emerging and will have interest from niche segments for realizing parts with small footprint at low lead times and comparable costs. Failures at developmental stages provide an opportunity to understand the material behavior under operating conditions and detailed analysis should be carried out to avoid their recurrence. A good database of the effect of process variables on the properties, deviations and their effect on part performance will enable to establish the marginalities, within which the part performance is ensured. Finally, the following conclusions are felt pertinent and appropriate for the contents of this special article:

1. Materials are the backbone of any engineering structure and aerospace material technologies are therefore closely guarded, in view of their dual use. Materials play a key role in the performance and success of aerospace missions.
2. Aerospace systems are characterized by controlled mass, limited volume and high reliability. Limits on materials behavior are among the greatest technical obstacles to designers in improving the safety and reliability of aerospace systems.
3. Identifying and selecting materials that not only survive but also perform under extreme operating conditions is a major challenge in space materials research.
4. When subjected to extremely hostile environments, materials can behave in unexpected, unpredictable manner and therefore a fundamental understanding of the materials' response under extreme conditions of heat flux, stresses, strain rates, and corrosive environments is essential. In view of these complexities, aerospace materials are produced under strict process control to meet stringent quality control norms as per well-established standards/specifications.

Special Note of Gratitude and Acknowledgements :

It is sincerely believed that the details shared in this lecture are interesting, thought provoking and motivate young metallurgists to take research as their profession and tackle the challenges posed to them. I sincerely thank the IIM for awarding me the GD Birla Gold Medal – 2022 and more importantly to share my experiences with numerous Metallurgical and Materials luminaries of our country who were present at Hyderabad and also, the one that would go through this special article. Now let me express my profound thanks by acknowledging help and encouragement that I received from the following mentors and close associates: I was fortunate to have worked under the supervision of Prof. Y.V.R.K.

Prasad (IISc) for my masters, Dr. B. Nageswara Rao (VSSC) and Prof. B.P.Kashyap (IITB) for my Ph.D. and Prof. Shiro Torizuka (NIMS, Japan) for my post-doctoral work and I sincerely thank them for initiating and motivating me to work in this fascinating area of deformation processing of materials. The present lecture is based on the results of extensive work conducted in understanding the behavior of materials under operating conditions at Materials and Metallurgy Group, Vikram Sarabhai Space Centre. I wish to place on record the support received from Dr. T.S. Lakshmanan, Dr. K.V. Nagarajan, Shri. M.C. Mittal, Shri. K. Sreekumar, Dr. S.C. Sharma, Dr. Bhanu Pant and Dr. P. Ramesh Narayanan of Materials and Metallurgy Group at VSSC. Much of the research presented here has been from the results obtained from my doctoral students and I wish to acknowledge the contributions of Drs. A.K. Shukla, Niraj Nayan and V. Anilkumar. Besides these, I owe special thanks to all my friends and colleagues in Materials and Metallurgy Group of VSSC and Materials Development and Production Group at LPSC, who have lent invaluable support for the multifarious contributions in my chosen area of work. I am indebted to Chairman, ISRO and Director, Liquid Propulsion Systems Centre, for their support and encouragement.

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Special Article Women in Mining (WIM) India

Mining currently contributes to ~2% of the GDP of India and is a critical sector to achieve the vision for USD 5 Trillion economy and also the net zero target by 2070. Being the world's second-largest coal producer, second largest steel producer-consumer & home to the second largest integrated Zinc producer, India has a prominent place on the global mining map. However, India is still far behind the global estimates of 10% representation of women in her mining workforce.

Women from the Indian mining fraternity have come together and established **Women in Mining** (WIM) India - an industry body run by young women professionals under the mentorship of some senior industry veterans. WIM India joins together to partner and support global WIM groups, collaborating closely with WIM UK during its establishment phase. This gives WIM India access to a strong and active global network of 500 + inspirational women in mining.

The major objective of the organization is to actively participate as an industry body to promote employment, retention, participation, mentorship, and upward mobility of women associated with the entire value chain of the Indian mining Industry.

WIM India's vision is to see Indian women leading change and creating a meaningful impact in the value of mining and associated industries. According to the findings of a study by Catalyst, companies with female board representation also have higher return on sales and equity.

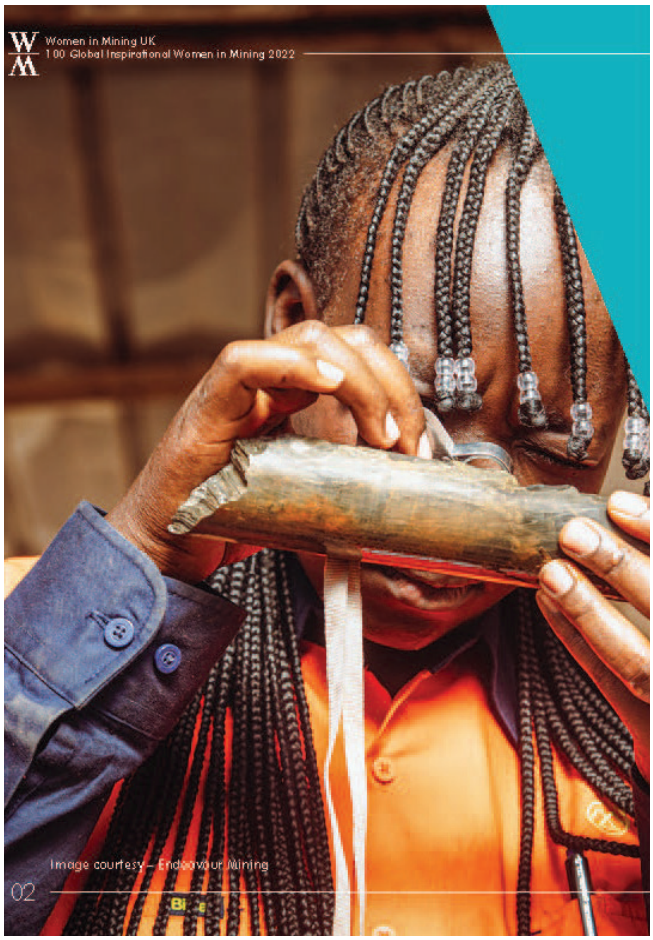
However, drop-off from entry level to the executive level for females in mining industry is among the most dramatic (highest) across industries. The organization intends to address these issues by a three-pronged approach: **networking, mentorship & participation.**

