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E-mail: thesecretarygeneral.iim@gmail.com, iimmetalnews@yahoo.com
Phone: 033-2367 9768 / 2367 5004
Website: www.iim-india.net
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@ the AGM of IIM Bokaro Chapter on 4th May, 2023

THE INDIAN INSTITUTE OF METALS

Notification — Appointment of New Secretary General

Brigadier Arun Ganguli's (Retd.) appointment has been approved by Council as Secretary General of the Indian Institute of Metals with effect from August 1st 2023.

Brief Profile of Brigadier Arun Ganguli (Retd.)

Brigadier Arun Ganguli (Retd.) is an alumnus of National Defence Academy, Pune and passed out from prestigious Indian Military Academy, Dehra Dun in December 1984. He is an ex-Army Officer from the Corps of Electronics and Mechanical Engineers (EME) in Indian Army having done his M.Tech from Military College of Electronics and Mechanical Engineering (MCEME), Secunderabad affiliated to Jawaharlal University, New Delhi. He has been a Tank Technology qualified Officer in Indian Army.

He has over thirty-seven years of diverse experience in the Indian Army in the field of Inventory Management, Operational Readiness, Repairs & Maintenance of Vehicles and Equipment, Management of Personnel and Resources, Dean of an Engineering Faculty in MCEME, Commander of Training of Cadets into Officers as Technical Graduates at Cadets Training Wing at Secunderabad and Chairman of Army Public School.

He had done all mandatory courses of Army and EME with distinction and outstanding grading. He had the privilege of serving in units and regimental appointments, both in EME and General Staff tenures. As an instructional appointment, he has served in MCEME, Secunderabad twice. He also had a unique distinction of raising new EME units twice in trying conditions of semi-dessert and jungle terrain as part of Southern and Eastern Army Commands respectively. He had been Colonel (Administration) and Brigadier General Staff (Information System) in Eastern Theatre of Indian Army.

The officer has the honour of having been awarded twice Army Commander's Commendation while serving in Western and Training Command respectively.

He has also been a qualified Independent Director having done a course at MDI, Gurgaon and Fellow of Institute of Engineers, Kolkata.

Arun to his repute has been an Outstanding Squash player having represented India/Services and recipient of award from Govt. of India for achieving outstanding excellence in the game of Squash in the year 1985, 1987 and 1991 respectively.

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Technical Article

Assessment of Deformation Resistance across Dissimilar Weld Joint of 316LN SS and Grade 91 Steel after Creep Failure

V D Vijayanand[a,b] , Deepshree D Awale[c] and G V Prasad Reddy[a,b]

Abstract

The influence of creep associated microstructural evolution on the strength gradients occurring across dissimilar joint made with P91 steel and 316LN stainless steel has been investigated. As there is a significant variation in the microstructure over a narrow width of the dissimilar weld joint, conventional testing techniques cannot be used to assess the corresponding deformation behavior. In this study Automated Ball Indentation (ABI) - a miniature specimen technique was used to probe the mechanical properties of individual regions occurring across the weld joint. The testing was carried out in both post weld heat treated and creep tested conditions. ABI results showed that creep exposure alters the strength gradient across the P91 steel's side to a greater extent when compared to the 316LN SS side.

1.0 Introduction

Developing high temperature resistant materials has been one of the important domains of research for material scientists in recent years. The need for such materials is imminent for sodium cooled fast reactors (SFRs) whose components must withstand elevated temperature and load during service **[1]**. Therefore, deploying creep deformation resistant materials which enhance the design life is an important criterion for success of SFRs on a commercial scale. Development of high temperature materials is usually evolutionary in the sense that mostly minor modifications in alloying content or processing routes of conventional materials is prescribed for improving its performance at elevated temperature. This is because of the availability of design data and international experience in using these materials. This conservatism is an unequivocal aspect of high temperature component design where safety is a prime concern.

Depending on the functionality, different types of materials are used when fabricating components of SFRs which make welding of dissimilar materials inevitable. Welding can substantially alter the microstructure and result in creep strength inferior to both the parent materials. Therefore, developing compatible welding techniques and methods for new evolving materials is usually pursued simultaneously to developing high temperature materials. Studies on dissimilar weld joint failures especially the ones made between austenitic stainless steels and ferritic-martensitic steels are crucial as they help to provide insight to the mechanisms of failure, based on which modifications on welding procedures can be undertaken which can avert catastrophic failures during service.

Dissimilar joints between P91 steel and 316LN stainless steel (SS) occurs in the steam generator circuit of SFRs **[2]**. It is the region where the heat energy from liquid sodium is transferred for generating steam. The secondary heat exchanger side of this circuit which houses liquid sodium is subjected to relatively higher temperature. Materials used in this region must be compatible with liquid sodium in addition to being creep resistant. 316LN SS is the material chosen for fabricating components in this section of the steam generator circuit. The composition of this alloy was tailored with careful additions of nitrogen in order to withstand elevated temperature exposure. The steam generator side of the circuit is fabricated using P91 steel as stress corrosion cracking is the important life

[a]Metallurgy & Materials Group, Indira Gandhi Centre for Atomic Research, Kalpakkam-603102, India
[b]Homi Bhabha National Institute, Training School Complex, Mumbai-400094, India
[c]Indian Institute of Technology Bombay, Mumbai-400076, India
Email: *prasadreddy@igcar.gov.in*

limiting factor in these components. Therefore, bi-metallic joints inevitably occur in SFRs. Several studies are being pursued on assessing creep deformation behaviour of dissimilar joints made between these two materials to provide new insights to the failure **[1-7]**. This article presents results from a novel approach in which deformation resistance was estimated by Automated Ball Indentation (ABI) technique on weld joint specimen which failed due to creep exposure.

2.0 Experimental

The dissimilar joint was fabricated using shielded metal arc welding process using a nickel based Inconel-182 electrode. PWHT of the welded joints were carried out at 760 °C for 1 hour. Cross-weld sample was extracted from the weldpad for creep testing. Uniaxial creep testing was carried out at 550 °C with an applied stress of 200 MPa. ABI testing was carried out using tungsten carbide indenter of 0.25 mm diameter. A total of five loading and unloading cycles were used for constructing the ABI's load displacement curve. Microstructural examination was carried out after standard metallographic preparation and etching with Villella's reagent.

3.0 Results and discussion

The microstructure of various regions in the P91 steel side is shown in **Figure 1**. Welding generated more heterogeneity in the microstructure of P91 steel when compared to 316 LN SS. The heat affected zone (HAZ) in the P91 steel side was around 3.5 mm wide, which is quite significant enough to influence failure during prolonged elevated temperature exposure. Three distinct regions were observed in the HAZ of P91 steel viz., coarse grain (CG-HAZ), fine grain (FG-HAZ) and intercritical (IC-HAZ). The CG-HAZ and the FG-HAZ comprised of martensitic microstructure within the prior austenite grains in the as-welded condition. However, the IC-HAZ exhibited a composite structure consisting of over-tempered martensite and fresh martensite. The heterogeneity in the microstructure suggests that gradient in mechanical strength would exist across the regions of the HAZ. Quantification of the strength variation is viable using miniature specimen testing techniques like ABI testing.

ABI has been widely used in recent years, for probing mechanical properties using small specimen volumes **[8]**. It can be used in-situ to evaluate mechanical properties of narrow regions non-destructively. The advantage of this kind of testing is that it can assess the strength and property variations of the components in service. It uses a small diameter indenter which penetrates the polished material surface for multiple loading and unloading cycles and makes a shallow mark on the surface. The evaluation of variations in

