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Technical Article

Indigenization of Alloy 800 (UNS N08800) Steam Generator Tubes for 700MWe PHWRs

K V K Deshpande, N Harsha, S V Ramana Rao, R K Chaube, M V Ramana, Komal Kapoor

Abstract

Alloy-800 (UNSN08800) grade Steam Generator (SG) tubes are selected for Indian PHWRs due to their inherent properties, including resistance to SCC & high temperature strength. These tubes are very well suited to for Condenser and Heat-exchanger applications. With the sanction of Fleet mode PHWRs (10 x 700 MWe) by the Government, requirement of SG tubes has grown multifold. These are 26 mtr long tubes, cold worked in finished condition to enhance Mechanical strength and subjected to rigorous quality tests including ECT, UT, IGC, SCC, Tensile Testing at room & elevated temperature, etc. Tubes qualified against these stringent tests are U bend into wide range of radii from 91 to 1014 mm CLR and further subjected to shot peening on external surface to improve resistance to SCC. NFC has developed complete in-house facilities for indigenous manufacturing of SG tubes. With the successful supply of over 32,000 tubes, NFC has established bulk production of these tubes for self reliance of the Indian Nuclear Power program under ***'Atma Nirbhar Bharat'*** *Mission.*

1.0 Introduction

Alloy-800 (UNSN08800) is used in the Nuclear Steam Generators as tube material for its inherent properties including Stress Corrosion Cracking resistance and high temperature strength. The tubes of Alloy-800 are very well suited for Condenser and Heat-exchangers applications. In Nuclear Power Plants it resists carburising environment in primary circuit due to ^{14}C produced by (n,α) reaction from ^{17}O in the coolant water and by (n,p) reaction of ^{14}N present as an impurity in Zircaloy clad and Fuel. Thus this material is preferred over conventional Austenitic Stainless Steel grades (ASS) in Nuclear Power plants. Unlike ASS, this material is resistant to Stress Corrosion Cracking (SCC). The material is well studied with respect to its corrosion, mechanical properties and creep properties. Tubes for Steam Generators are required in U bend form with external surface shot peened to further strengthen resistance to SCC. Finished tubes are in cold worked condition for improved strength (mechanical properties).

Tube fabrication starts with hot extrusion of mother hollows from forged and machined round billets followed by multiple cold reduction steps with combination of pilgering and drawing. Each cold reduction step (except final drawing) is followed by mill-Annealing, which typically consists of passing tube lengths through a furnace on a travelling belt at temperatures high enough to recrystallize the material and dissolve all the carbides (~1000°C). Final size of tubes is cold worked through drawing process with optimum cold work to achieve enhanced Mechanical properties (YS & UTS) along with specified ductility. Chemical composition of the Alloy-800 used in the SG tubes for the Nuclear Power Plants is modified by controlled addition of Ti for stabilization (Table-1). Alloy-800 Nuclear Grade (NG) as compared to the standard ASTM grade specification has lower Carbon content to minimize sensitization, an increased stabilization ratio (Ti/C: ≥12, Ti/(C+N): ≥ 8, N: ≥ 0.03), and marginally increased Chromium and Nickel contents to achieve a higher resistance to pitting and Trans-Granular Stress Corrosion Cracking (TGSCC). Alloy-800 (NG) also has higher resistance to caustic induced SCC and it is almost immune to Pure Water SCC (PWSCC).

Ternary phase diagram at 400°C for Fe-Cr-Ni is given in Fig. 1 which shows Alloy 800 and series of other alloys containing varying Ni and Cr content. Alloy 800 is a γ solution strengthened alloy which is designed for corrosion resistance under severe environment. The γ-phase consist primarily of small

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coherent precipitates embedded in FCC matrix. The precipitates, denoted as γ', have an L12 crystal structure based on the Ni_3Al ordered compound which are solutionised in the final annealing. Fig.2 shows the as-solutionised material with absence of any precipitate after annealing. The finished tubes are cold worked to a small extent to increase the Tensile properties. There is no change in the microstructure during this cold working i.e. drawing. Higher carbon content requires a higher mill-annealing temperature to dissolve all the carbides. Undissolved Inter granular carbides are undesirable because they provide nucleation sites for the dissolved carbides and prevent precipitation of the carbides on the grain boundaries and, therefore, prevent appropriate grain boundary carbide coverage. The mill-annealing temperature controls the material yield strength and in turn the residual stresses.

Table1: Chemical composition of the Alloy 800 tubes

Element	Specification (%)	Typical (%)
C	0.03 max	0.028
Si	0.3-0.7	0.68
Mn	0.40-1.0	0.90
P	0.015max	<0.01
S	0.015max	0.001
Co	Aim for 0.015 max	0.005
Al	0.15 to 0.45	0.3
Ti	0.6 max	0.45
N	0.03 max	0.0095
Cu	0.075 max	0.005
Cr	20-23	22.8
Ni	32-35	34.3
Fe	Remainder	Remainder
Ti/C	12 min	16
Ti/(C+N)	8 min	12
(N+P)	0.045 max	0.0195

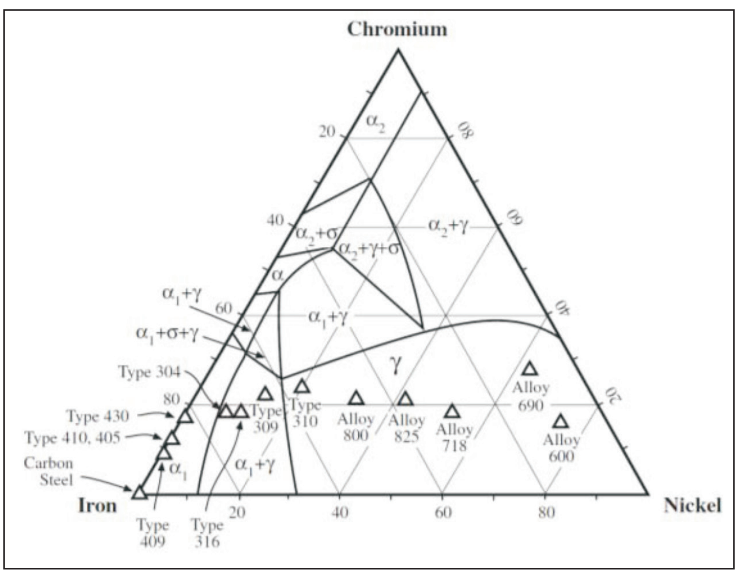


Fig. 1 : Ternary phase diagram showing the Fe-Cr-Ni and Fe-Cr alloys, Alloys of interest to steam generators superimposed on Fe-Cr-Ni ternary diagram for 400°C [9]

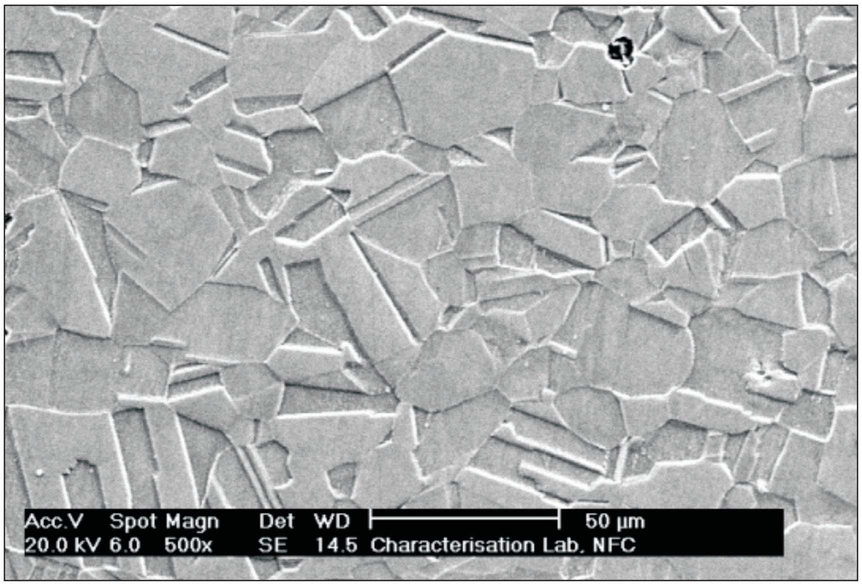


Fig. 2 : Microstructure of solutionised Alloy-800 showing single phase austenitic structure and absence of any intermetallic precipitates.