With these objectives in mind, WIM India now plans to partner with leading mining and related companies, universities, associations, and the concerned industry to establish and provide an ecosystem for capability-building and opportunities for women to make a promising career.

The Mining sector in India has been witnessing a fast-paced transformation in areas like sustainability, digitization, application of cutting-edge technology etc. As an Industry body, the organization also aims to bring in thought-leadership in fields like digitization and sustainability, leading a positive change towards responsible and sustainable mining and making the mining sector future-ready.

With the launch of Women in Mining India, the WIM network also celebrates the release of the 2022 edition of Women in Mining UK's publication: "100 Global Inspirational Women in Mining" (WIM100), with special congratulations to the nominee in

India: Ruchika Jha, Founder, Arkya Consulting and co-founder of Women in Mining, India.



The WIM100 highlights the wealth of female talent within the global mining industry, celebrates their 'above & beyond' contributions to the industry, and identifies role models for future generations. WIM UK received 915 nominations for 491 women from 61 countries, out of which a total of 100 nominees were finally selected.

Ruchika Jha, Founder, Arkya Consulting said, *"I am thankful to WIM UK for this recognition. I am especially thankful to Vedanta's leadership and my mentors for supporting me all the way in my career lifecycle from a management trainee to Group CMO & CEO – Silver in a span of 16.5 years. The news also comes just at the time when we are laying the building blocks of Women in Mining India together with other fellow passionate women leaders including A. Sumathi – a WIM 100, 2020 alumnus. We hope to see many more Indian women leading change and making a meaningful impact to the mining industry at large."*

Dr. Stacy Hope, Managing Director at Women in Mining UK, said, *"Congratulations to India's WIM100. She is being celebrated because of her commitment to making mining a stronger, safer and more sustainable industry for everyone. We are incredibly inspired by her actions and look forward to following how her initiatives develop and grow."*

The 2022 edition of the WIM100 can be downloaded from this link Women in Mining UK website.

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Report Launching of CorSciTech Distinguished Lecture

Conservation of resources and the environment whilst meeting the growing needs of the modern society drives technology development. This pushes the use of materials to their threshold limit and at times beyond their ability to sustain hostile operating conditions. The impact of corrosion (typically 3.5 % GDP of a nation) is not only limited to the cost of material loss but also imposes unaccountable indirect costs through the loss of life and downtime. There is therefore increasing relevance of corrosion research and development, and education to meet the stringent demands of developing safe, sustainable, and cost-effective materials and technologies. In India, such activities are pursued by leading academic institutions and public and industrial research laboratories. CorSciTech, established under the aegis of The Indian Institute of Metals, Mumbai Chapter endeavours to bring in academia and industries with the mission to sensitize, educate and empower the stakeholders to manage and mitigate the corrosion issues.

'CorSciTech', organised its first distinguished lecture on April 30, 2022 through hybrid mode. The venue was the Seminar Hall, Dept. of Metallurgical Engineering and Materials Science, Indian Institute of Technology Bombay, Mumbai. Dr. U. Kamachi Mudali, Vice Chancellor of VIT Bhopal University and former President of The Indian Institute of Metals, was the speaker. Prof. N. N. Viswanathan, Department of Metallurgical Engineering and Materials Science, Indian Institute of Technology Bombay, Mumbai graced the occasion as the Chief Guest.

The chief guest, Prof. N. N. Viswanathan, addressing the audience

Prof. V.S. Raja, Chairman of CorSciTech welcomed the attendees and gave a brief overview of the activities of CorSciTech. Prof. Raja stated that CorSciTech was founded to bring together academia and industries with the mission to sensitize, educate and empower the stakeholder to manage and mitigate corrosion issues: the vision and mission of CorSciTech is given below. The CorSciTech Distinguished Lecture is held to commemorate the World Corrosion Awareness day. He subsequently introduced the Chief Guest Prof. N. N. Viswanathan and invited him to address the audience and launch CorSciTech. Prof. Viswanathan formally launched CorSciTech. In his address, he emphasised the importance of understanding

CorSciTech members along with the speaker and the Chief Guest
From left to right: Kamlesh Chandra (BARC, Mumbai), Prof. V.S. Raja (IITB, Mumbai), Dr. U. Kamachi Mudali (Speaker), Dr. S. Roychowdhury (BARC, Mumbai), Prof. N. N. Viswanathan (Chief guest) and Prof. S. Parida (IITB, Mumbai).

and learning corrosion and pointed out that IIT Bombay is the only institute in the country offering a Master's degree in Corrosion Science. He mentioned that joining Bhabha Atomic Research Centre, where high quality Cor rosion Research is being carried out adds immense value to the mission of CorSciTech.