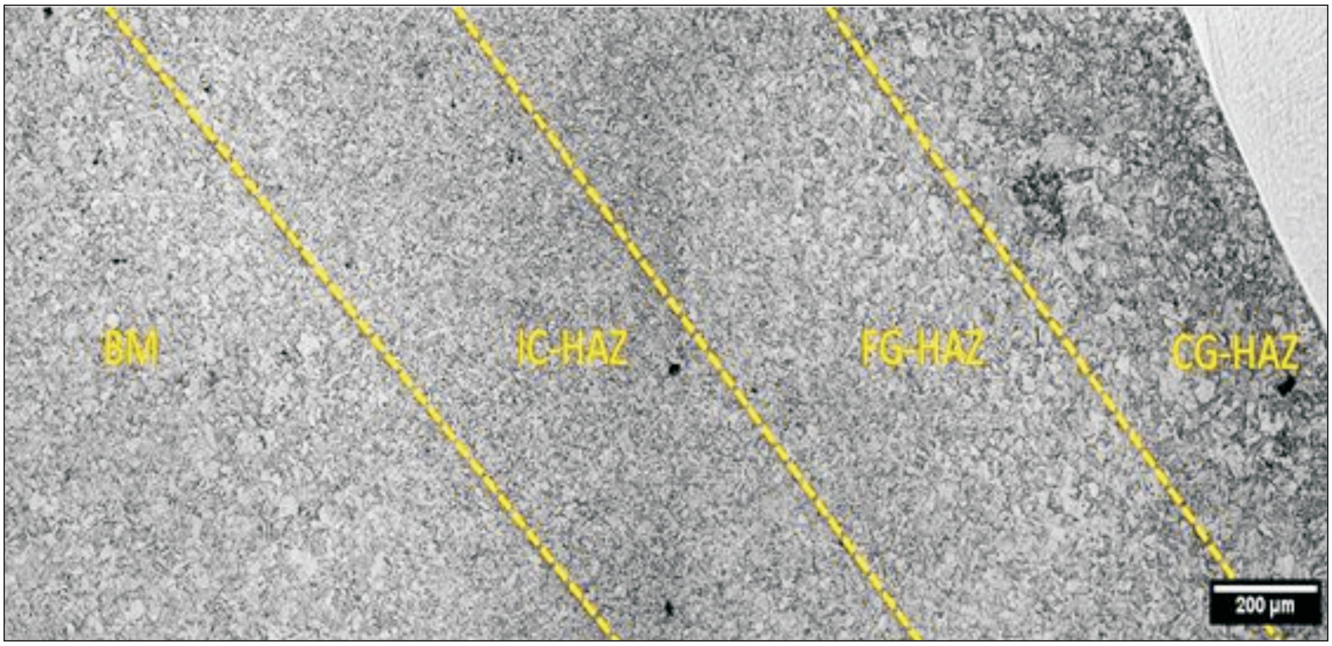

Fig. 1 : Microstructure of the P91 steel side demarcating variosu consitutent regions with the heat affected zone (HAZ).

properties provides essential insight for their safe operation during services. The properties derived using these techniques are converted to uniaxial properties through empirical equations. This helps in providing a baseline data which can be used for assessment studies of nuclear reactor components. In this investigation five cycles of loading and unloading were done in using ABI in each of the regions of the weld joint. The peak load obtained from this test was used to interpret the strength and deformation resistance in the corresponding region.

ABI was done on both PWHT and uniaxial creep tested conditions. The rupture life of the joints was 441 hours. The failure occurred in the P91 steel's base metal region quite far from the HAZ. The PWHT and the subsequent heat treatment did not considerably alter the microstructure in the 316LN SS side. The locations where ABI were performed are shown in **Figure 2**.

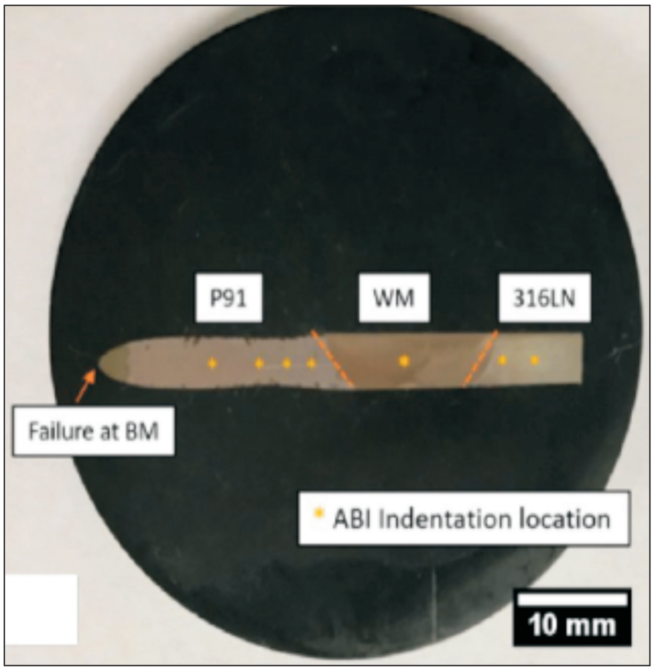

Fig. 2 : Locations were ABI tests were performed on the failed specimen.

The load vs. depth graph for various regions in both the conditions is shown in **Figure 3 a-d**. In PWHT condition, the CG-HAZ, and the weld metal regions exhibited the highest and lowest load respectively. For the 316LN SS side, the highest peak load was observed in the weld metal, followed by base metal and the HAZ. The ABI test results after creep testing showed that higher peak loads were exhibited in the weld metal and CG-HAZ regions. The peak load for IC-HAZ was the lowest among all the other regions in the P91 steel side. In the 316LN SS side the peak load was highest for the weld metal. The peak load in the HAZ was marginally higher than that of the 316LN SS base metal.

The gradient in the peak load which was more drastic in P91 steel's HAZ after PWHT became less pronounced after creep testing. Due to the presence of dense martensitic structure in CG-HAZ the strength as depicted from peak load was relatively higher in the PWHT condition **[9]**. In the PWHT condition, the microstructure of the FG-HAZ and IC-HAZ consisted of transformed and untransformed fractions of prior austenitic grains and coarse carbides as compared to the CG-HAZ. This accounted for lower strength in these regions **[10]**. Though not that drastic, after creep exposure the strength variation across the P91 steel's HAZ constituents followed a similar trend. Creep exposure resulted in recovery of the tempered martensitic microstructure and coarsening of the carbides. This is the reason for the degradation of strength in the P91 steel's side. Despite IC-HAZ region being weakest, failure did not occur in this region due to the geometrical constraint caused by the presence of relatively less complaint P91 base metal and FG-HAZ regions on either side of IC-HAZ. At higher stress levels such as the one which the current joint was subjected to, stress assisted recovery in the base metal was quite dominant which caused failure to occur in this region. It is only the prolonged creep exposure which causes damage evolution in the IC-HAZ/FG-HAZ regions resulting in Type-IV failure of these joints **[11]**. The creep performance of the dissimilar weld joint ultimately depends on the microstructural stability of the ICHAZ region. The instability in this region can be attributed to presence of composite microstructure and coarsened carbides. Based on the above studies, two possible methods for enhancing the creep life of dissimilar P91 steel-316LN SS has been proposed. Addition of B is one of the methods which can retard the coarsening kinetics of the carbides, which in turn can enhance the stability of the ICHAZ region **[12]**. Use of high energy density processes like electron beam welding and laser welding generates a narrower HAZ; this can also mitigate failure in such dissimilar weld joints **[13]**.

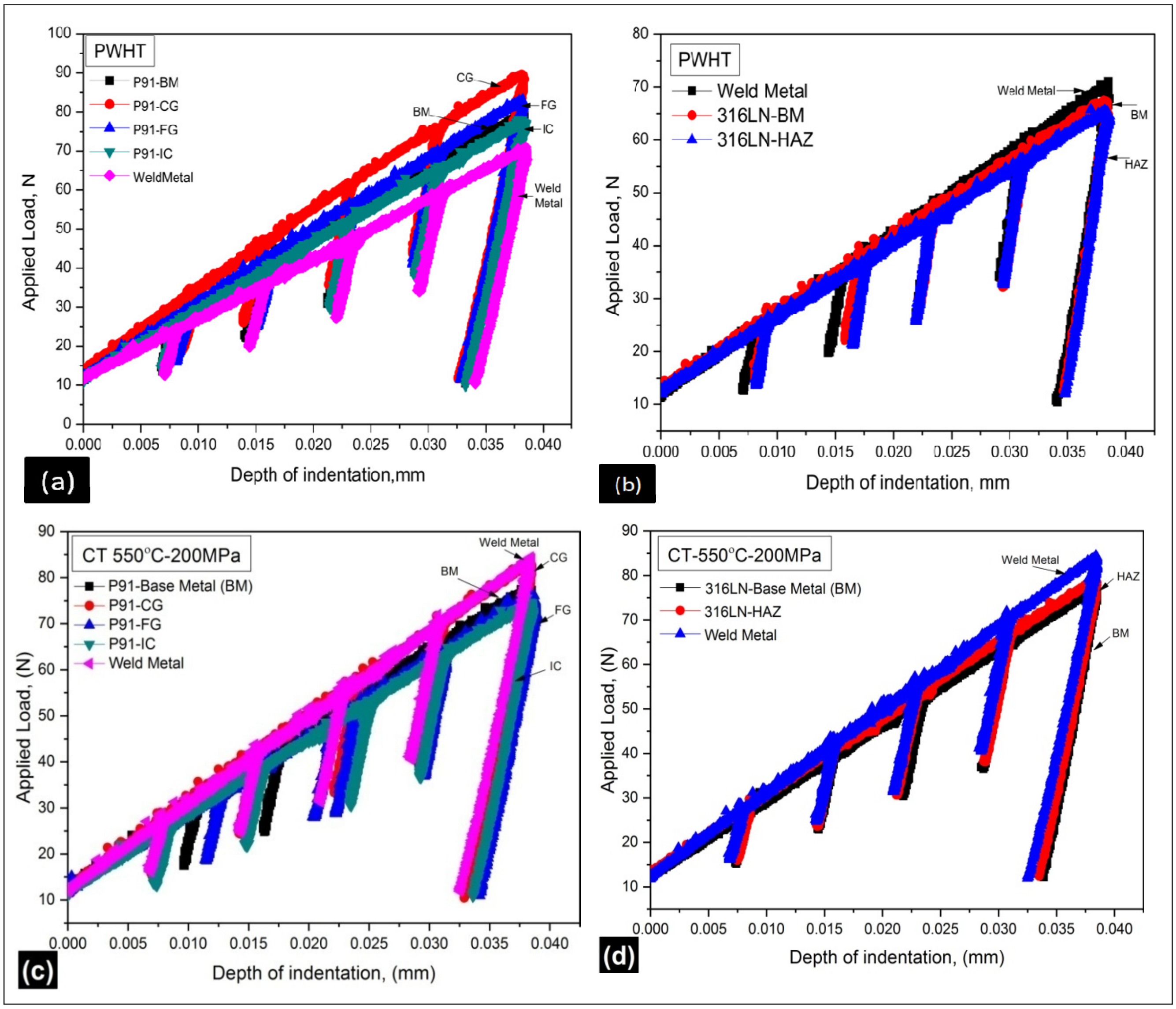

Fig. 3 : Load-depth of indentation curves for a) PWHT-P91 steel side, b) PWHT-316LN SS side, c) Creep tested (CT)- P91 steel side, and d) Creep tested (CT)-316 LN SS side. CG, FG and IC denotes coarse grain, fine grain and inter-critical heat affected zones respectively.