2.0 Indigenous Development

Alloy-800 tubes are one of the most critical tubes in the Nuclear Power plant. These tubes with lengths up to 26m are required in U bend and shot peened surface condition for the 700 MWe PHWR Steam Generators (SGs) under construction by NPCIL. Alloy-800 is used in the Nuclear Steam Generators as tube material for its inherent stress corrosion, creep and high temperature strength properties. Erstwhile these tubes for all the earlier reactors were imported. The challenging task of indigenous development and supply of these critical tubes on par with international quality standards was taken up at NFC, Hyderabad. The development of these tubes began with a pilot order from NPCIL for Alloy-800 U bend tubes for 700 MWe PHWRs covering all the bend radii required for fabrication of the Steam Generator. This was followed by a bulk order from M/s. L&T for 8 sets of SG tubes (~20,000 tubes) and 3 sets (~7500 tubes) from BHEL. Presently, manufacturing of tubes for 40 sets of SGs for NPCIL under Fleet mode (10x700 Mwe PHWRs) is in progress.

Specification requirements w.r.t. dimensions, chemical composition, mechanical, metallurgical, corrosion properties, residual stress, etc. are stringent to avoid any failure during service. Finished U bend tubes having 19 mm OD x 1.1 mm wall thickness and length up to 26m are formed into wide range of bend radii (total 72) starting from 91 to 1014mm, with one bend radius at every 13mm interval. Specifications for U bend tubes are stringent with respect to tolerance on bend radius, leg spacing (2R), ovality & out-of-roundness in the bend region. Further, the finished tubes after U-bending are subjected to Hydrostatic pressure testing (250 bar) followed by Glass bead shot peening on entire external surface, on bend region as well as on both straight legs to induce residual compressive stresses up to a minimum depth of 0.12 mm. The finished tubes before bending are tested with stringent reference standards in Eddy Current with 0.8 mm dia. through holes instead of ASTM specification of 1.5 mm dia. and Ultrasonic Testing with 100µm depth, 1.5 mm length, saw tooth notch with 60o angle. Also, finished tubes required with enhanced yield strength and low corrosion rate are tested for IGC as per ASTM G-28 and SCC as per G-36.

3.0 Manufacturing Process of Alloy-800 Steam Generator Tubes :

The development of process route was divided in two stages, Ist to manufacture straight tubes of length up to 27 m meeting all the stringent requirement of dimensions, chemical composition, mechanical properties, corrosion properties, NDE, etc. and IInd stage of development of two new processes namely

'U bending' and 'Glass bead shot peening'. These facilities were not existing prior to taking up this important work.

3.1 Manufacture of long straight tubes :

The specifications for procurement of raw material in the form of forged and solution annealed rounds were arrived at considering the variables during thermo-mechanical processing and final product specifications. Thermo-mechanical processing consists of hot extrusion followed by cold working which include a combination of pilgering and drawing with intermediate and final heat-treatment. The forged rounds were procured after conducting requisite checks for its soundness, inclusion rating, carbide precipitation, grain size, chemical composition, etc.

Alloy-800 is having poor hot workability because of its low thermal conductivity due to presence of γ' precipitates such as Ni_3Al, $Ni_3(Ti, Al)$ and carbides precipitates such as TiC and $Cr_{23}C_6$. The presence of the precipitates in Alloy-800 and relatively higher grain size in as received forged billet are responsible for its relatively higher elevated temperature strength and hence characteristically difficult to extrude. Extrusion parameters such as temperature, strain rate, lubrication and container preheating temperature were optimized to successfully produce mother blanks from these rounds.

To meet the final stringent Ultrasonic testing requirement, extruded blanks were subjected to extensive conditioning on internal as well as external surface. Internal surface was conditioned by means of honing and external surface through machining. Such conditioned blanks were ultrasonically qualified for its soundness and taken up for further processing by cold pilgered in three stages to the pre-final size, followed by final drawing with controlled cold work to meet the enhanced Yield strength specifications. The intermediate cold work process parameters such as area reduction, lubrication, tooling design and heat treatment parameter such as soaking time, temperature and atmosphere were optimized in order to achieve consistent quality of tubes with close control on dimensions, surface finish, corrosion properties, (IGC rate < 0.6mm/Yr) and SCC resistance. The final cold work imparted through drawing was established successfully to achieve enhanced yield strength. With this development, plant has achieved recovery of around 80%.

3.2 Development of U bending process :

The finished straight tubes tested and accepted in all aspects such as ECT, UT, dimensions, ID boroscopy etc having length up to 27 m are required to be bent to 72 different radii varying from 91 to 1014 mm. This was performed on a special purpose bending machine having innovative tooling concept of both individual bending dies and inverted truncated cone type dies. These inverted truncated cone type dies have a special feature of achieving continuously adjustable bend radius by varying plane of bend to achieve the desired bend radius. Thus, a single cone die caters to several bend radii thereby reducing tool change over time and more importantly saving in terms of tool inventory. The machine also has a feature of bending tube with or without mandrel. The machine is designed to impart bending angle up to 230^0 with a provision of imparting pre-bending of $10\text{-}15^0$ bending angle to accommodate higher spring back, specially while bending higher bend radii to achieve bend angle of 180^0. The process parameters for bending such as angle, radius of bend were optimized to carry out bending of all 72 different radii meeting the stringent dimensional specifications like tolerance on bend radii (±0.75 mm), ovality (<5%), out of roundness (<6%), wall thinning , etc.

3.3 Development of Glass Bead Shot peening process :

Finished tubes after U bending are subjected to Glass Bead shot peening to induce residual compressive stress on the external surface up to a depth of 0.12 mm (min), to impart improved resistance against SCC while limiting the external surface finish within 3.3µ Ra as per the specifications. This was a new process inducted into the production line. A special purpose automated Glass Bead shot peening machine (Fig-3) was developed indigenously, having 3 sets of nozzle assemblies housing 3 nozzles placed at 120^0 configuration (Fig-3a) for uniform blasting over entire external surface covering bend region and both straight legs of U bend tubes of 72 different radii (91 to 1014 mm CLR). The process parameters such as Glass bead media i.e. 'C' Grade

(Fig-3b), blasting pressure, linear speed, etc. were optimized and established through extensive performance tests involving measurement of residual stress pattern of shot peened tubes across section as against the operating parameters, using X-ray diffraction technique. With the optimized parameters, tubes of various bend radii were shot peened consistently meeting all the specification requirements of residual compressive stress up to desired depth, while maintaining the surface finish within the specified limits.

3.4 Inspection & Testing of tubes:

During the development of the process flow sheet, several trials were carried out for meeting the quality requirement. While establishing the processes, array of inspection, testing techniques were developed, essential inspection and testing equipment were designed, developed and commissioned successfully, to achieve the quality requirements and match the production capacities. Following is a brief description of the inspection and testing carried out for meeting the stringent specifications.

a) UT of OD machined & ID honed tubes:

In order to improve the acceptance (%) i.e. the ratio of number of tubes accepted against tested in UT at the finished stage, several experimental process studies were carried out. The typical defects observed in the final stage were traced back to be originating from the extruded material. Standards for ultrasonic testing for extruded tubes after OD machining & ID honing stage were established. Regular feed-back to production regarding material to be removed from OD and ID of extruded hollows was given by analyzing the defects intercepted by UT. The feed-back process along with the extensive analysis of UT defects in the extruded hollows resulted in improvement of acceptance in UT from 50% in the initial lots to 85% in the subsequent lots after its successful implementation.

b) Ultrasonic testing of tubes :

A high-speed UT system with advanced testing features was needed for carrying out Ultrasonic testing in the final stage, in order to meet the production rate. Existing equipment for UT at NFC was capable of testing at low speeds i.e 1 m/min, limiting the testing capacity. To overcome the limitation, specifications of high speed system were evolved and new system was procured. The advanced UT system could be developed through extensive interactions and feedback with the equipment manufacturer (Fig-4). This system was installed, successfully commissioned and established for testing of Alloy-800 tubes at higher speeds (4-5 m/min) which could be achieved through several modifications as compared to the existing system at NFC.