The speaker, Dr. U. Kamachi Mudali, delivering the lecture

Dr. Supratik Roychowdhury introduced the distinguished speaker Dr. U. Kamachi Mudali. Dr. Mudali then delivered the distinguished lecture titled 'Corrosion and Sustainable Development'. In the presentation, he covered the basic concepts and types of corrosion along with the methods for mitigation and prevention, especially in industries. He discussed a broad notion of corrosion management for sustained development of the country. Dr. Mudali also spoke on the significance of steel in our daily lives and the importance of recycling for long-term growth of the country. It was a proud moment to learn that India has become the 2nd largest steel producer in the world since 2018. It was noteworthy to know that the steel sector is working hard to replace 20-30% of coal with hydrogen, with the goal of lowering energy usage and CO_2 emissions. The presentation concluded with a detailed discussion on E-waste and the need of recycling it. The recycling is required not only to recover precious and rare earth metals, but also for its safe handling, as the E-wastes contain some hazardous elements. Dr. Mudali highlighted that the country can reduce its material demand in a sustainable way by recycling E-waste. Following this, he answered the questions asked by participants, both online and offline.

The lecture was attended by 42 people at the venue and 15 participants in the online mode. The talk was also live streamed on YouTube, with more than 110 views in a week's time. Prof. Smrutiranjan Parida of IIT Bombay gave the Vote of thanks at the end.

Vision and Mission

CorSciTech will carry out, and not be limited to the following activities:-

1. Institute awards/distinguished lectures to create and promote awareness on corrosion and its management.
2. Provide financial assistance to research scholars in the field of corrosion to galvanize their growth and aspirations.
3. Organize workshops and conferences to kindle interest, train and advance corrosion education.
4. Collaborate with professional societies in the country.

CorSciTech is currently administered by the following committee

Chair	:	Prof. V. S. Raja, IIT Bombay
Vice Chair	:	Dr. Supratik Roychowdhury, BARC
Secretary	:	Prof. Smrutiranjan Parida, IIT Bombay
Member	:	Prof. Vijayshankar Dandapani, IIT Bombay
Member	:	Dr. Kamlesh Chandra, BARC
Member	:	Dr. Kartikey K. Yadav, BARC

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- A Report by Kamlesh Chandra, (BARC) Member, CorSciTech

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Seminars & Conferences

International Conference on Corrosion and Coating (i3C)

The two days International Conference on Corrosion and Coating (i3C) was inaugurated by Dr. Debashish Bhattacharjee, Vice President, Technology and New Materials Business, TATA Steel Ltd, at CSIR - NML Auditorium, Burmamines, Jamshedpur. The conference has been organised by the Indian Institute of Metals (IIM) Jamshedpur Chapter in association with Tata Steel Ltd, CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur, and NIT Jamshedpur, on December 7-8, 2022 at CSIR-NML premise. The themes of the conference focus primarily on latest cutting-edge technologies and advances in hot dip, physical, aqueous & non-aqueous coatings processes for corrosion resistance enhancement.

During inauguration of the conference, Dr. Arvind Sinha, Chief Scientist CSIR-NML gave the welcome address on behalf of the director of NML. He heartily greeted all the participants of this international conference. Afterwards, Dr. A.N. Bhagat, Head of the Surface Engineering Research Group, Tata Steel and Chairperson of the IIM Jamshedpur gave the details of the different activities of the local IIM Chapter. He emphasised the fact that this chapter of IIM is one of largest and most active chapters of the country. Throughout the year the chapter conducts various programs to propagate the importance of material science and metallurgy. Immediately after his deliberation, Dr. Siddhartha Misra, Chief of Product Research, Tata Steel and Chairman of i3C talked about the importance of this particular international conference. Later on, he also introduced the Chief Guest of this conference, Dr. Debashish Bhattacharjee, Vice President, Technology and New Materials Business, Tata Steel Ltd. In his address, the Chief Guest talked about the various facets of corrosion and coatings in our daily life. Nowadays, different aspects of coating such as aesthetic, dust resistivity, self-healing etc. are also being explored. He also emphasised the fact that coating is definitely one of the solutions to prevent corrosion of any engineering material, such as steel. However, we must look into the other solutions in terms of changing the base material from steel to some other ceramic based material which are inherently not prone to corrosion. The conference souvenir was released during the inaugural program. Finally, Dr. Raghuvir Singh, Chief Scientist and Group Leader Corrosion Engineering, CSIR-NML gave the vote of thanks to all the participants present in this conference.

The Chief Guest of the conference Dr. Debashish Bhattacharjee addressing to the audience

The inaugural session was followed by two plenary lectures which was chaired by Dr. Soumitra Tarafder, Ex-Chief Scientist, CSIR-NML. The first lecture was given by Dr. Frank Goodwin of International Zinc Association, USA in an online mode. He talked about the various advancement in hot-dip coatings over the years, which is still be one of most industrially important methods for coating. The second lecture was delivered by Dr. Indranil Chattoraj, Ex-Director CSIR-NML. His topic was hydrogen in metals and alloys. Since in the coming days the hydrogen economy will be of paramount importance, he touched upon many aspects of interaction of hydrogen with base metal. At the end of his lecture, Dr. Chattoraj was felicitated by the organisers for his exemplary service and contributions to Corrosion Science and Technology, which happens to be the theme of the present conference. Afterwards, the poster session was inaugurated by Mr. Chaitanya Bhanu, Vice President Steel Manufacturing, Tata Steel and technical sessions were started.