4.0 Summary

Automated Ball Indentation technique could be used to assess the deformation behaviour of all the constituents of the P91-316LN SS dissimilar joint in both post weld heat treated (PWHT) and creep tested condition. In the PWHT condition, the strength gradient in the P91 steel was more prominent. All the constituents of the P91 steel's heat affected zone (HAZ) exhibited higher peak load when compared to the weld region in this condition. However, upon creep exposure the peak load of these regions fell below that of the weld metal. Creep exposure resulted in homogenising the strength gradient in the P91 steel side. The strength gradient across the 316LN SS side was less prominent in the PWHT and creep exposure did not significantly alter this gradient.

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Technical Article

Nanocrystalline Materials : From Promise to Products

Srikant Gollapudi*

Abstract

The development of thermally stable nanocrystalline materials has widened the scope of applications of these materials. From corrosion resistant coatings for waterproof smartphones to kinetic energy penetrators for defense applications, nanocrystalline materials are finally coming of age and delivering on the promise they always held. These developments are ushering in a fresh wave of interest in nanocrystalline materials from both a scientific and technological standpoint. This article discusses the many developments in nanocrystalline materials from a thermal stability, strength, corrosion and creep resistance point of view. It also discusses the possibility of using nanocrystalline materials as a reinforcement for soft metals and also highlights the developments in the field of nanocomposites.

Keywords : nanocrystalline; thermal stability; corrosion; creep; nanocomposites

Nanocrystalline (nc) materials are a class of materials bearing grain or crystallite size smaller than 100 nm [1] (Figure 1). Interest in these materials stems from their superior properties vis-à-vis their coarse-grained counterparts [2, 3] and also from their intriguing behavior [2, 3]. For example, the nc materials are known to provide high hardness, high wear resistance [4] and good corrosion resistance [5, 6]. At the same time, the physics of deformation in these materials is quite different compared to their coarse-grained cousins [7]. The inverse Hall-Petch effect (Figure 2) [8] which was earlier unheard of in coarse-grained materials is a regular feature of nc materials especially at grain sizes smaller than approximately 15 nm [9]. As a result of the large number of grain boundaries decorating these materials, grain boundary sliding and diffusion creep tendencies are accentuated which in turn leads to grain size weakening instead of strengthening [7, 8].

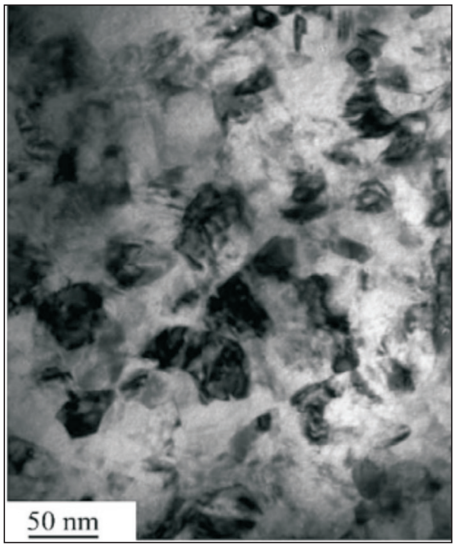

Fig. 1 : Bright field TEM micrograph of electrodeposited nanocrystalline Ni with an average grain size of 30 nm [3].

School of Minerals, Metallurgical and Materials Engineering
Indian Institute of Technology Bhubaneswar, Odisha 752050
E-mail : *srikantg@iitbbs.ac.in

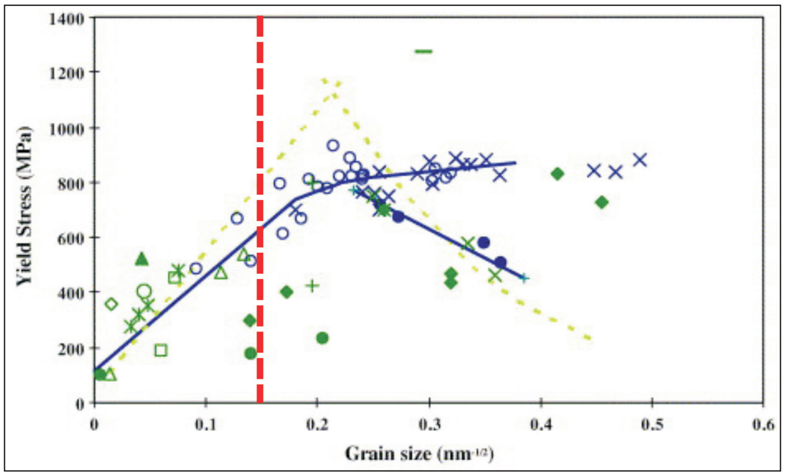

Fig. 2 : Plot showing the variation of yield strength with the inverse of square root of grain size in copper. At very small grain sizes, some studies have indicated a breakdown of the Hall-Petch correlation resulting in the inverse Hall-Petch effect. [2]

As mentioned earlier, nc materials have been actively pursued since their invention [10, 11] roughly four decades back due to a suite of interesting properties. For example, nc metallic materials offer hardness in the range of 7 to 8 GPa [12] which is significantly higher than that of their coarse-grained counterparts whose hardness is usually in the range of 1 to 2 GPa. In other instances, the extraordinary superplasticity [13] (Figure 3) reported in nc materials evokes ambitions of high strain rate forming of materials. Similarly, the superior corrosion resistance of these materials under certain conditions enables their application for waterproof smartphones, smart wearables, data communication connectors etc. as evident from the product portfolio of the company Xtalic [14] which has introduced a range of corrosion resistant nanocrystalline coatings (Figure 4). While the nc materials produced as coatings using electrodeposition techniques have found success, their applications otherwise have been rather limited which is mainly due to the challenges with bulk production of these materials [15]. Due to their metastable nature, conventional powder metallurgical processing invariably causes the nanograins to grow leading to loss of nanostructure and associated benefits. To overcome these issues, both kinetic (Zener drag approach) and thermodynamic (focused on reducing the grain boundary energy) models have been adopted with varying degree of success [16]. The thermodynamics based approach employed by Schuh and co-workers [17] helped in identifying nanocrystalline W based alloys [18] bearing extraordinary thermal stability (Figure 5). The nc W-Ti system, in contrast to nc W, as reported by Schuh and co-workers retained its grain size of 22 nm despite exposure to 1100 °C for a week [18]. Our recent investigations on nc W-Ti system revealed its microhardness to be 18 GPa [19] indicating its suitability for reinforcing soft metals such as Mg, Al etc. The high hardness of the nc W-Ti system could also encourage its use as an armor material or as a kinetic energy penetrator where the high density of W combined with high hardness of W-Ti and adiabatic shear banding tendencies of bcc W could ensure higher performance of the nc W-Ti KEP's compared to conventional W based KEPs. Recently a patent was granted for invention of nanocrystalline alloy penetrators which suggests that this could be a potential application of nanocrystalline materials [20].