Fig. 3 : Glass Bead Shot Peening m/c

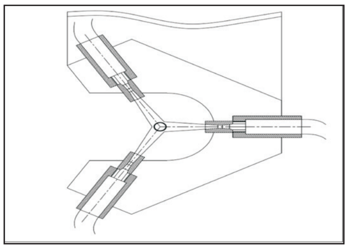


Fig. 3a : Nozzle configuration

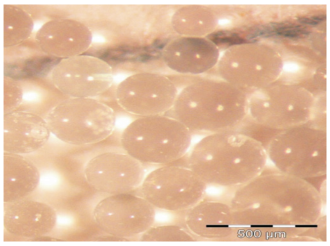


Fig. 3b : Glass Bead media

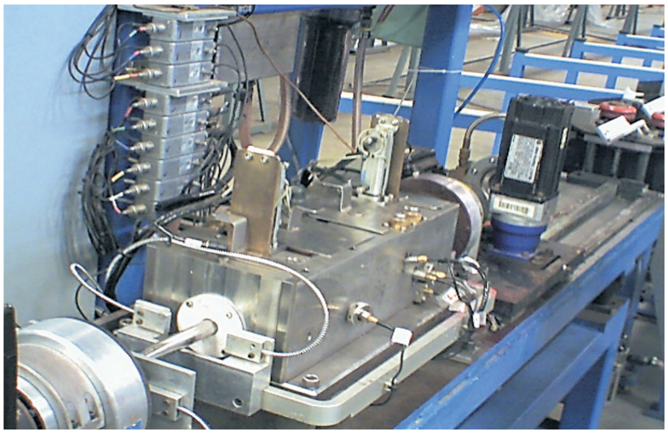


Fig. 4 : High speed Ultrasonic testing m/c.

c) Eddy current testing of Tubes :

Against the conventional 1.5 mm dia through hole as the reference standard, a stringent standard with size of 0.8mm dia hole was required as per customer specification. An automatic tube handling system with defect marking for long length tubes was used for testing. This Eddy current unit with specially developed sensing coil and tube handling system was developed indigenously and installed for testing of SG tubes.

d) Pressure testing of U bend tubes :

A new automated Hydrostatic Pressure Testing system for U bend tubes with combined end cutting after pressure testing was developed indigenously and was commissioned (Fig-5) for testing of tubes at 250 bar pressure using DM water of low conductivity as per specifications.

e) Bending Qualification :

Qualification of bending involves extensive testing of minimum radius bend formed over Ring dies & Cone dies (Fig-6) including dimensional measurement i.e. bend radius, leg spacing (2R), flatness, outer diameter, wall thickness, Hydrostatic Pressure Testing (HPT), Liquid Penetrant Test (LPT), ball pass test, visual Examination of internal surface, Surface finish, wall thinning, ovality, out of roundness, optical illustration & hardness in the bend region. Bulk manufacturing can only be commenced after successful qualification of Bending process as per specifications. Dimensional parameters including bend radius, leg spacing ovality, out of roundness are checked at regular interval during production as a part of Process Control.

f) Special purpose out-of-roundness measuring unit :

Measurement of out-of-roundness is required for all the tubes with bend radius ranging from 91 to 1014 mm. The measurement needs to be carried out at different sections in the bend portion, to verify extent of distortion during the forming operation. A Non-destructive roundness measurement unit (Fig-7) especially designed at NFC was successfully qualified and adopted for measurement of out-of-roundness (limit < 6%) which is a critical parameter for the U bend tubes.

Fig. 5 : Pressure testing Unit

Fig. 6 : U bending over Conical dies

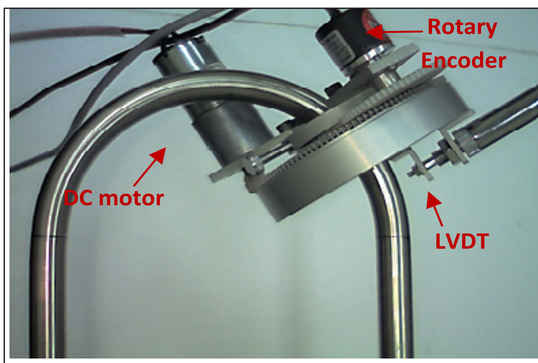
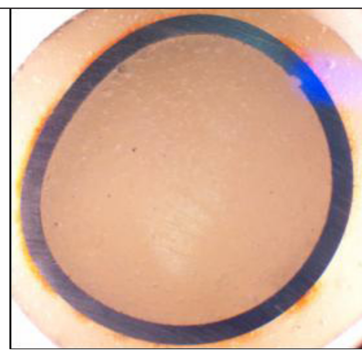
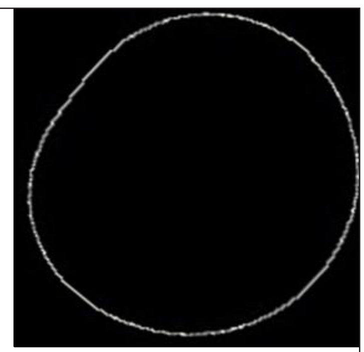


Fig. 7 : Out of roundness measurement gauge for U bend tube



Profile in section of bend region as seen in a section in a section in Metallograph



Profile at bend region as generated by the gauge

g) Shot Bead Peening qualification:

As per specification for the peened surface quality, compressive stresses, have to be present up to a minimum depth of 0.12 mm from tube outside surface, both in the straight and bent portions of the tube. Stress profiles of the shot peened samples with set of blasting parameters were analyzed at the OD (outside of the bend) and ID (inside of the bend) as a function of depth for the U bend region. Optimum blasting pressure and linear speeds were established after multiple experimental trails, to consistently achieve the required compressive stresses in the bend region as well as the straight legs.

h) Measurement of residual stress profiles:

Establishing the depth of residual stress induced through shot peening over the external tube surface, requires generating profile of residual stress in the tube along the depth from OD. A new method using X-Ray diffraction (Fig-8) was developed to evaluate the residual stresses along the thickness. The profile of stress was measured by carrying out successive removal of layers from the OD surface using electro polishing technique. This method was used to qualify the shot bead peening operation as well as for regular measurement of Stress in the Production lots.

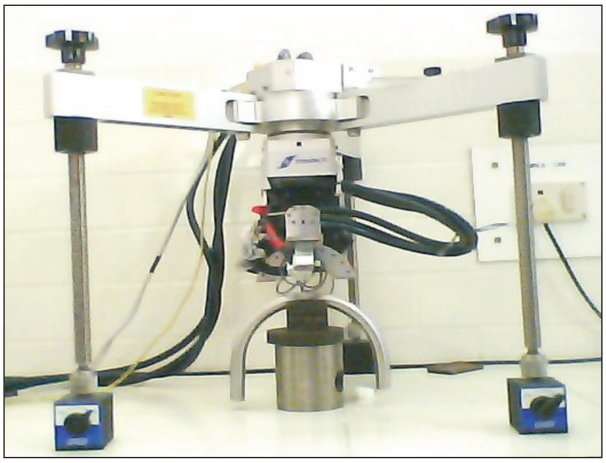


Fig. 8 : XRF Stress Measuring Unit

i) Dimensional inspection of U bend tubes using gauge block :

In order to measure the dimensions of the U bend tubes e.g. radius, leg spacing, leg length difference, etc. a special purpose gauge block, suitable for all 72 radius ranging from 91 to 1014 mm was designed and commissioned at NFC.

j) Straightness measurement on surface plate (13m long) :

One of the critical requirements of the U bend tubes is straightness measurement. This requires a very long surface plate with precise alignment along the length. A Granite surface plate (Fig-9) with 8 precisely crafted blocks, aligned over 13m length was developed indigenously and installed with an accuracy of 50 microns over the entire length for measuring the straightness of the U Bend tube.

k) Visual examination using boroscopy:

Each tube with length of nearly 26 meters was examined by ID boroscopy. Special purpose long length ID video-scope was used to examine the ID surface of the tubes (Fig-10) at high magnification (10X).

l) Metallurgical, Corrosion, Mechanical and Chemical tests: Stress corrosion testing in boiling liquid $MgCl_2$ is one of the most crucial test for this material. This test was carried out on the U bend tube to certify its resistance against stress corrosion cracking. Product Chemical analysis, Metallography, grain size, IGC, SCC and tensile testing at room (RT) as well as elevated temperatures (HT @350^0C) were carried out for these tubes as required in the specification.