The inaugural program was attended by several executive members of the IIM Jamshedpur Chapter and senior dignitaries from Tata Steel, CSIR NML and NIT Jamshedpur. Around 250 participants representing several leading global organisations, the conference is promised to provide an exclusive technical platform to discuss, deliberate, exchange and explore critical areas on Corrosion and Coatings and assist the stakeholders. Some of the other notable speakers of this conference are Professor J McDermid (McMaster University, Canada), Dr K D'souza (International Zinc Association, Canada), Professor Kallol Mandal (IIT Kanpur), Dr. Siva Bohm (Imperial College London), Dr Kannan Chandrasekaran (IOCL, Haryana), Professor Ivan Cole (RMIT University, Australia), Dr. Kamachi Mudali (VIT Bhopal), Dr. Subasri (ARCI Hyderabad), Professor N Birbilis (Deakin University, Australia), Dr Hans Van-der-Weijde (Tata Steel, the Netherlands), Professor Sumantra Mandal (IIT Kharagpur), Professor Anup Keshri (IIT Patna) and Professor Christopher Taylor (Ohio State University, USA).

The conference is supported by many industrial partners namely Tata Steel Ltd., JSW Steel Ltd., Grauer & Weil Ltd., Tenova, Pesmel, The Tinplate Company of India Limited, Tata BlueScope Steel Pvt. Ltd., Henkel Adhesives Technologies India Pvt. Ltd., ZwickRoell Pvt. Ltd., Visioncraft Industries (India) Pvt. Ltd., DuPont (DuPont Speciality Products (India) Private Limited), and Chemcoaters.

The audience

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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.

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•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.

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Shyam Metalics enters stainless steel business with Mittal Corp buyout

Indian metal producer Shyam Metalics seeks to conclude its acquisition of Mittal Corp to strengthen its metal portfolio by entering the stainless steel/ wire rod & bar mill business.

"This inorganic growth will witness the establishment of manufacturing footprints in the state of Madhya Pradesh and add capacities of 1,50,000 tpa Stainless Steel (SS) / Wire Rod & Bar Mill," the company said in a statement.

To meet SEBI's norms, the promoters need to dilute their current holding of 88% in Shyam Metalics by at least 13% within the next 18 months. The process of dilution will depend on the market situation but is likely to begin in the next 6-9 months. The company said that stake dilution will be a combination of a fresh equity and an offer for sale which will fuel the company's integrated capacity from 8.8 Mt to 14.4 Mt by 2025.

The Economic Times

More initiatives on anvil to boost steel sector in 2023

With increasing steel production in the country, the focus in 2023 will be on boosting raw material supplies and producing more special grade steel, according to Union minister Faggan Singh Kulaste. India produced 113.43 Mt of crude steel in January-November 2022, which is 10% higher compared to the year-ago period. The government aims to double the country's annual crude steel making capacity to 300 Mt from 150 Mt at present.

In an interview to PTI, Shri Kulaste, the Minister of State for Steel, said more initiatives to boost steel sector will be taken in 2023. Last year, the government introduced the Production Linked Incentive (PLI) scheme for specialty steel to enhance the production of the high-end alloy.

Special grade steel is used in various sectors, including power, shipping, railways and auto. The demand for this steel is being met through imports. "Our focus will also be on taking measures to support industry besides finding new markets as the production of steel continues to grow in the country," he said.

Ensuring the raw material security for steel production will be a key focus area for the government as the country is mostly dependent on import of raw materials like coking coal.

While other minerals are available in sufficient amounts, Kulaste said India is dependent on imports for coking coal. The country imported 57 Mt of coking coal in FY22 to produce 120 Mt crude steel.

New reserves of coking coal are being identified. The country has around 34 billion tonne of coking coal, of which about 18 billion tonne have already been proven, the minister said. "The development of technology for mining and washing can make the country self-reliant besides ushering in huge employment opportunities and accelerating the process of development of urban, semi-urban and rural areas," Kulaste said.

The Economic Times

Modi's building boom setting up India as global steel savior

With China's massive construction sector still in a funk and the US and Europe likely heading into recessions, India has emerged as a savior for flagging global steel demand.

Poised to overtake China as the world's most populous country next year, India is in the midst of a building boom. Prime Minister Narendra Modi is seeking to modernise roads, rail networks and ports in attempt to vie with China as a manufacturing hub. That's set to translate into a 6.7% jump in steel demand to around 120 Mt in 2023, according to the World Steel Association, the highest growth among major economies. India, which also saw a similar expansion this year, overtook the US to become the world's No. 2 steel consumer after China a couple of years ago.

"The nation-building phase of any economy requires a lot of steel and commodities," said Jayant Acharya, deputy managing director at JSW Steel Ltd., the nation's biggest producer. India is going through that phase in this decade, and it could boost the country's steel consumption to over 200 Mt by 2030, he said. The buoyant outlook has set off a flurry of activity.