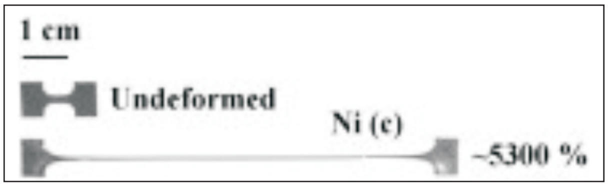

Fig. 3 : Extraordinary superplasticity in electrodeposited nanocrystalline Ni [13]

Fig. 4 : XTRONIC a proprietary product of Xtalic corporation employs nanocrystalline coatings for enhanced durability of the charging connection [14]

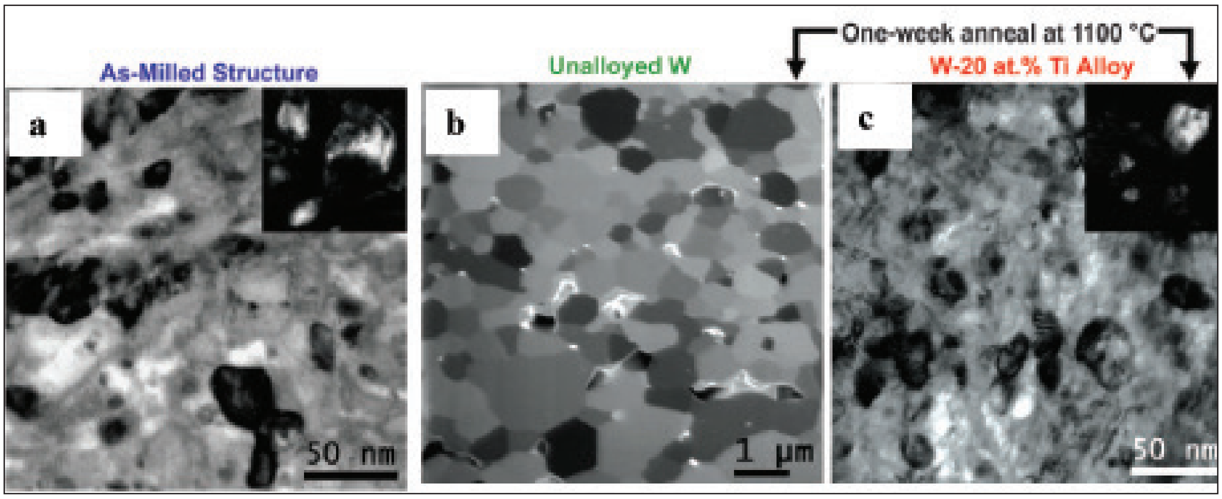

Fig. 5 : a)TEM micrograph illustrating the nanostructure of as milled W and W-20Ti b) Micrograph illustrating extensive grain growth in unalloyed W after exposure to 1100 °C for 1 week c) Stable nanostructure of W-20Ti despite exposure to 1100 °C for 1 week [18]

While the thermodynamic approach mainly relies on identifying solute atoms capable of stabilizing the nanostructure of a given element [21], the role of crystallographic texture [22], grain size distribution [23] and grain boundary energy spectrum [24] cannot be overlooked. The amount of solute required for stabilizing the nanostructure is apparently dependent on the crystallographic orientation distribution [22], the grain size distribution [23] and grain boundary energy spectrum [24]. Calculations have revealed that nanostructures bearing a random crystallographic texture would probably require a higher amount of solute for nanostructure stabilization in contrast to a textured material [22]. Hence, accounting for these factors will enable a more efficient design of stable nc materials.

While reducing grain boundary energy renders higher thermal stability, it could also improve the corrosion resistance and hardness of the nc material [25, 26]. Controlled heat treatment releases the excess energy associated with the grain boundaries and makes the nc material (e.g. nc Ni-P, nc Ni-W) more resistant to corrosion (Figure 6) and plastic deformation. This process is termed as grain boundary relaxation [27] where the nc material lowers its free energy without undergoing any change in grain size.

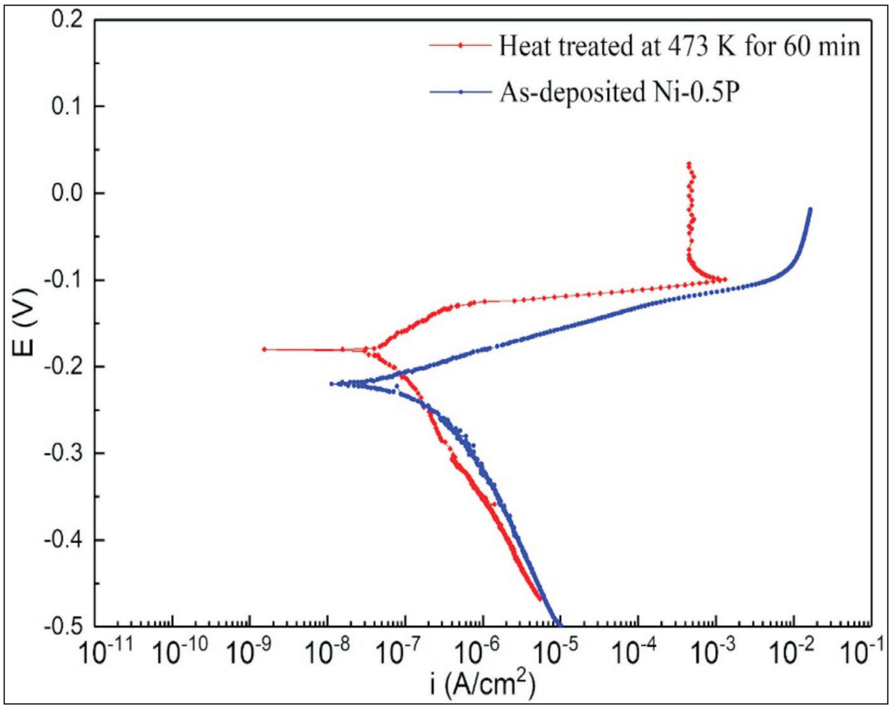

Fig. 6 : Improvement of corrosion resistance in nanocrystalline Ni-0.5P following grain boundary relaxation inducing heat treatment [26]. The equilbrium corrosion current density of the heat treated nc material is lower than its as-deposited counterpart.

The stability achieved by reducing grain boundary energy also allows investigations into the creep behavior of nc materials [28, 29]. Creep is understood as time dependent plastic deformation under constant load or stress operating at high homologous temperatures. The poor grain size stability of nc materials had for long prevented an understanding of their creep behavior [30]. It is of interest to check if the principles which confer thermal stability could also cause significant improvement in their creep resistance. The thermodynamics based design of nc materials is based on choosing a solute element that binds and lowers the energy of the grain boundaries of the parent element. Since solute segregation would alter the grain boundary diffusivity, it is possible that the creep resistance of stable nanocrystalline alloys will be higher than an equivalent nanostructure of the pure parent element. Our recent calculations have shown that solute segregation enhances creep resistance but this improvement does not render the thermally stable nc material superior to their coarse-grained counterpart [31] (Figure 7). Hence it appears that despite the improvement in thermal stability, nanocrystalline materials may not be able to replace their coarse grained cousins for high temperature applications; albeit there is scope for detailed experimental investigations into this topic.

The thermodynamic based approach for design of nanocrystalline alloys has also been exploited by Schuh and co-workers to identify phase separating compositions which allowed accelerated sintering of W based systems [32]. Due to the high melting point of W, its sintering becomes a rather high temperature affair and any approaches which reduce the sintering temperature or time of sintering would make bulk W alloy processing affordable and adoptable.

While the discussion so far has been about structural applications of nc materials, high thermal stability could generate opportunities for thermoelectric applications of nc materials. The large number of grain boundaries in nc materials would provide scattering sites for phonons and lead to reduction of thermal conductivity which in turn will enhance the thermoelectric figure of merit [33, 34]. Hence, the field of thermoelectrics stands to gain from the development of stable nc materials.

The field of nanocomposites [35] (classification shown

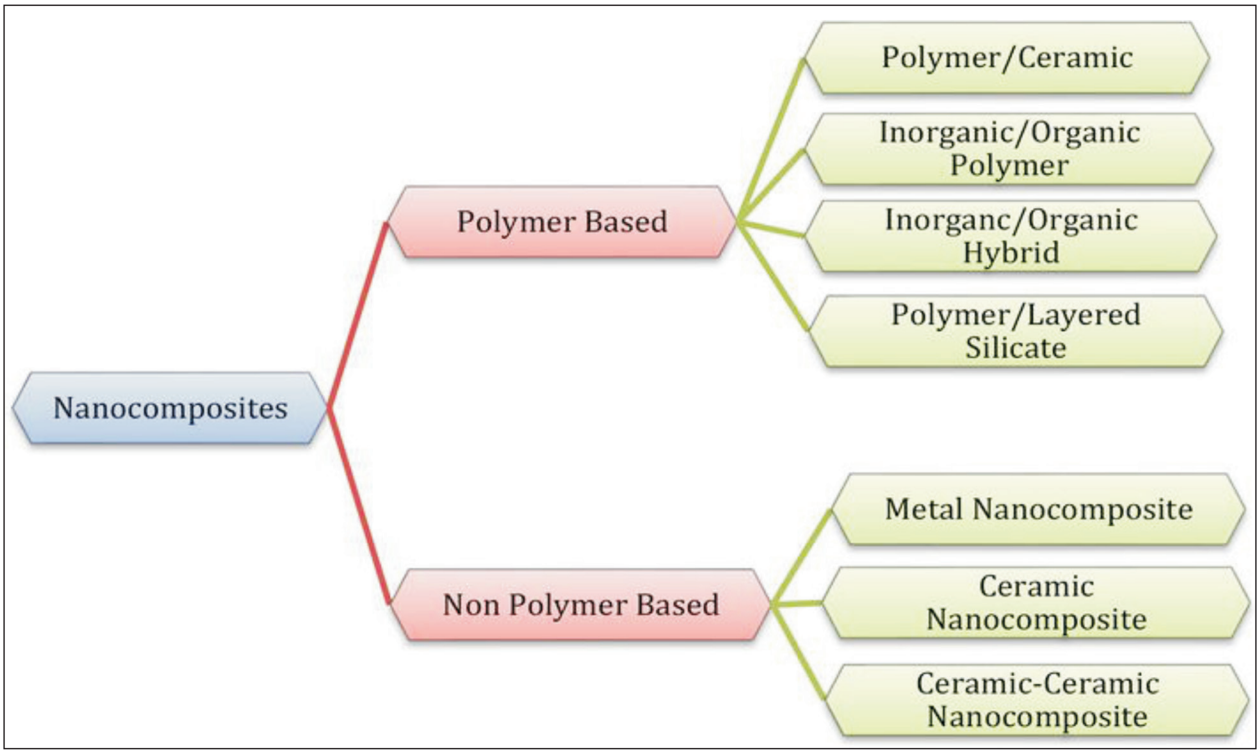

Fig. 7 : Classification of nanocomposites [35].