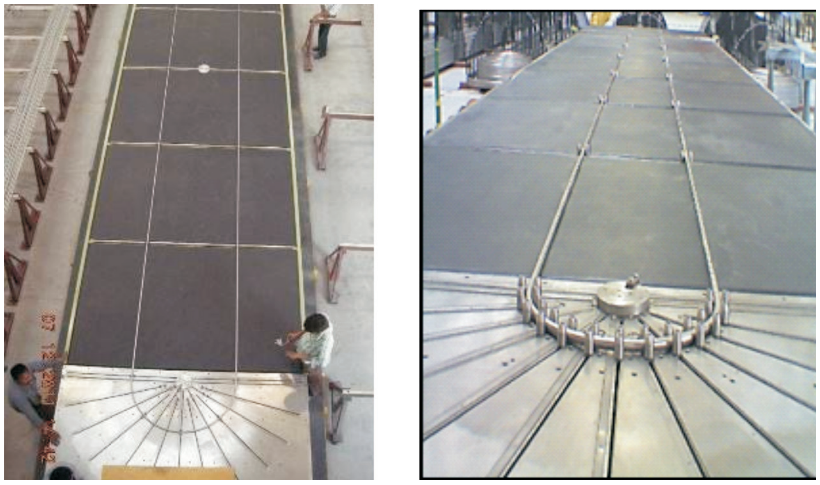


Fig. 9 : Surface Plate Gauge Block for U bend tubes

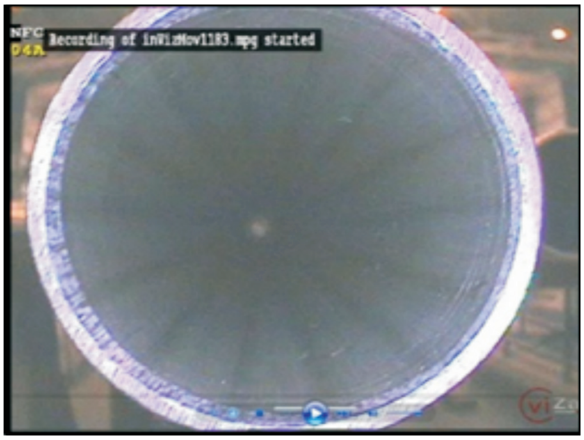


Fig. 10 : Boroscopy of 26m long tubes

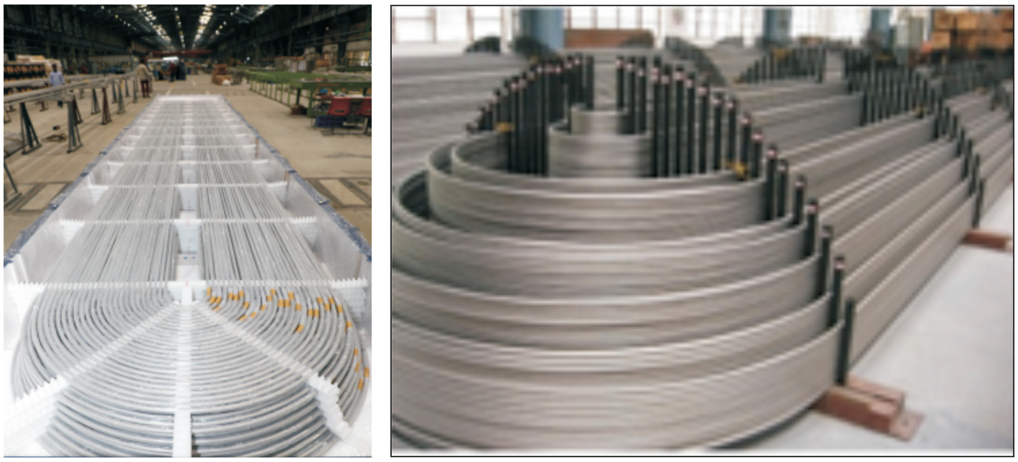


Fig. 11 : U Bend Storage Racks

3.5 Storage, checking & Packing of U-bend tubes

Packing is one of the most critical operations in case of SG tubes, as total 2489 Nos of tubes covering 72 different bend radii (91 to 1014 mm CLR) required for one set of Steam Generator are to be packed in 89 rows with alternate odd (91,117,143....1001mm) & even (104,130,156....1014) radii series configuration, distributed into 13 boxes as per the sequence of tube insertion during final assembly for fabrication of Steam Generator. Tubes are manufactured radius wise i.e. total quantity for each bend radius for full set at a time. Tubes cleared in all respects including QS are stacked radius wise in specially fabricated U bend storage racks (Fig-11). During packing, tubes of required radii from the storage racks are taken out row by row, thoroughly cleaned and placed on to layout checking fixture (Fig-12) with supports placed at specified distances for simulating the assembly condition, as per Grid baffle position of the SG. Each tubes is internally sealed at two locations from each end (100 mm & 300 mm from both the open ends) using special threaded halogen free plastic ID plugs. Both the open ends are closed with a halogen free plastic end cap. This is followed by polythene tube sleeving over the entire length and final heat sealing at both ends. Sealed tubes are then placed in structurally reinforced plywood box in alternate even and odd radii layers (Fig-13) with grooved foam spacers between each layer at regular interval along the length of the box. Thus the triangular pitch required for assembly of the Steam generator is maintained during packing. Total, 2489 tubes packed in 13 boxes along with necessary documentation after obtaining QS clearance & Shipping Release is supplied to the fabricator for further assembly of the SG.

Fig. 12 : Layout check fixture

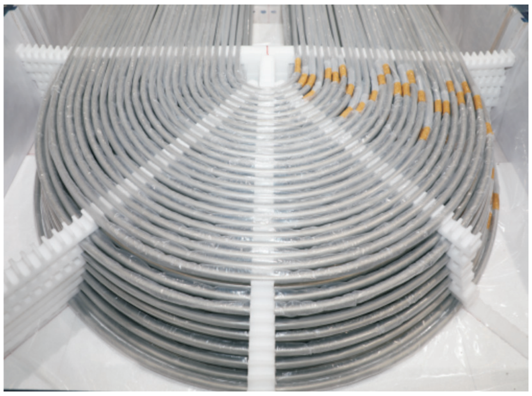


Fig. 13 : Even & Odd row packed

4.0 Conclusion

With the above developmental works, NFC has established complete set up for manufacturing of Steam Generator tubes for Nuclear applications and has successfully manufactured and delivered 32500 U Bend tubes for total 13 sets of Steam Generators. Manufacturing of 3rd set against 40 set order for Fleet mode PHWRs is under progress. This has led NFC to become the fourth manufacturing unit in the world having capability to manufacture Steam Generator tubes for Nuclear application.

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Technical Article

Charpy Impact Bend Test: Peculiarities and Significance

V Yu Filin[1]

Abstract

Carbon and low-alloyed steels with body centered crystalline (BCC) structure have their minimum service temperatures (T_{min}) due to the ductile to brittle transition phenomenon. Fracture of structures initiate in areas of high stress stiffness at acute concentrators including flaws. Stress stiffness may be assessed as $\eta = \sigma_1/\sigma_i$, where σ_1 is the primary stress, σ_i is the stress intensity (equivalent stress). The resistance to cleavage fracture is related to the property of metal to withstand high strain before fracture at lowered temperatures. The main acceptance parameter of steels in question is the impact energy obtained with standard Charpy specimens tested as per ASTM E23, ISO 148-1 or national standards. This is the only acceptance parameter that is useful to estimate T_{min}. The impact test temperature T_{test} and striker radius should correspond to the specifications while the acceptance impact energy value in Joules is usually close to 1/10 of the yield strength σ_Y in MPa. This research investigation is to clarify some important points related to the test procedure, requirement and significance.

Keywords: Charpy Impact Bend Test Procedure, Fracture Mechanics, Crack Initiation and Arrest.

1. Background

The idea of bend tests of specimens in unnotched condition by the impact of a pendulum hammer was suggested by S.B.Russell in 1896. In 1901, Georges Augustin Albert Charpy redesigned the hammer and suggested notched specimens that allowed for getting stable results. Impact energy is easy to calculate as a difference of the initial and final potential energies of the pendulum that are determined by its elevation or angle. Several types of specimens with different sizes were tried; thereby selecting the main specimen type with 10×10 mm full cross section, length of 55 mm and the span length of 40 mm.

Notch radius in specimens can vary depending on the intended objectives. U-type notch of 1 mm radius was suggested by Augustin Mesnager. It was expected that a big radius will pass through a larger number of grains of metal with the aim of finding the weakest grain. However, the stress stiffness of such specimens makes only $\eta = 1.56$ while V-notch with 0.25 mm radius (Charpy V-notch, CVN) allows to attain η up to 2.7 that is close to the ultimate values at acute concentrators in structures. CVN specimens allow for better characterization of the behaviour of metal so they are commonly used since the 1960s for testing steels. The required impact energy values were initially set empirically [1], CVN energy became an acceptance parameter during the same years.

The first edition of IACS UR S6 [2], in the year 2002, formulates the requirements for the application of steels for ship hulls operated in different climatic conditions. In this report, steel grades characterized by the min yield strength, σ_Y (MPa), T_{test} (°C) and max thickness S (mm) are tabulated against T_{min} (°C). In Russia, similar requirements were formulated in 1990 and can be found in RMRS Rules [3].