ArcelorMittal Nippon Steel India Ltd., a joint venture between India's Mittal family and the Japanese producer, has plans to more than triple capacity to 30 Mt in the coming decade. South Korean steelmaker Posco Holdings Inc. and Indian tycoon Gautam Adani, Asia's richest person, are also exploring setting up mills in the country. India produces the vast majority of the steel it uses, but it's also being forced to import more to meet the surge in demand.

Inward shipments rose 15% in April through October from a year earlier to 3.1 Mt, according to government figures. Local producers are becoming worried about the flood of cheap imports as demand dries up in traditional steel producers. China accounted for more than a quarter of imports in October, while some Russian steel is also reaching India, the government data show.

The Economic Times

Three SAIL projects worth over Rs 1,500 cr face delay: Kulaste

Three projects worth Rs 1,564 crore of state-run SAIL have been delayed due to reasons like slow progress in work, delay in obtaining clearances among others, Parliament was informed.

"Three projects i.e. installation of new sinter plant and rebuilding of COB 8 at Bokaro Steel Plant, and modification in washing circuit of CSW plant at Dalli mines have been delayed primarily due to slow progress of work by contractor, impact of Covid, delay in obtaining requisite clearance etc," Minister of State (MoS) for Steel Faggan Singh Kulaste said in a written reply to the Rajya Sabha.

According to the minister, installation of new sinter plant is being done at an investment of Rs 1,111 crore, while rebuilding of coke oven battery (COA) 8 is being carried out for an investment of Rs 285 crore at SAIL's steel plant in Bokaro, Jharkhand.

Another modification in the washing circuit of CSW plant of Dalli mines is underway at Rs 168 crore at Bhilai Steel Plant, Kulaste informed the Upper House.

Steel Authority of India Limited (SAIL), under the Ministry of Steel, is the country's largest steel making company having an annual production capacity of about 21 million tonnes.

The Economic Times

Increase use of scrap in production: Minister Kulaste to steel makers

Union Minister Faggan Singh Kulaste directed the domestic seel industry to increase use of scrap in their production, underscoring that carbon emission is a serious concern. India uses 30 Mt scrap annually to manufacture steel, out of which 26 Mt is generated domestically and remaining through imports.

Currently, India's overall steel production stands at around 120 Mt. "Carbon emissions are a concern.... the steel sector must increase use of scrap in their steel production," he said at CII Steel Summit 2022.

The industry must also adopt new-age technologies to lower their carbon emissions, the Minister of State for Steel said. However, he did not speak on the quantum of scrap which steel makers must include in their production.

According to a ministry document, the iron and steel industry globally accounts for around 8% of total carbon dioxide (CO_2) emissions on an annual basis, whereas in India, it contributes 12% to the total CO_2 emissions. The steel ministry has also asked the stakeholders of the sector to develop a time-bound action plan to lower emissions in the steel industry.

The Economic Times

Anil Agarwal-led Vedanta looks to sell Electrosteel and exit steel business

Four years after scooping up Electrosteel Steels Limited to make a big splash in the steel industry, Anil Agarwal-led Vedanta Group has decided to sell business to focus on its core mining and industrial businesses and deleverage the balance sheet which had a debt of $11.7 billion at March-end, said people with knowledge of the matter. The group has approached steel companies such as Arcelor Mittal Nippon Steel (AMNS), Tata Steel, JSW and

Jindal Steel and Power Limited, and a select group of financial investors, said the people. Top executives like ArcelorMittal CEO Aditya Mittal have also visited the site along with Vedanta Group officials in recent weeks, they said.

Vedanta Group said it did not want to comment on market speculation. ArcelorMittal Nippon Steel and JSW declined to comment. "We don't have any acquisitions under evaluation currently", Tata Steel CFO Koushik Chatterjee told. Mails sent to JSPL did not generate a response till press time. Vedanta beat Tata Steel, whose facilities are next to Electrosteel, to take over ESL for Rs.5,320 crore in the summer of 2018, after the creditors took the ailing steelmaker to the insolvency process, and it became the second steel company to see completion of the bankruptcy process after Tata Steel took control of Bhushan Steel in April 2018.

Vedanta had said at the time that the acquisition will complement its existing iron ore business as the vertical integration of steel, manufacturing capabilities has the potential to generate significant efficiencies.

Electrosteel Steels was a subsidiary of Electrosteel Castings. Upon taking over, Vedanta delisted the company. Vedanta (VDL), the Indian operating company which houses the diversified portfolio of oil and gas, zinc, lead, silver, aluminium, iron ore, steel and power businesses, owns 95.5 % of ESL Steel.

The Economic Times

Well-developed non-ferrous metals industry crucial for India: Saraswat

India needs a well-developed non-ferrous metals industry as it provides important raw material to many sectors which are the backbone of economic development, Niti Aayog Member V K Saraswat said.

Addressing a webinar on 'Indian Non-Ferrous Metals Industry', organised by industry chamber Ficci, Saraswat said as the demand in end-use sectors picks up in future, the non-ferrous metals industry will undergo a complete paradigm shift.

"With increasing usage of non-ferrous metals in several existing as well as emerging applications coupled with new technologies, we can expect a paradigm shift that can change the way non-ferrous metals will be produced and consumed in the future," he said.

In order to further boost the sector, Saraswat emphasised on early implementation of the recycling policy.