in Figure 7) too stands to benefit from developments in nanocrystalline materials. In a very recent work, Xiao et al. [36] report the development of thermally stable nanoparticles of a complex Ni-Co alloy containing Fe, Cr, Al, Ti and B as minor alloying elements. These nanoparticles can help in the development of the field of nanocomposites which are defined as materials where either the size of at least one of the phases is in the nanoscale or the spacing between the phases constituting the composite is in the nanoscale. Smith et al. [37] reported the development of a NiCoCr alloy containing nanoparticles of Y_2O_3 for high temperature structural applications. This alloy was found to exhibit a two-fold increase in strength and over 1000-fold higher creep resistance when compared to conventional Ni based super alloys. Interesting and vastly superior properties have been also reported in Al metal matrix nanocomposites wherein carbon nanotubes were used as the second phase [38]. The use of CNTs is encouraged by their high strength (ranging from 35 to 110 GPa) and stiffness (elastic modulus ranging from 600 to 1100 GPa). Addition of even tiny quantities such as 1 to 2 vol. % of CNTs to aluminium resulted in nanocomposites bearing tensile strength almost 1.5 to 2 times higher than pure aluminium [38]. Akin to metallic materials, polymers nanocomposites are also being pursued actively [39] and polymers reinforced with CNTs have also demonstrated superior properties and are currently under consideration as an electromagnetic interference shielding materials [40]. Metal matrix nanocomposites with ceramic nanoparticles are also being pursued actively. Introduction of 2 wt.% of nanoparticles of Al_2O_3 in an Al-Si hypereutectic alloy resulted in almost 30% enhancement in strength and 90% enhancement in ductility [41].

In the case of nanocomposites, the dispersion of the nanoparticle or nanomaterials controls the enhancement in property that can be achieved [42]. Interfacial bonding with the matrix in the case of carbonaceous nanomaterials is another challenge which can limit the strengthening achieved. The interfacial bonding decides the extent of load transfer occurring between the matrix and the nanoparticle, especially so in the case of metal matrix nanocomposites. Ball milling has been observed to be an effective processing technique for overcoming the challenges associated with uniform dispersion of the nanoparticles or nanophase within the matrix. On the other hand, enhanced interfacial bonding is achieved in the case of carbonaceous nanomaterials by coating them with metals such as nickel, chromium etc [42]. In the case of ceramic nanoparticles, encapsulation with graphene has been observed to enhance both the dispersion as well interfacial bonding with the metal matrix [43]. Due to the superior properties offered by nanocomposites, they have garnered a lot of attention. However, challenges with their disposal and environmental pollution remain and hence biorenewable resources [44] are under consideration and these will pave the development of the next generation nanocomposites.

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Editorial Board of IIM Metal News


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परमाणु ऊर्जा विभाग की एक इकाई A Unit of Department of Atomic Energy, भारत सरकार Govt. of India
(आई.एस.ओ.9001, 14001 & 45001 संगठन ISO 9001, 14001 & 45001 Organization)
भारत के शांतिपूर्ण परमाणु कार्यक्रम को बढ़ावा देना Fuelling India's peaceful Nuclear program
महत्वपूर्ण उत्पादन और परीक्षण सुविधाएं
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Recent Developments — New Technologies

Innovative Steel Battery Housing

Electric vehicles came to market demonstrating new technologies and new challenges for the OEMs and their suppliers. A significant focus of current research and development has been related to the cells chemistry, which has been improving fast. In addition to this, new requirements regarding safety and performance are demanded which cause the battery-tray to constantly evolve. In this direction, Gestamp defines an innovative steel battery-box solution, which can be applied in a wide range of electric vehicle segments.

Four basic requirements have been established for this revolutionary system; they are: High energy capacity, Stampings with high formability, Simplified assembly process and High safety performance. These four pillars were used to develop the first cell-to-pack concept. The cross members were deleted, allowing more space for additional cells. The enclosures were redesigned taking advantage of extra deep-drawing steel alloys. The joining technologies were selected taking into account the process energy input to decrease the final distortion and improve the final assembly quality.

The new Gestamp steel battery box design achieved 15% increase in the energy storage using the same exterior packaging. Components have simple geometries with a high degree of manufacturability. The body and battery housing work as a all-inclusive system resulting in high crash performance and a lighter weight solution.

Source: https://www.steel.org/steel-markets/automotive/gdis/presentations/ (Track 1 - Session 2 – 2023)

STAF Process Maximizes Light weighting of Car Body Frame

Sumitomo Heavy Industries has developed a new press forming technology: Steel Tube Air Forming (STAF) for forming Body-in-White (BIW) parts such as A-pillar reinforcement, bumper reinforcement, and side frame. The concept of STAF focusses on maximum weight reduction and reduction of manufacturing cost with a single process. In the STAF process, a steel tube is processed through 'a single step' in the tooling of press machinery. A steel tube is heated (high-speed), air-formed and hardened. STAF-formed parts have characteristic appearance with optimally designed flanges, Tensile Stress over 1500 MPa, and continuously varied closed cross-section structure. First of all, these parts can significantly improve basic performance against conventional hot-stamped parts due to their closed and flanged geometry. Sumitomo can expect weight reduction by around 30%. Moreover, the most unique part of the process is forming various flanges, which can integrate surrounding parts into STAF, improve joining and enhance performance. STAF's flanges dramatically reduce part count, thereby reducing manufacturing costs and tooling investments. Furthermore, we put a compact heating device into practical use, replacing the conventional large heating furnace. The heating process will bring not only high power savings but will significantly reduce CO_2 emissions from equipment. STAF is the latest technology that can drastically improve performance and reduce weight and manufacturing costs.

Source: https://www.steel.org/steel-markets/automotive/gdis/presentations/ (Track 1 - Session 8 – 2023)

Novel adaptation for existing furnaces to reduce steelmaking emissions by 90%

Researchers from the University of Birmingham, U.K. have designed a novel adaptation for existing iron and steel furnaces that could reduce carbon dioxide (CO_2) emissions from the steel-making industry by nearly 90%.

The new recycling system captures the CO_2 from the top gas and reduces it to CO using a crystalline mineral lattice known as a 'perovskite' material. The material was chosen as the reactions take place within a range of temperatures (700-800 ^{0}C) that can be powered by renewable energy sources and/or hot air generated using heat exchangers connected to the blast furnaces. Under a high concentration of CO_2, the perovskite splits CO_2 into oxygen, which is absorbed into the lattice, and CO, which is fed back into the blast furnace. The perovskite can be regenerated to its original form in a chemical reaction that takes place in a low oxygen environment. The oxygen produced can be used in the basic oxygen furnace to produce steel.

The new system can be retrofitted to existing furnaces, with the addition of an array of additional gas-separators and heat exchangers required to support the perovskite splitter.

Source:https://www.steel-grips.com/738 researchers from-university-of-birmingham,-uk-,-show-novel adaptation-for-existing-furnaces could-reduce steelmaking-emissions-by-90 (10 March 2023)

Kobe's increased blast furnace efficiency

Japanese steel manufacturer Kobe Steel recently developed a new technique for producing steel in natural gas fired blast furnaces that use less coke, By adding hot briquetted iron (iron ore with the oxygen removed) to the blast furnaces as a fuel source at a precise ratio, Kobe claims to have perfected a way to maintain the efficiency of the CO_2 reduction process using less coke as fuel.

"It's an optimization of the distribution of substances that go into the blast furnace," said Masahiro Motoyuki, executive officer of Kobe Steel.

According to Kobe, the process reduces CO_2 emissions associated with production by about 20%. While this is not a final solution to the steel industry's carbon emission problems, Kobe is positioning this as a transitional technology to help reduce emissions while it develops major changes. "If you need to gradually get to zero emissions over 30 years, cutting your emissions by 20 percent buys 20 percent of the 30 years, so that gives you six years," he said. "That technology is only relevant for six years. They need more effective technologies installed very soon; otherwise, they're not on track. But they're actually reducing their carbon footprint, which is to their credit a lot more than most of the steel industry. It seems Kobe knows it has a time-line issue and is investing in other production technologies such as hydrogen in parallel with more efficient blast furnaces. Its U.S. subsidiary, Midrex Technologies, is working on natural gas blast furnaces that also can use hydrogen for a completely carbon-free process once there is enough hydrogen available for commercial steel use.