2. Peculiarities of the test procedure

A precooled specimen is placed on the anvil of a pendulum hammer and subjected to an impact with the velocity about 5 m/s. The tested piece may be measured to find other parameters in addition to impact energy. After an audit of many test laboratories, some hints may be formulated for simple self-checking of the result accuracy. In general, standard specimen thickness is 10 mm and for thin products, subsize specimens are considered

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carrying out these tests. In case of subsize specimens, there is no linear dependence of impact energy and thickness because a portion of plane state of stress in specimen ligament increases. Therefore, it would be inappropriate to test subsize specimens (for example-5 mm thick specimens) and double the impact energy values in the reports (private communication). Based on the personnel experience of the author who has performed audits in the test laboratories, following checks are supposed to be conducted before carrying out the impact tests:

(1) Specimen orientation: In case of rolled products, specimen orientation, i.e., in relation to the rolled surface is essential and shall be followed as per specifications (Figure 1a shows a case when the notch was erroneously made from the surface instead through-thickness). Specimen dimensions must be within standard tolerances including the length and notch position relating to the length. The notch shall be at the centerline because different length of specimen sides causes different forces of inertia during the impact. As the simplest check, one may take a couple of specimens and put them together side by side to check that the lines of notches coincide. Subsequently, turn the specimen to 180° other side and check the centerline again. If the lines of notches again coincide than the specimens are testable (Figure 1b).

(2) Notch configuration: Notching may be performed by milling with a toothed wheel or a diamond wheel, by a single turning cutter, by broaching or electric discharge machining (EDM). These tools introduce different strain into the specimen (hardening) around the notch that may result in difference in the impact energy obtained [4]. EDM is the most expensive and slow method but it introduces no strain. All other methods are good when the tools are sharp and new. A special attention should be paid on the back angle of every cutting tooth. If this angle is zero, left out metal cannot be properly removed which may causes increase in hardening of the metal. Broaching is therefore good for mild steel but for extra strength steel special broaches have to be used. A case was witnessed by the author when an old broach applied led to the dramatic impact energy decrease while the notch shape seemed to be excellent (private communication). Therefore, it is suggested to perform a mini round robin exercise with notch preparation in different laboratories and getting the samples tested in certified laboratories. Only after checking the consistent values of impact energies (with acceptable deviation), the notch preparation should be given a go ahead. Notch shape is usually checked with a shadowgraph. In this case an operator sees the minimum notch dimensions throughout the specimen thickness. On contrary, if

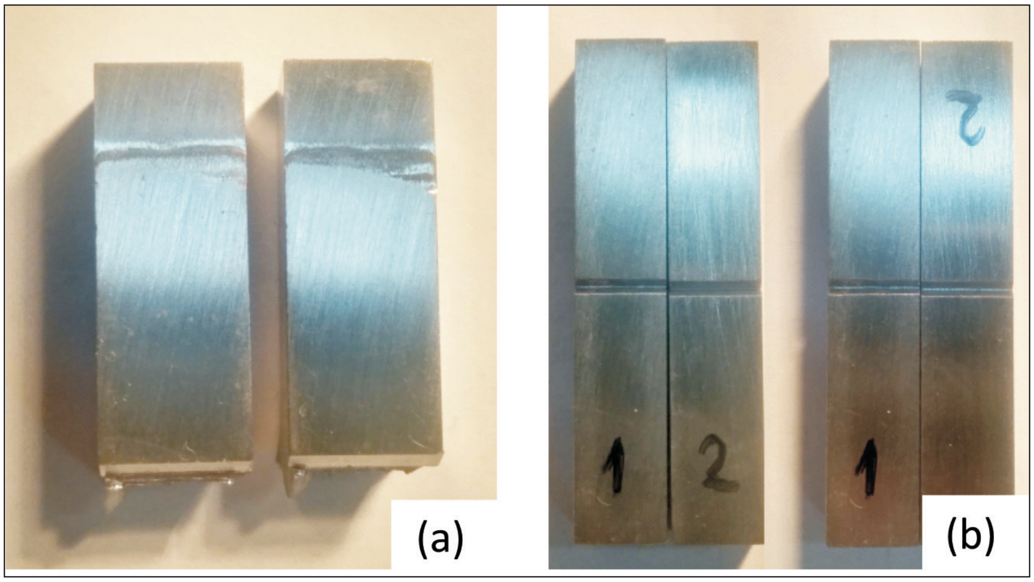

Fig. 1 : Photographs of CVN samples showing (a) irregular notch and (b) both sides of CVN specimens displaying the centerline of notch.

an optical microscope is applied, an operator clearly sees the nearest specimen surface. Therefore, these two methods may give different results for the same test piece. The simplest way to check the notch shape is a use of go/no-go templet.

(3) Pendulum hammer: A pendulum hammer may have two different types of strikers, 8 mm radius (American) or 2 mm radius (European). Many researchers have reported that the impact energy may be different with these strikers [5-7]. A thorough check of the test machine includes an inspection of the surfaces of the anvil and striker for wear, an inspection of anvil traces on a tested dummy specimen - these traces must be symmetrical in relation to the notch (Figure 2), otherwise specimen alignment is invalid. A hammer drop without a specimen allows to assess the energy loss due to friction that shall be less than 0.5 Joule. A case was recently witnessed by the author in a newly opened laboratory (private communication) when metallic chips were found inside the machine directly on electric controls. It appeared to be drilled in order to screw a safety fence. This exercise may lead to a short circuit and therefore, it attracts to the safety related issues in the overall testing. As far as the working range of the pendulum is concerned, it usually makes 10 to 90 per cent of its maximum capacity, otherwise the test results are considered invalid. To increase the working range, hammers with detachable weights are applied.

3. Concept of crack initiation resistance

In a component or a structure, 'crack initiation' refers to the stage when a macrocrack extension starts in a stable manner. An application of shipbuilding steels since 2002 is regulated by the document of International Association of Classification Societies, IACS UR S6. It gives T_{min} values depending on strength, thickness and T_{test} of impact bend. No reference is given to the background of these requirements, but a fracture mechanics-based approach may be in brief described as follows:

One of known empirical correlations of CVN and K_{Ic} fracture toughness applicable from the lower shelf CVN values up to the half of the upper shelf CVN values was suggested by Barsom and Rolfe [8]:

$$K_{Ic}^2 / E = 0.000222\ \mathrm{CVN}^3 \qquad (1)$$

where K_{Ic} is measured in MPa·m$^{0.5}$, Young's modulus E ≈ 200000 MPa for steel, CVN is a mean value of impact energy in Joules.

Fig. 2 : Photograph showing the symmetricity of anvil trace with respect to notch of the tested CVN specimen.

For further considerations, elastic-plastic fracture mechanics is invoked as steels under consideration have a high static fracture toughness and they are heavily loaded while in service. Therefore, J-integral can be expressed as:

$$J_{\mathrm{Ic}} = 1000(1-\nu^2)\frac{K_{\mathrm{Ic}}^2}{E} \qquad (2)$$

where J_{Ic} is measured in N/mm, $\nu \approx 0.3$ is a Poisson's ratio. Index '$_{\mathrm{Ic}}$' is used for common understanding that at high loads *K* should be calculated from *J*, but not vice versa. From (1) and (2),

$$\mathrm{CVN}\big|_{T_{\min}} \approx 2.9 J_{\mathrm{Ic}}^{\ 2/3} \qquad (3)$$

Equation (3) gives the necessary mean impact energy at the minimum temperature of application. Now a correlation of this CVN and the acceptance value and test temperature may be formulated as a temperature reserve, i.e. $\Delta T = T_{\mathrm{test}} - T_{\min}$.