Business Standard

India's steel ministry seeks import tax waiver for coking coal

India's steel ministry has asked the finance ministry for a waiver of import tax on coking coal among a slew of raw materials, as it scrambles to fill a shortage of steelmaking ingredients, two government sources said.

The proposal to scrap levies ranging from 2.5% to 7.5% in the world's second biggest producer of crude steel comes ahead of the national budget for 2023/24 set to be unveiled in February.

The ministry's plan to scrap the tax on limestone, manganese ore, steel scrap, graphite electrodes, chrome ore, and ferro nickel, in addition to coking coal, has been sent to the finance ministry, said the sources, who spoke on condition of anonymity.

"The idea is to import raw materials, whichever is available, at the lowest possible import duty," said one of the sources. "We have asked for a waiver, complete removal." If agreed, the tax waiver on the raw materials would cost about 37 billion rupees ($449 million), the sources said.

The Economic Times

Steel prices continue sliding, pose a risk to the recovery of steelmakers

Prices of steel continue to slide locally even as input costs remain high, posing a risk to the recovery of steelmakers in the latter half of the year after a miserable July-September quarter performance.

There has been a pressure on steel prices in the domestic market due to average demand, lower exports and increased competition from imported steel.

Prices of benchmark hot-rolled coil (HRC) steel as of December first week have declined by around Rs 3,000 per tonne compared to November to

Rs 54,000-55,500 ex-Mumbai, according to data from SteelMint.

Experts believe that prices will remain under pressure throughout December and could decline further by Rs. 1,000-1,500 per tonne. "The market will definitely correct further in December," said a Mumbai-based dealer.

This, after steel industry executives said during earnings calls last month that prices of the alloy have bottomed after months of continuous decline.

The Economic Times

JSPL acquires Monnet Power for Rs. 410 crore at auction

Jindal Steel and Power (JSPL) has acquired bankrupt Monnet Power for Rs. 410 crore at an auction held last month, said two people aware of the development.

Adani Power and J Kumar Infraprojects were also in the fray to acquire the distressed thermal power company, one of the persons cited above said.

Naveen Jindal-promoted JSPL acquired Monnet Power for a captive purpose. The 1,050 MW Monnet Power plant is located next to JSPL's Angul steel plant in Odisha, making the acquisition synergistic, the people cited above said.

The winning bidder will need to invest at least about Rs. 1,000 crore to operationalise the plant, the first person said. The liquidator had admitted claims of Rs. 8,610 crore, of which Rs. 7,426 crore were from financial creditors.

After a string of unsuccessful auctions over the last two years, the liquidator sold the company last month. JSPL bid at Rs. 410 crore as against a reserve price of Rs. 400 crore. In the first round of the auction in July 2020, the liquidator had set a reserve price of Rs. 859.5 crore.

The Economic Times

India's April-November finished steel exports plunge 55% y/y - data

India's finished steel exports more than halved during the first eight months of the current fiscal year that began in April, according to the latest government data reviewed by Reuters.

Finished steel exports slumped 55% to 4.3 Mt during April to November period due to a slowdown in global demand and the decision by India to impose an export tax on some steel products.

Last month, the government scrapped the export tax but steel makers and industry officials said it would be a challenge for mills to regain their traditional markets, including Europe. Despite a drop in exports, India, the world's second-biggest crude steel producer, was a net exporter of the alloy.

India imported 3.8 Mt of finished steel in the first eight months of its financial year, up 22.5% from a year earlier. Crude steel production jumped 5.6% to 81.9 Mt. The country's finished steel output rose 6.4% to 77.7 Mt, while consumption went up by 12% to 75.3 Mt between April and November.

The Economic Times

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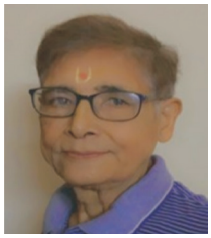
Obituary Late Shri P N Shali



With deep anguish and sadness we would like to convey that Shri P N Shali, a very active member of IIM Delhi Chapter, breathed his last on 20th December, 2022 at the age of 81. He was a Life Member of IIM, EC Member, Former Secretary and Former Chairman of IIM Delhi Chapter.

May his soul rest in peace eternally.

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Chapter Activities — Bhubaneswar, Ichapur, Jaipur, Hisar

Bhubaneswar Chapter

The conference "Odisha Minerals & Metals Industry : Exploring Opportunities & Addressing Concerns" on November 18, 2022 was organised by ASSOCHAM in association with IIM Bhubaneswar Chapter. The venue was at Hotel Pal Heights, Bhubaneswar. Dr. D.S. Rao, Vice Chairman of IIM Bhubaneswar chapter has delivered the talk on "Mineral resources of Odisha and their utilization". Eminent dignitaries around the minerals and metals industry in Odisha engaged in varied discussions on the subject.