Source:https://www.greenbiz.com/article/3 innovations-green-steel (April 14, 2023)

SpaceX relies on stainless-steel for Starship Mars Rocket

Stainless-steel's high melting point is a major advantage when it comes to space travel. Aluminium or carbon fibre are limited to a steady-state operating temperature of 150 °C, with short periods operating at around 180-200 °C, but which lead to a weakening of the material. Some carbon fibres can operate continuously at 200 °C, but these come with compromises in strength.

Steels, with appropriate heat dissipation controls, can perform at temperatures as high as 820-870 °C. As such, an innovative steel-built system will be used for the Starship's heat shield, which protects the vessel from the high temperatures experienced during entry into a in an atmosphere such as that of the Mars or Earth.

The heat shield has two stainless-steel layers joined with stringers, with water flowing between them. The exterior has micro-perforations which then allow for water to 'bleed' out, keeping temperatures low through transpiration cooling.

In the cold darkness of space, the temperature sits at a frosty -270 °C. At these cryogenic temperatures, stainless steel's strength is increased by 50%. Its chrome-nickel content means it does not become brittle even at very low temperatures.

For an interplanetary rocket, high ductility, high toughness, and very little chance of fracture when operating in cryogenic environments, make the perfect material. These properties mean that less material can be used, lowering the weight and making the specific stainless-steel highly viable for space travel.

The Starship is designed for repeated use, with SpaceX claiming the vessel can be ready for relaunch just an hour after landing. With this in mind, the company's materials team has been working on a new stainless-steel alloy with higher chromium content. This 304L alloy is even more resistant to both corrosion and degradation making it perfect for the continued re-use required for planetary colonisation.

Source : https://worldsteel.org/steel-stories/innovation/spacex-relies-on-stainless-steel-for-starship-mars-rocket/

Recycled steel could herald new era for batteries

Researchers from the Chinese Academy of Sciences and Jilin University have developed an innovative, environment friendly method of recycling stainless steel to make new electrodes for potassium-ion rechargeable batteries.

Using an innovative technique, and under the guidance of Prof. Xin-bo Zhang, a team of scientists from the Chinese Academy of Sciences and Jilin University, used corroded stainless steel meshes as iron sources. These stainless steam-meshes were converted to develop stable, low-cost, high-performance cathodes for potassium-ion batteries.

The stainless steel mesh is immersed in an acid environment, which dissolves the iron, nickel and chromium ions. These are immediately consumed by excess ferricyanide ions in the acid to form a complex salt known as cubic Prussian blue on the surface of the meshes. The nickel and chromium in stainless steel make it the perfect alloy for this process.

Prussian blue is a dark blue pigment that is found as deposits on the surface of a mesh as scaffold-like nano-cubes. Thanks to this process, potassium ions can be stored in and released from these structures easily and rapidly.

According to Prof. Zhang's team, compared with existing cathodes of potassium-ion batteries, the as-prepared Prussian blue electrode shows excellent electric conductivity and a unique reduced graphite oxide-coated structure, which enables fast electron transfer and great cycle stability. This means increased stability during charge and discharge cycle, resulting in better battery performance.

Source : https://onlinelibrary.wiley.com/doi/full/10.1002/anie.201702711

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News Updates National

Tata Steel's NINL plant reaches 100 pc capacity utilisation within 1 year of acquisition

NINL, a 1.1-Mt steel manufacturing unit in Odisha, has reached 100 per cent capacity utilisation within one year of its acquisition by Tata Steel. On July 4 2022, the steel major completed the acquisition of Neelachal Ispat Nigam Ltd (NINL) through subsidiary company Tata Steel Long Products Ltd (TSLPL) for a consideration of Rs 12,000 crore.

After being shut for almost three years, operations at the NINL unit was started by Tata Steel in October 2022. "NINL has successfully ramped up production to its rated capacity of 1 Mt on an annualised basis within just nine months of its acquisition," Ashish Anupam, MD of Tata Steel Long Products Limited (TSLPL), told PTI in reply to a query on the progress in one year of acquisition.

The acquisition was efficiently implemented even though the NINL plant had been mothballed for nearly three years. In August 2023, the company will complete the commissioning of its last major facility, a coke oven unit at NINL, he said.

The Economic Times (4.7.23)

SAIL records best ever production in Q1FY24, posts 8% growth in crude steel output

Steel Authority of India Ltd (SAIL) said that it has achieved record-breaking performance in the first quarter of FY 2023-24 in terms of production and sales, the Ministry of Steel said in a release.

The company reported a growth of 8 per cent on-year in its crude steel production at 4.667 Mt during the Q1FY24, and saleable steel witnessed a growth of 8 per cent at 4.405 Mt during the same period. "The production of hot metal, crude steel, and saleable steel of 5.037 Mt, 4.667 Mt, and 4.405 Mt, respectively, marked the best ever first quarter results," it said.

The ministry also stated that SAIL attained its highest-ever sales performance in the first quarter by achieving a sales volume of 3.9 Mt, up 24 per cent during the same period last year. "This record breaking performance by SAIL has come up in the light of its continued focus on maximizing capacity utilization and meeting the customer demands," it added.

Earlier, World Steel Association (worldsteel) released data which said that India has registered a 4.1 per cent growth in its crude steel production at 11.2 Mt amid 5.1 per cent downfall in the global output at 161.6 Mt in May 2023. Despite a 7.3 per cent year-on-year (y-o-y) fall, it said, China remained the top steel producing country in May with 90.1 Mt crude steel production.

Financial Express (5.7.23)

JSW Steel aims to double capacity to 50 Mt in 3 yrs; renewables to power all plants : Sajjan Jindal

JSW Steel is aiming to nearly double its capacity to 50 Mt in the next three years, chairman Sajjan Jindal said. The city-headquartered company is also aiming to shift to renewable sources of power to fire the entire 50 Mt of production, Jindal said speaking at an event organized by the Bombay Chartered Accountants Society.

"Today, at JSW Steel we are at 28 Mt capacity and next year we will be 37 Mt capacity and (in) three years' time we will be 50 Mt capacity," he said. He said the company is also paying a lot of emphasis on sustainability and has devised a plan to completely shift its power usage to renewable sources.

"At JSW Steel, we would probably be the first steel company in the world which will be 50 Mt capacity and operate 100 per cent on renewable power, that is the plan we are doing," Jindal said. Jindal said as the company goes ahead with its planned capacity additions, it is already adding renewable power capacities in a departure from the conventional system of depending on fossil fuels like coal.

The Indian steel manufacturing landscape has come a long way and has the potential to be the supply centre for catering to world demand, Jindal said.

The Economic Times (7.7.23)

Steel companies' Q1 margins hit by rising costs, low prices

The operating profit of steelmakers is estimated to have dipped by ₹2,000-3,000 per tonne of metal sold during the April-June period compared to the preceding quarter, experts said. Steel prices and sales volume during the quarter dipped sequentially while input costs continued a northward march, resulting in lower profitability, they said.

"We expect the tug of war between the slowdown in the West and Chinese recovery expectations to continue to weigh on Indian metal equities," analysts at Kotak Institutional Equities said in a pre-earnings note.

Steel prices have fallen steadily through the quarter with the prices of benchmark hot-rolled coils (HRC) of steel a little above ₹55,000 per tonne at the end of June, as compared to around ₹60,000 at the end of March. The average price of HRC for the June quarter - at around ₹57,655 - is around 3% lower sequentially, and 17% lower on year.

Meanwhile, local prices of iron ore, a key input, have risen around 4% sequentially. This rise in prices is expected to impact players such as JSW Steel and Jindal Steel and Power relatively more as they have higher dependence on the open market for procuring iron ore. JSW Steel gets about 50% of its iron ore from captive mines while Jindal Steel gets about 40-50%, analysts said. Captive sourcing of iron ore is significantly higher for Steel Authority of India (SAIL) and Tata Steel.

Prices of coking coal, another key input, came down by a third during the quarter. However, steelmakers are unlikely to get the complete benefits because of a consumption lag. Steel producers are still using high-cost inventory of coal, because of which the effective cost of coal for the quarter is up by around $10-$20 per tonne sequentially, Edelweiss Securities said.

The Economic Times (6.7.23)

Tata Steel offers Rs. 83 lakh funding for R&D projects in low carbon segment

Tata Steel will fund research and development (R&D) projects in low carbon hydrogen segment under the partnership with British High Commission in India. As part of the 'UK-India Hydrogen Partnership Sprint Series', Tata Steel said it will grant 80,000 pounds (Rs 83 lakh) funding for two innovative projects in the low carbon hydrogen segment.

The initiative is open for participants from India and the UK, Tata Steel said in a statement.

The proposals bidding for the grant are expected to address two challenges: first, development and deployment of hydrogen technologies for greening the industrial sector and solutions for hydrogen storage/purification, the company said.

"The priority of the steel sector today is to decarbonise and do it in a way that is both technologically and economically sustainable.

"While the current levels of carbon footprint from the steel sector is unsustainable, the available version of clean hydrogen faces numerous challenges like high operational cost and energy loss," Tata Steel Vice President, Technology and R&D, Debashish Bhattacharjee said.