The known analytical temperature dependence of fracture toughness is:

$$K_{\mathrm{Ic}}(T) = K_{\mathrm{Ic\,min}} + A \cdot \exp(B\,(T - T_0)$$

where B ≈ 0.02, see ASTM E1921 or [9], and the values $K_{\mathrm{Ic\ min}}$ and T_0 correspond to the lower shelf of the dependence. Omitting K_{Ic} min and taking into account that $J_{\mathrm{Ic}} \sim K_{\mathrm{Ic}}^{\ 2}$, .

$$J_{Ic}\Big|_{T_D} = J_{Ic}\Big|_{T_H} \cdot \exp(B^2(T_{\min} - T_{\mathrm{test}})). \qquad (4)$$

From (3) and (4), the CVN temperature dependence within the lower half of ductile-to-brittle transition interval should be as follows,

$$\mathrm{CVN}\Big|_{T_{\min}} = \mathrm{CVN}\Big|_{T_{\mathrm{test}}} \cdot \exp(0.027(T_{\min} - T_{\mathrm{test}})). \qquad (5)$$

Considering that $\mathrm{CVN}|T_{\mathrm{test}} = 0.1\,\sigma_{\mathrm{Y}}$, the temperature reserve is:

$$\Delta T = 37 \cdot \ln\left(\frac{2.9 J_{\mathrm{Ic}}^{\ 2/3}}{0.1\sigma_{\mathrm{Y}}}\right) \qquad (6)$$

Hence, the next question arises how to find the necessary J_{Ic} from the condition of no crack initiation, i.e., the static fracture toughness of the material shall be not lower than the loading parameter of a structural member containing a crack that is also derived in terms of J-integral, with some safety factor *n*. For instance, such calculation procedures are available in [10] and modern British standard BS 7910. In the simplest case, for base metal of thickness S (mm) with an edge crack of the depth α (mm), loaded by membrane tensile stress $\sigma_t = 0.7\,\sigma_{\mathrm{Y}}$,

$$J_{\mathrm{Ic}} \geq n \cdot 1000(1-\nu^2)/E \cdot \left(K_{\mathrm{I}}^{d}\right)^2 \cdot f\left(L_r\right) \qquad (7)$$

where $L_r = \sigma_{\mathrm{ref}}/\sigma_{\mathrm{Y}}$ is a relative load in which the reference stress $\sigma_{\mathrm{ref}} \approx 0.933\sigma_{\mathrm{Y}}$ for the considered case (see item P.9 of BS 7910). Subsequently, $f(L_r) \approx 0.835$ (formula (29) of BS 7910), *n* is the safety factor needed to account for the probabilistic nature of cleavage fracture. Stress intensity factor $K_{\mathrm{I}}^{\mathrm{d}}$ [MPa·m$^{0.5}$] in presence of membrane stress can be written as:

$$K \qquad \sigma_t Y_t \sqrt{0.001\pi\sigma} \qquad (8)$$

where, for an edge crack of the critical depth α = S/4 the value of function Y_{t} = 1.55. Therefore,

$$K_{\mathrm{I}}^{\ d} = 0.7\sigma_{\mathrm{Y}} \cdot 1.55 \cdot \sqrt{0.001\pi S/4} = 0.03\sigma_{\mathrm{Y}}\sqrt{S} \qquad (9)$$

Safety factor *n* for the most critical structural members calculated via numerical experiment amounts to the following for the case of three test specimens in a set and typical test data scatter [11]:

$$n = 0.63 \times \exp(2.8 - 0.28\ \mathrm{In}S) + 0.3. \qquad (10)$$

Therefore, from (6), (7), (9) and (10),

$$\Delta T = 37 \cdot \ln\left(0.0066\,\sigma_{\mathrm{Y}}^{\ 1/3} \cdot S^{2/3} \cdot \left(0.63 \times \exp(2.8\text{-}0.28\ln S) + 0.3\right)^{2/3}\right) \qquad (11)$$

These ΔT values describing the necessary temperature reserve between T_{test} and $T_{\min}$ are close to the requirements of IACS UR S6 leaving aside extra considerations relating to the technology of rolled steel manufacturing. It is to be noted that in some cases, steel appears to be applicable at the temperatures lower than the one at which it has been impact bend tested.

4. Concept of crack propagation resistance

Resistance of metal to a crack to propagate may be not enough for certain critical structures (Figure 3). Base metal should arrest an initiated cleavage crack. Special BCA (brittle crack arrest) steel grades are known for meeting these requirements [12]. It is feasible to assess CVN values needed to arrest a crack. In brief, our model of a tunneling cleavage crack gives the required dynamic fracture toughness of steel as:

$$K_{1a} = \sqrt{3.5 \times 10^{-5}\ \sigma_{\mathrm{YD}}^{2.42} \cdot S} \qquad (12)$$

where σ_{YD} is an effective yield stress at impact loading (MPa). This value integrally accounts for dynamic hardening, waves of elastic deformation and the loss due to adiabatic heating.

Fig. 3 : Photograph showing the crack arrest of a structure.

The simplest way to determine σ_{YD} is a comparison of load-displacement records obtained at instrumented testing of CVN specimens subjected to impact and static bending. For low-alloyed steels our investigations give $\sigma_{YD} \approx 1.33\ \sigma_Y$.

Cleavage crack propagation and arrest was FEM simulated in the models of CVN specimen and a structural member with a central crack giving the stress intensity factor equivalent to the same of the above-mentioned edge crack of the critical depth. Some correlations of CVN and K_{Ia} were found; which facilitated the conclusion that impact energy values necessary to arrest a crack may amount up to in the range between 120 to 150 Joules that is much higher than 0.1 σ_Y. Nevertheless, such a level of impact energy is usually provided by modern steel grades. On the other hand, for special application like main gas pipelines, the acceptance CVN values now make up to about 200 Joules.

5. How to maintain the steel quality in batch production

Any special mechanical tests performed at the certification stage cannot be repeated in everyday practice of batch production. Therefore, the only feasible way to maintain the production quality of steel, as suggested by the Russian maritime register of shipping [13] is the following:

"The initial extensive test program performed to approve a certain manufacturer of a certain steel grade gives a local experimental correlation of CVN impact energy with the results of special mechanical tests. In batch production acceptance tests, it is necessary to maintain the same or higher CVN level that may be several times higher than the formal requirement".

6. Conclusions

- Impact bend test is a single acceptance test allowing to assess the safe operation of steel structures at lowered temperatures. Indications described in this paper, with fracture mechanics approach, suggest that the obtained test results should be valid for its intended application.
- Safe operation of steel structures in respect of crack initiation resistance in some cases may be proved even for the climatic temperatures below the test temperature.
- Crack arrest property being the second safety barrier needs much more impact toughness.
- In some circumstances, all the correlations of CVN impact energy with fracture mechanics parameters may not be a meaningful approach when the production technology does not provide for steel homogeneity, as through-thickness/as in-plane conditions. Cases are witnessed when acceptance values above 300 Joules appeared not enough to get a good cold resistance in high thickness.

7. Acknowledgements

The author would like to acknowledge Dr. A.V.Ilyin, Deputy General Director and the outstanding scientific adviser, Prometey, Russia.

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News Updates Domestic

JSP to make Angul facility India's largest single-location steel plant : MD

Jindal Steel and Power (JSP) is planning to make its Angul unit India's largest single-location steel manufacturing facility, its Managing Director Bimlendra Jha has said.

Currently, the capacity of the Odisha plant is being ramped up to 11.6 Mtpa from the existing 5.6 Mtpa, Jha told PTI in an interaction.

"We are more than doubling the capacity in Angul by next year...we have ambitions to further double it up to 24 Mtpa, making it India's largest single-location steel plant," the Managing Director said without sharing any timeline for the plan.

The steel plant in Raigarh will also undergo an expansion of up to 9.6 Mtpa from the current 3.6 Mtpa, the company said in a statement. On the expansion of the Angul plant, Jha said the company aims to complete the trial production by the end of 2023 and commercial production by next year.

Business Standard (8.10.23)

Iron ore supply from NMDC to Visakhapatnam Steel Plant through KK railway line resumes on October 10

The supply of iron ore to the Rasthriya Ispat Nigham Limited (RINL), the corporate entity of Visakhapatnam Steel Plant (VSP), from the Bailadila based NMDC has resumed on october 10.

The supply was stopped from September 24 to October 9 due to the damage of the transportation line (Kottavalasa-Kirandul railway line) on September 24. The line was damaged due to massive landslide on the tracks under the influence of the adverse weather conditions in the region during the southwest monsoon period.

During this period, the RINL team made alternative arrangements till October 9 for supply of iron ore from other sources like NMDC Karnataka, SAIL Bolani/Barsuan, Orissa Minerals Development Corporation Ltd, and Orissa Mining Corporation, to meet the VSP's requirements of iron ore to ensure smooth and uninterrupted operations of the plant's two blast furnaces.

'Major landslide'

"On September 24, there was a major landslide in the KK line between Jaypore and Koraput, and supplies through KK line stopped from NMDC Bailadila sector, which is the main source for the iron ore supplies to RINL. This created a massive challenge for sustaining the plant operations as the inflow of iron ore was already constrained and stock level of iron ore had reached to a critical level because of heavy monsoon rain in the mines area," said an official RINL spokesperson.