Ichapur Chapter

IIM Ichapur Chapter and Metal & Steel Factory, Ishapore jointly organised the lecture on the topic "Metallography and Defect Investigation" at the Conference room of Metal & Steel Factory, Ishapore on 24th November, 2022. The lecture was delivered by the eminent speaker Shri K. Sharma, SSO-II/ CQA (Met), Ishapore. The lecture was of one hour duration and covered various fundamental as well as practical aspects of sample preparation and inspection of Metallography and Micro structure of failure Barrel for various applications in Defence sector. The officers and staffs of Metal & Steel Factory, Ishapore and DQA (M&E), CQA (Met), Ishapore etc. along with the IIM Members attended the programme. The AGM was also organised on the same day. The newly committee was formed as follows :

Chairman : Shri A K Hazra, Addl. General Manager/ MSF, Ishapore

Secretary : Dr. Raghu Nandan Jha, Jt. General Manager/MSF, Ishapore

Treasurer : Shri T K Pusty, SSO-II/CQA(Met), Ishapore

Jaipur Chapter

The EGM (extraordinary general meeting) was held on 24th November, 2022 at 11:00 am at thecommittee room of the Dept. of Metallurgical and Materials Engineering, MNIT Jaipur. The EGM was called to constitute the new executive committee. The new executive committee was formed as follows:

Chairman : Dr. Rajendra Kumar Goyal

Secretary : Dr. Vijay Navaratna Nadakuduru

Treasurer : Dr. Swati Sharma

Hisar Chapter

The Indian Institute of Metals, Hisar Chapter organised a technical talk on 23rd December, 2022 at Tulsi Bhawan Auditorium, Jindal Stainless Hisar Limited. The talk was delivered by Dr. Shantanu Ray on the topic "Process & Quality of Stainless Steel". The session was a blend of technical and commercial aspects to improve the quality of Stainless Steel. The gathering consisted of around 100 participants

across various departments of Jindal Stainless Ltd. During the session, there was a good exchange of doubts and ideas. It was a great initiative to develop the thought process of new engineers into the manufacturing of superior quality Stainless Steels. The lecture mostly consisted of detailed discussions on different aspects of continuous Casting, surface defects, their analysis etc. It helped to create new perspectives in the young minds of JSL towards making of quality Stainless Steel. In nutshell, the session was very enlightening to all the participants and helped to create a vision towards manufacturing of quality stainless steel. We are very thankful to Dr. Shantanu Ray for sparing his valuable time and sharing his knowledge to help us further to improve our quality in future.

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Member in the News Prof U K Chatterjee

Prof. U. K. Chatterjee, Formerly Professor, IIT Kharagpur, the Life Member of IIM and former Managing Editor of IIM Metal News (2008-2017) was conferred 'IIT Kharagpur Life Fellow Award' at the 68th Convocation held on 24 December 2022.

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Steel Statistics — Crude Steel production

Crude Steel production by region (Nov)

	Nov 2022 (Mt)	% change Nov 22/21	Jan-Nov 2022 (Mt)	% change Jan-Nov 22/21
Africa	1.3	-11.4	13.8	-6.4
Asia and Oceania	101.4	2.7	1,246.7	-1.7
EU (27)	10.5	-17.9	127.4	-10.1
Europe, Other	3.2	-25.1	41.5	-11.2
Middle East	4.0	11.6	40.2	7.7
North America	8.9	-6.3	102.8	-4.8
Russia & other CIS + Ukraine	6.5	-24.6	79.0	-19.6
South America	3.4	-14.3	40.0	-5.2
Total 64 countries	**139.1**	**-2.6**	**1,691.4**	**-3.7**

The 64 countries included in this table accounted for approximately 98% of total world crude steel production in 2021. Regions and countries covered by the table:

- **Africa:** Egypt, Libya, South Africa
- **Asia and Oceania:** Australia, China, India, Japan, New Zealand, Pakistan, South Korea, Taiwan (China), Vietnam
- **European Union (27)**
- **Europe, Other:** Bosnia-Herzegovina, Macedonia, Norway, Serbia, Turkey, United Kingdom
- **Middle East:** Iran, Qatar, Saudi Arabia, United Arab Emirates
- **North America:** Canada, Cuba, El Salvador, Guatemala, Mexico, United States
- **Russia & other CIS + Ukraine:** Belarus, Kazakhstan, Moldova, Russia, Ukraine, Uzbekistan
- **South America:** Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela

Top 10 steel-producing countries

	Nov 2022 (Mt)	% change Nov 22/21	Jan-Nov 2022 (Mt)	% change Jan-Nov 22/21
China	74.5	7.3	935.1	-1.4
India	10.4	5.7	114.2	6.0
Japan	7.2	-10.7	82.3	-6.9
United States	6.4	-10.5	74.4	-5.5
Russia	5.6 e	-9.6	65.9	-7.0
South Korea	4.8	-18.1	60.6	-6.1
Germany	2.8	-17.9	34.2	-7.9
Türkiye	2.4	-30.7	32.5	-12.3
Brazil	2.6	-16.3	31.5	-5.9
Iran	2.9	3.9	27.9	8.5

e - estimated. Ranking of top 10 producing countries is based on year-to-date aggregate

Source : worldsteel.org

Non-Ferrous Metals Statistics — Domestic Scenario

Production (unit : Lakh Tonnes)

	Oct'22	Sep'22	Aug'22	2021 - 22	2020 - 21
ALUMINIUM					
National Aluminium Co Ltd	0.38	0.37	0.38	4.60	4.18
Hindalco Industries Ltd*	1.13	1.09	1.12	12.94	12.28
Bharat Aluminium Co. Ltd	0.47	0.46	0.47	5.80	5.68
Vedanta Ltd	1.43	1.42	1.45	16.78	13.72
TOTAL	3.41	3.34	3.42	40.12	35.86
*Renukoot, Hirakund, Mahan, Aditya					
ZINC (One major producer)					
Hindustan Zinc Ltd	0.70	0.63	0.61	7.76	7.15
COPPER (Cathode)					
Hindustan Copper Ltd	0	0	0	0.62	Nil
Hindalco (Birla Copper)	0.34	0.35	0.36	3.95	2.89
Vedanta Ltd.	0.11	0.13	0.14	1.37	1.118
TOTAL	0.45	0.48	0.50	5.94	4.008
LEAD					
Hindustan Zinc Ltd	0.16	0.16	0.19	1.91	2.14