The Economic Times (14.7.23)

Indian traders scoop up cheaper Chinese steel, says industry executives

Indian traders have been scooping up Chinese steel at a deep discount, industry officials and analysts said, spooking Indian producers ahead of a seasonal pick up in domestic demand.

Lured by discounts of $30 to $50 a tonne on hot-rolled and cold-rolled products, Indian buyers are signing a flurry of import deals, they added. Domestic industrial activity is set to pick up over the next two months after the monsoon rains recede.

Indian traders are buying the grades used in automobiles and construction, main drivers of domestic steel demand, the officials and analysts said.

“The Chinese are offering discounts because other markets are not doing well and we are seeing good growth in Indian automobile and construction sectors,” said Snehdeep Bohra, a director at Fitch Ratings in India.

Traders near port cities in the eastern state of Odisha and the western state of Gujarat find it cheaper to import steel from China than spend on local freight, a senior executive at a major Indian steelmaker said on condition of anonymity.

The Economic Times (17.7.23)

India-Japan discussion steel decarbonisation and safety at bilateral

India and Japan have held bilateral talks for cooperation in the steel sector and to address decarbonisation issues. A statement issued after Steel Minister, Jyotiraditya Scindia and Japan's Minister of Economy, Trade and Industry, Nishimura Yasutoshi's meeting, said both decided to support the cooperation between the public and private sectors of the two countries.

“Both the sides stressed on the importance of pursuing a policy approach that takes into account the circumstances of each country's industry, with the underlying fundamental principle of pursuing both the economic growth and low carbon transition in the steel sector,” the statement said.

According to officials aware of the discussions, Japanese expertise in safety training for Indian steel plants was sought by Scindia. The Japanese sought India's cooperation in steel decarbonisation.

An official statement said both sides affirmed the importance of cooperation for achieving their respective net zero goals while recognizing the heterogeneity of steel decarbonization pathways.

Further discussions under a 'Steel Dialogue' and other cooperation programs have also been planned for November 2023. There will be due focus on innovative technologies for increasing energy efficiency and decarbonization of steel production.

The Economic Times (20.7.23)

Hindustan Zinc keen to participate in lithium auctions: CEO Arun Mishra

Hindustan Zinc Ltd (HZL) is keen to acquire lithium assets as and when they are put on the block for auctions, CEO Arun Mishra said.

Lithium reserves of about 5.9 Mt have been identified in Salal-Haimna areas of Reasi district in Jammu and Kashmir (J&K) for the first time in India.

Auctions of the said reserves are likely to be held in December. The J&K administration is also in the process of appointing a transaction advisor.

"Absolutely. Why not?" Hindustan Zinc is already in the base metal (sector). Whatever lithium asset will come it will be strategic interest, Mishra told PTI in reply to a question on plans of acquiring lithium reserves.

The CEO further said, "As base metals are our (company's) area of interest and lithium being one of them, we look forward to exploring the opportunities as such metals are going to be the future which will drive the new world."

The Economic Times (23.7.23)

Tata Steel Q1 profit falls 92% on Europe hit

Tata Steel has posted a 91.84% fall in consolidated net profit to Rs. 634 crore for the first quarter ended June, impacted by weak European operations, but was much ahead of analysts' estimates of the company posting a net loss.

The steel major had posted a net profit of Rs. 7,764.96 crore for the comparable year-ago period.

During the quarter under review, the Tata Group firm's consolidated revenue from operations fell 6.21% to Rs. 59,490 crore from Rs. 63,430 crore recorded in the year-ago quarter. A consensus estimate of Bloomberg analysts was expecting the firm to post a consolidated net loss of Rs. 122 crore on revenues of Rs. 56,338 crore, and Ebitda of Rs. 5,050 crore.

Financial Express (25.07.2023)

Our made-in-India chip will be ready in 2.5 years: Vedanta chairman Anil Agarwal

Vedanta group chairman Anil Agarwal said that first phase of its semiconductor project will involve USD 5 billion investment of the overall USD 20-billion outlay, and the venture will be ready with made-in-India chip in two and a half years. Vedanta is talking to three companies to rope them in as technology partners for its mega plans entailing foundary, chip manufacturing, and packaging and design.

"In 2.5 years, we will give you Vedanta made-in-India chips," Agarwal told reporters on the sidelines of SemiconIndia 2023 event.

The first phase of its semiconductor investment will be to the tune of USD 5 billion, which is being structured.

The Economic Times (20.7.23)

Tata Steel 1st Indian firm to use LNG powered carrier for raw material

Tata Steel became the first Indian company to use clean fuel Liquified Natural Gas (LNG) powered Capesize carriers for its raw material movement from Australia to India, the company said.

In an initiative to lower the company's Scope 3 carbon footprint, the steel major imported 1,65,700 metric tons of coal from Australia's Gladstone to Dhamra port in Odisha using MV Ubuntu Unity, a cape vessel powered by clean fuel LNG.

Capesize' is the largest class of cargo ship. They are called so as they cannot pass through the Panama Canal and have to go around the Cape of Good Hope to sail between the Pacific and Atlantic oceans.

"In 2021, Tata Steel became the first in the Indian Steel Industry to deploy a ship powered by biofuel. We continued the decarbonation drive with seven biofuel shipments in FY23. In continuation to our sustainability drive, in FY24, we are the first to deploy an LNG powered vessel for transportation of raw materials to India," said Peeyush Gupta, the company's Vice President, Group Strategic Procurement and Supply Chain.

LNG is cleaner compared to heavy fuel oil used in bulk ships. Tata Steel claimed that carbon emission for this voyage was around 35 per cent less compared to traditional Baltic specification cape vessels.

Business Standard (28.7.23)

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Government of India
Ministry of Steel
Udyog Bhavan, New Delhi 110011

National Metallurgist Awards (NMA)-2023

The National Metallurgist Awards are conferred by the Ministry of Steel, Government of India to recognize outstanding contributions in the metallurgical field, covering Operations, Research & Development, Waste Management and Energy Conservation. Individuals from Industry and Research & Academia can apply for the Awards.

The Awards will be given in the following four categories:-

1) Lifetime Achievement Award
2) National Metallurgist Award
3) Young Metallurgist Award
    a) Environment
    b) Metal Science
4) Award for R&D in Iron & Steel Sector.

Guidelines regarding eligibility criteria and other terms and conditions related to National Metallurgist Awards are available at **https://awards.steel.gov.in**

Application will only be received online through web portal **https://awards.steel.gov.in**

Receiving of applications is open from 07/08/2023.

The deadline for receiving the applications is 05:00 PM of 06/09/2023

This scheme is only for Indian nationals who have made contribution in the field of metallurgy in India through their work in industry, R&D or academia. Eligibility of candidate will be considered from 01/01/2023.

Chapter Activities — Bokaro, Kanpur, Kolkata, Jamshedpur

Bokaro Chapter

IIM Bokaro Chapter has started to host a series of technical talk related to Iron and Steel Industry. The 1st technical talk on "Identification of Flexible rotors and their balancing" was held on 24th May'2023 at Bokaro Steel Plant. The talk has been delivered by Shri Deepak Roy, CGM, CRM I&II, BSL.

Shri Deepak Roy delivering the Lecture on 24th May, 2023

Shri Deepak Roy was felicitated by the Bokaro Chapter

Kanpur Chapter

IIM Kanpur Chapter organised a technical talk on June 6, 2023 at FB421, Department of Materials Science and Engineering, IIT Kanpur. The talk was delivered by Prof. Surendra Kumar Makineni, Assistant Professor at the Dept. of Materials Engineering, Indian Institute of Science, Bangalore. The topic of the talk was "Correlative EM (electron microscopy) and APT (atom probe tomography) studies on defects, interfaces, and grain boundaries in multicomponent alloys".

Kolkata Chapter

1) IIM Kolkata Chapter organised four webinars in the month of June 2023.

Sl. No	Date	Speaker	Topic of the Lecture
1.	05.06.23	T K Chakraborty, Past Chairman, IIM, Kol Chp & Ex-ED, SAIL, Environment Management Division	World Environment Day Theme: Beat plastic pollution
2.	09.06.23	D Chattaraj, Ex-CEO, SAIL, Rourkela Steel Plant	Process Industry and Stakeholder Management
3.	17.06.23	P Raychaudhury, Life Member, IIM	Benefits of positive attitudes in industries
4.	24.06.23	Dr. A Majumder, Director, M &M, KNU, Asansol.	Quality Assurance in iron making

2) The first meeting of the new executive committee of The Indian Institute of Metals, Kolkata Chapter was held on 30.06.2023 evening at Metal House, IIM HQ in presence of Shri S K Basak (Chairman), Shri J K Chatterjee (Vice Chairman), Shri S K Dutta (Hon. Secretary), Shri Arnab Banerjee (Hon. Treasurer), Dr. J K Saha, Dr. Rajib Dey, Dr. Arga Majumdar and Shri B Nath (Executive committee members). The meeting was chaired by Chairman of the chapter and Dr A K Ray (Immediate Past Chairman & Permanent Invitee) and Shri B P Sarkar and Shri P K Sen (Past Chairmen & Invitees) also attended the meeting.