RINL will be further ramping up its production with the receipt of stranded rakes on KK line and also with the continued supplies from NMDC besides the quantities secured from other sources, the official added.

The Hindu (10.10.23)

JSW Steel declared preferred bidder for Jaisinghpura North Block iron ore mine in Karnataka

JSW Steel said it has emerged as the preferred bidder for the Jaisinghpura North Block iron ore mine in Karnataka. JSW Steel has received a communication from the Karnataka government in this regard, the company informed the exchanges.

"The Company has been declared as a preferred bidder vide communication dated October 11, 2023, received from the Office of the Director, Department of Mines and Geology, Government of Karnataka, for Jaisinghpura North Block, in the Auction held on August 2, 2023," the filing said.

The highest final offer price by the company to become a "Preferred Bidder" is 150.3 per cent of the value of the mineral dispatched. The projected iron ore resource is 17.66 in metric million tonnes.

The Economic Times (11.10.23)

Tata Steel plans to meet 25% of energy needs via green sources

Tata Steel, Asia's oldest manufacturer of the primary infrastructure alloy, plans to meet at least a fourth of its energy requirements through green energy by FY30 on its path to become net neutral on carbon emissions by 2045. It plans to do so using a mix of hydrogen injections and renewable energy including solar and wind at its plants across the country, Rajiv Mangal, vice president for safety, health and sustainability, Tata Steel, told ET.

Earlier this year, the company had successfully injected hydrogen at one of its blast furnaces in Jamshedpur, aimed at reducing carbon emissions by 7-10% for each tonne of crude steel produced.

“We wanted to test hydrogen because transportation of hydrogen is very costly and risky. So, we wanted to be sure. Those fears are now behind us, so we are looking at either a 15 tonne per day hydrogen plant, or someone else providing it to us," Mangal said.

"The price of hydrogen in the market will not be less than $5 to $6 per kg. To be commercially viable in a steel plant, we need it in the range of around $1. So, hydrogen technically can solve the problem, but commercially cannot," he said.

The Economic Times (13.10.23)

SAIL plans to begin trial production of special rails by month-end: Chairman Amarendu Prakash

New Delhi, Steel maker SAIL plans to start the trial production of head hardened (HH) rails, used in metro rail and freight corridor projects, by month-end, its Chairman Amarendu Prakash said. The steel PSU was earlier looking to start the trial production of HH rails in August but deferred it due to the demand for normal rails like 880 grade from the Indian Railways, Prakash told PTI in an interview.

"We have the technology. We had planned for it (HH rail production) but then...they (Railways) requested us to defer the trials and now it is at the end of October," the Chairman said.

The Economic Times (15.10.23)

World Steel Association elects Leon Topalian as Chairman, India's T V Narendran as Vice Chairman

Global body worldsteel said it has elected Leon Topalian as its Chairman and India's T V Narendran as one of its Vice-Chairman. Topalian is the President & CEO of Nucor Corporation and Narendran is the MD & CEO of domestic steel giant Tata Steel.

Jeong-Woo Choi, the CEO of POSCO Holdings, was also elected as a Vice Chairman, according to the World Steel Association's (worldsteel) list of newly elected officers and members.

The association also appointed Narendran to the Executive Committee alongwith JSW Steel CMD Sajjan Jindal and ArcelorMittal Executive Chairman L N Mittal.

The Economic Times (16.10.23)

India to see "healthy growth" in steel demand at 8.6 pc in 2023: Worldsteel

The demand for steel in India is expected to register a 'healthy growth' of 8.6 per cent against the overall global rise of 1.8 per cent in 2023, worldsteel said. It forecasts that global steel demand will grow 1.8 per cent in 2023 and reach 1,814.5 Mt after having contracted by 3.3 per cent in 2022. In 2024, the demand will see an increase of 1.9 per cent to 1,849.1 Mt, the World Steel Association (worldsteel) said.

For India, the global body said, "after a growth of 9.3 per cent in 2022, steel demand is expected to show healthy growth of 8.6 per cent in 2023 and 7.7 per cent in 2024."

The Indian economy remains stable against the pressure of high interest rate environment, and the steel demand is expected to continue its high growth momentum.

The Economic Times (17.10.23)

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Chapter Activities
Delhi, Kolkata, Vizag, Jamshedpur, Bhubaneswar, Bangalore, Baroda

Delhi Chapter

1) The 71st Annual General Meeting of IIM Delhi Chapter was held on 8.7.2023 @ chapter's premises. The New Executive Committee for 2023-24 are as follows :

• Chairman	Mr. R K Vijayavergia
• Hon. Secretary	Mr. K R Krishnakumar
• Hon. Treasurer	Mr. R K Narang

2) A team of 14 members of the Delhi Chapter visited M/s Samyak Metals Pvt. Ltd. located at Dharuhera (Haryana) on 23rd September 2023. This company is one of the leading manufacturers of Aluminium Alloys (Ingots & Liquid) & Stainless Steel of different grades and specifications as per the stringent national and international standards. The team received an warm welcome and a detailed presentation about the products, technology and operations of the company was delivered. The Chairman, IIM Delhi Chapter briefed the management about the activities of IIM and requested the management to promote the membership of IIM in M/s Samyak Metals Pvt. Ltd. The members were taken around to the different units of the Plant and explained the operation and quality aspects. The members had the opportunity to witness the operations of segregation of aluminium scrap, recycling procedure, melting process and ingot casting and also the process of transportation of molten alloy to nearby customers and associated safety measures for transportation of the molten material.

Members from IIM Delhi Chapter @ the meeting with M/s Samyak Metals Pvt. Ltd.

@ plant visit

Kolkata Chapter

1) July activities :

• The EC meeting of IIM Kolkata Chapter was held on 24th July 2023 on virtual platform.

• On July 29, 2023 a meeting was organized amongst Executive Members of the Chapter at The Royal Bengal Tiger Café.

@ the meeting held on July 29, 2023

2) August activities :

• The EC meeting of IIM Kolkata Chapter was held on 3rd August 2023 in the Department of Metallurgical and Material Engineering of Jadavpur University.

• A Quiz competition was organized on 19.08.2023 in the Department of Metallurgical and Material Engineering of Jadavpur University. Students from R K Mission School, Narendrapur and M P Birla High School, secured first and second position respectively. These two teams participated in the BPMMQ 2023 competition at IGCAR Kalpakkam.

@ the Quiz competition held on 19th August 2023

Vizag Chapter

1. Technical Talk on Pattern making and Methoding of Casting :

IIM Vizag Chapter organized the technical training session on "Pattern making and Methoding of Casting", by Mr. Siva Kumar Subbarayan on 5th August, 2023 at Learning and Development Centre, Rashtriya Ispat Nigam Limited. The Session proved to be an informative and engaging event. It equipped participants with valuable knowledge and practical skills, emphasizing the advantages of efficient methoding practices for the foundry industry. The event's success was attributed to the expertise of the speakers, the interactive sessions, and the enthusiastic participation of attendees. The event was meticulously organized by the executive committee, under the leadership of Hon. Secretary Shri Lalan Kumar and Hon. Treasurer Shri Mahesh Kumar Sharma.

2. Quiz Competition :

A quiz competition was organized with the primary objective of identifying the most adept teams to represent vizag chapter in the prestigious Prof Brahm Prakash Quiz 2023 competition. The competition proved to be an intellectually invigorating event, showcasing the students' knowledge, quick thinking, and teamwork abilities. The involvement of Mr. Pratik as the Quiz Master lent a dynamic and engaging dimension to the event. His well-crafted questions and interactive approach kept the participants and the audience thoroughly engaged. The executive committee, led by Honorary Secretary Shri Lalan Kumar meticulously organized the event.

3. Technical talk on the "Utilisation of Solid Wastes Generated by Steel Industries for Sustainable Development" :

CGCRI (Director) and IIM Council Member, Dr. Suman Kumari Mishra delivered an enlightening technical talk on the "Utilisation of Solid Wastes Generated by Steel Industries for Sustainable Development." The event took place on 29th August, 2023, at Rashtriya Ispat Nigam Limited, and was attended by esteemed invitees, including IIM members. Dr. Mishra's talk revolved around the critical theme of leveraging solid waste generated by the steel industry to foster sustainable development. She delved into innovative strategies for repurposing these waste materials, ensuring that they contribute positively to environmental and economic sustainability. By addressing the challenges posed by industrial waste, she showcased how these materials can be harnessed for various applications, reducing their environmental impact. The executive committee, led by Hon. Secretary Shri Lalan Kumar, Hon. Treasurer Shri Mahesh Kumar Sharma, painstakingly orchestrated the entire event.