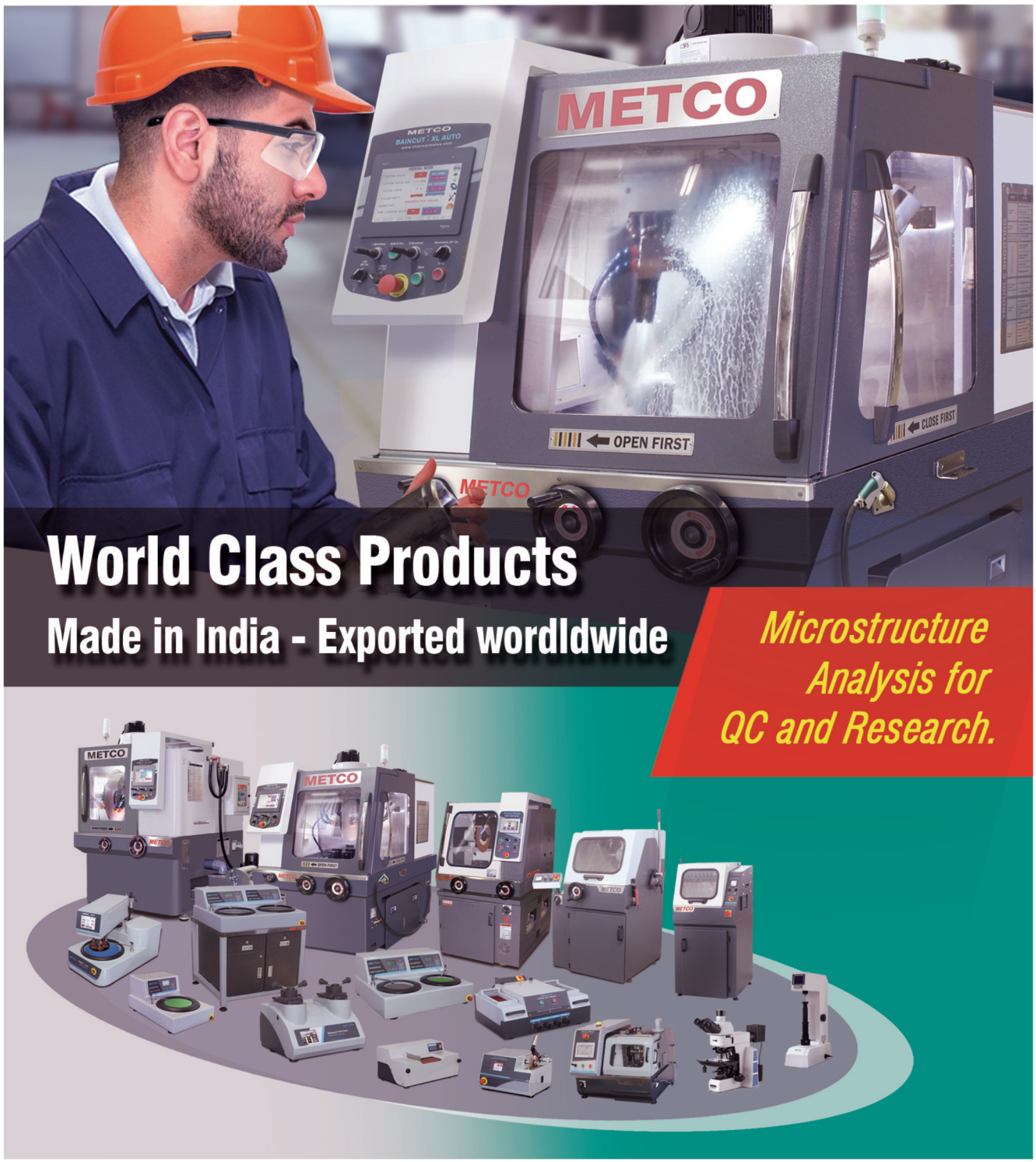
Source : https://mines.gov.in/

Prices in India (as on 10th December, 2022)

(Mumbai Local Price in Rs. / kg)

Product	Rs. / kg	Product	Rs. / kg
Copper Armature	655	Brass Honey scrap	452
Copper cathod LME ++	749	Brass Shell 40mm	568
CC Rod LME ++	757	Aluminium Ingot	222
Copper Cable scrap	683	Aluminium utensil scrap	161
Copper shell 40mm	705	Zinc Slab	287
Electrolytic Copper strip 25mm	705	Lead ingot	195
ACR Copper Coil 3/8	765	Tin Slab	2113
Brass Sheet scrap	508	Nickel Cathod	2475

Source : http://www.mtlexs.com/



Chennai Metco

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STEEL FACTS
The steel industry uses its resources efficiently and produces very little waste. According to the data reported by our members, in 2021:
97% of steel industry raw materials were converted:
69% were converted into steel products.
28% were converted into co-products.
As little as:
3% became waste.
worldsteel.org