Jamshedpur Chapter

The Annual General Meeting of the IIM, Jamshedpur Chapter was held on July 27, 2023 @ Board Room, United Club, Jamshedpur. The new Executive Committee for the year 2023-24 has been formed which is as follows :

• Chairman	➢ Professor Ashok Kumar
• Secretary	➢ Dr G K Mandal
• Treasurer	➢ Dr Biraj Sahoo

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Upcoming Events National

1. **31st Prof. Brahm Prakash Memorial Materials Quiz 2023 &**
   Prof. Brahm Prakash Memorial Materials Lecture
   Organised by
   IIM Kalpakkam Chapter, Indira Gandhi Centre for Atomic Research Kalpakkam
   Dt : 8-9 September, 2023
   BPMML 2023 Speaker : Prof. B S Murty, Director IIT Hyderabad and VP-IIM
   E-mail : bpmmqkalpakkam@gmail.com
   Website : http://iim-kalpakkam.in

2. **77th Annual Technical Meeting of the Indian Institute of Metals (IIM-ATM) and International Conference on Metals**
   Organised by
   IIM Sambalpur Chapter, IIM Angul Chapter, IIM Bhubaneswar Chapter in association with Hindalco Industries Ltd and KIIT Deemed to be University
   Dt : 22-24 November, 2023
   Venue : KIIT, Bhubaneswar
   Contact : bibhu.mishra@adityabirla.com
   Website : https://iimatm.org/

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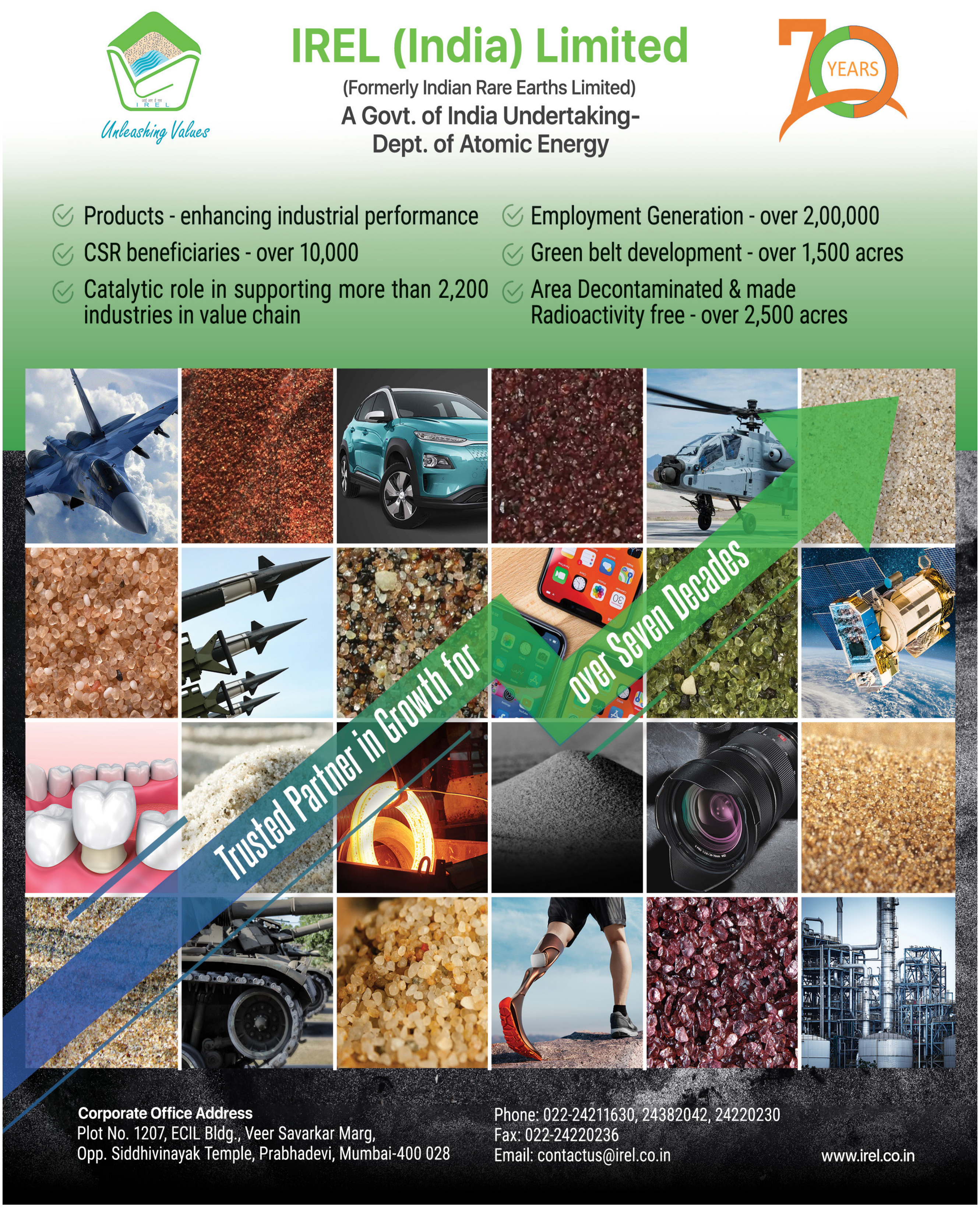
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Crude Steel Production June 2023 (World)

Crude Steel production by region

	Jun 2023 (Mt)	% change Jun 23/22	Jan-Jun 2023 (Mt)	% change Jan-Jun 23/22
Africa	1.3	11.5	7.6	4.1
Asia and Oceania	119.7	0.8	708.2	0.7
EU (27)	10.6	-11.1	66.3	-10.9
Europe, Other	3.7	-1.8	20.2	-14.1
Middle East	4.2	9.4	23.0	3.0
North America	9.2	-0.5	54.8	-3.5
Russia & other CIS + Ukraine	6.8	5.2	43.3	-3.4
South America	3.3	-12.4	20.4	-7.0
Total 63 countries	**158.8**	**-0.1**	**943.9**	**-1.1**

The 63 countries included in this table accounted for approximately 97% of total world crude steel production in 2022. Regions and countries covered by the table:

- **Africa:** Egypt, Libya, South Africa, Tunisia
- **Asia and Oceania:** Australia, China, India, Japan, Mongolia, New Zealand, Pakistan, South Korea, Taiwan (China), Thailand, Viet Nam
- **European Union (27)**
- **Europe, Other:** Macedonia, Norway, Serbia, Türkiye, 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, Russia, Ukraine
- **South America:** Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela

Top 10 steel-producing countries

	Jun 2023 (Mt)	% change Jun 23/22	Jan-Jun 2023 (Mt)	% change Jan-Jun 23/22
China	91.1	0.4	535.6	1.3
India	11.2	12.9	67.9	7.4
Japan	7.3	-1.7	43.8	-4.7
United States	6.8	0.5	39.9	-2.9
Russia	5.8 e	3.8	37.5	1.0
South Korea	5.5	-0.9	33.7	-0.5
Germany	2.9	-8.4	18.5	-5.3
Iran	3.2	17.4	16.1	4.8
Brazil	2.6	-12.5	16.0	-8.9
Türkiye	2.9	-1.5	15.9	-16.3

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

Source : worldsteel.org

Production (unit : Lakh Tonnes)

	Jun'23	May'23	Apr'23	2022 - 23	2021 - 22
ALUMINIUM					
National Aluminium Co Ltd	0.39	0.40	0.39	4.60	4.60
Hindalco Industries Ltd*	1.09	1.13	1.09	13.22	12.94
Bharat Aluminium Co. Ltd	0.48	0.49	0.48	5.69	5.80
Vedanta Ltd	1.43	1.49	1.43	17.22	16.92
TOTAL	**3.39**	**3.51**	**3.39**	**40.73**	**40.26**
*Renukoot, Hirakund, Mahan, Aditya					
ZINC (One major producer)					
Hindustan Zinc Ltd	**0.69**	**0.70**	**0.70**	**8.21**	**7.76**
COPPER (Cathode)					
Hindustan Copper Ltd	0	0	0	0.000073	0.62
Hindalco (Birla Copper)	0.25	0.18	0.28	4.07	3.59
Vedanta Ltd.	0.10	0.13	0.08	1.48	1.25
TOTAL	**0.35**	**0.31**	**0.36**	**5.55**	**4.85**
LEAD					
Hindustan Zinc Ltd	**0.16**	**0.18**	**0.17**	**2.11**	**1.91**

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

Prices in India (as on 31st July, 2023)

(Mumbai Local Price in Rs. / kg)

Product	Rs. / kg	Product	Rs. / kg
Copper Armature	706	Aluminium Ingot	207
Copper Cathod	765	Aluminium utensil	170
CC Rod	775	Zinc Ingot	225
Copper Cable scrap	730	Lead ingot	185
Brass Sheet Scrap	518	Tin Ingot	2420
Brass Honey Scrap	500	Nickel Cathod	1843

Source : https://mtlexs.com/

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NOTE : Due to the continuous Research and Developments, Technical Specifications of above all Creep Testing Machines, may change without any notice.

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