Speaker Dr. Suman Kumari Mishra with the organisers

Jamshedpur Chapter

1) The EC meeting of IIM Jamshedpur Chapter was held on 12th September 2023. The venue of the meeting was at CFE, Jamshedpur.

2) Dr. T. Bhaskar, Chief Technology Officer, Tata Steel Long Products Limited, and one of the executive committee members of the IIM Jamshedpur Chapter has been conferred with the Fellowship of Indian National Academy of Engineering (INAE), a highly prestigious Award for Career Achievements in

Engineering and Technology. In this regard, IIM Jamshedpur Chapter organised a programme on September 18, 2023 at CSIR-NML Jamshedpur, Lecture Hall, where Dr. Bhaskar delivered a talk on his Engineering journey. The topic of the talk was "My Engineering journey ! Tryst with Events, People, Places, Institutions and Organisations that defined me".

Dr. T. Bhaskar (4th from left) at the felicitation programme

Bhubaneswar Chapter

The Annual General Body Meeting 2023 of IIM Bhubaneswar Chapter was conducted on 24 September 2023 at SS Bhatnagar Hall, CSIR-IMMT Bhubaneswar. The welcome address delivered by Shri HK Tripathy, Chairman of IIM Bhubaneswar Chapter. Two minutes silence observed in the memory and honour of Prof. P.K. Jena, Founder of IIM Bhubaneswar Chapter and Prof. H.S. Ray, Former Director, CSIR-IMMT Bhubaneswar. The Chief Guest Shri Debasish Deb, Former ED, HAL delivered a technical talk on "Materials and Technological Gaps in the Indigenous Manufacture of Aeroengines for 5th/6th Generation Fighter Aircraft." The Chapter Chairman presented a memento to the Chief Guest. Dr. M.S. Anwar and Dr. P.M. Mishra jointly received IIM Bhubaneswar Chapter Award for their valuable contributions in materials research. Dr. N. Pradhan received 'RP Das Memorial award' for her valuable contributions in research work. A total of 65 people was present during the event. The event concluded with a vote of thanks by Dr. Ajit Panigrahi, Secretary of IIM Bhubaneswar Chapter.

Shri HK Tripathy delivering the welcome address

New office bearers of IIM Bhubaneswar Chapter

Bangalore Chapter

IIM Bangalore Chapter and IISc Bangalore, Department of Materials Engineering organised a technical talk on 26th September 2023 at the KPA Auditorium, Dept. of Materials Engineering, IISc, Bangalore. The lecture was delivered by Prof. Daniel Neumaier, University of Wuppertal, Chair of Smart Sensor Systems, 42119 Wuppertal, Germany, AMO GmbH, Otto-Blumenthal-Str. 25, 52074 Aachen, Germany and the title of lecture was "Flexible CMOS logic based on TMDC 2D materials".

Baroda Chapter

The 48th Annual General Body Meeting of IIM Baroda Chapter was held on 1st October 2023, at Royal Orchid Central Hotel, Akota, Vadodara. The New Executive Committee for 2023-24 are as follows :

• Chairman	Dr. Sunil D. Kahar
• Hon. Secretary	Mr. Hiren Panchal
• Hon. Treasurer	Mr. Sumit Kanithola

@ AGM of IIM Baroda Chapter

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Achievements Prof. U Kamachi Mudali

Prof. U Kamachi Mudali, Vice Chancellor of HBNI, Former President, IIM and formerly Vice Chancellor of VIT Bhopal University & Chairman and Chief Executive of Heavy Water Board, has been conferred "SMC Gold Medal – 2023" by Society for Materials Chemistry, for his outstanding contribution to Materials Chemistry.

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Achievements Prof. NK Mukhopadhyay

Professor NK Mukhopadhyay, Professor in Physical Metallurgy, Department of Metallurgical Engineering, Indian Institute of Technology (BHU), Varanasi and Fellow Member of IIM will be receiving the fellowship of the Indian National Science Academy. The Fellowship will become effective from January 1, 2024.

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Achievements Prof. Anish Upadhyaya

Prof. Anish Upadhyaya, Fellow Member of IIM, who is currently serving as Head of the Advanced Center for Materials Science (ACMS) and Professor in Department of Materials Science and Engineering has recently received award from the Bureau of Indian Standards (BIS) for his pioneering contributions in the utilization of standards in education. This award was conferred on the occasion of World Standard Day during a ceremony held at New Delhi on October 13, 2023. Prof. Upadhyaya currently serves as the Chairperson of the Powder Metallurgy Sectional Committee within the Metallurgical Division (MTD-25) of BIS. Through this role, he has spearheaded various initiatives, including the formulation of new standards, fostering industrial and academic outreach through courses and workshops, and effectively promoting the utilization of Indian Standards.

Prof. Upadhyaya (4th from left) receiving the award from Shri Piyush Goyal (Minister of Consumer Affairs, Food and Public Distribution), Shri Ashwini Kumar Chaubey (Hon'ble Minister of State for Consumer Affairs, Food and Public Distribution) and Shri Pramod Kumar Tiwari (Director General, BIS).

Recipients of IIM Awards 2023

	IIM Awards 2023	Award Recipient[s]
A) IIM Special Award		
I	IIM-JRD Tata Award for Excellence in Corporate Leadership in Metallurgical Industries	**Mr TV Narendran,** MD & CEO, Tata Steel Ltd.
B) Core Categories		
I	IIM Tata Gold Medal	**Mr Bibhu Mishra,** Advisor, Manufacturing Center of Excellence, Hindalco Industries Ltd.
II	IIM GD Birla Gold Medal	**Dr Raghavendra Tewari,** Outstanding Scientist & Associate Director, Materials Group, Head, Materials Sc. Division, BARC
III	IIM TSL New Millenium Award	**Mr Sharad Raghunath Suryawanshi ,** ED(Works), SAIL, Rourkela Steel Plant
IV	IIM Hindustan Zinc Gold Medal	**Ms Vaishakhi Salil Nandi,** Senior Manager (Lab.), HAL
V	IIM Essar Gold Medal	**Dr T Bhaskar,** CTO, Tata Steel Long Products
VI	IIM Nalco Gold Medal	**Mr Kausikisaran Misra,** Head-Operations (Alumina Refinery), VP, Utkal Alumina International Ltd.
VII	IIM Mecon Award	**Mr Sutanwi Lahiri,** Scientific Officer E, BARC
VIII	IIM Distinguished Educator Award	Jointly by **Prof Rajib Dey,** Professor, Dept. of Met. & Mat. Engg, Jadavpur University and **Prof Narendra B Dhokey,** Profesor, Met. & Mat. Sc., College of Engineering Pune
IX	IIM SAIL Gold Medal (For the best paper published under Ferrous Category in the Trans-IIM in 2022)	**Ferrous Category:** **Kumar, P., Maity, K.P., Dasgupta, A.** *et al.* Innovations in Thermo-mechanical Processing to Develop High Strength Steel Plates. *Trans Indian Inst Met* **75**, 2069–2076 (2022).
X	IIM Non-Ferrous Best Paper Special Medal (For the best paper published under Non-Ferrous Category in the Trans-IIM in 2022)	**Non-Ferrous Category:** **Tewari, R., Vishwanadh, B. & Vasudevan, V.K.** Formation of the Laves Phase in Nb-Ti-Cr-Si-X-Based Alloys. *Trans Indian Inst Met* **75**, 931–939 (2022).
XI	IIM Distinguished Contributor Award	**Mr Ramen Datta** Consultant, SRTMI
XII	IIM Certificate of Honor	**Mr Prem Ganesh,** Head, New Ventures, Technology and New Meterials Business, Tata Steel Ltd.
C) Other Categories		
I	IIM Organizational Awards	**• IIM National Sustainability Awards [Fe]** A] CATEGORY: LARGE INTEGRATED STEEL PLANTS **Joint Winners:** **JSW Steel Ltd., Vidyanagar** & **Tata Steel Ltd., Jamshedpur**

Recipients of IIM Awards 2023

	IIM Awards 2023	Award Recipient[s]
I	IIM Organizational Awards	B] CATEGORY: SECONDARY STEEL / ALLOY STEEL PLANTS **Joint Winners:** **JSW Steel Ltd., Salem Works** & **JSL, Hisar** C] CATEGORY: DRI Plants / Pig Iron Plants / Major Re-rolling Units **Winner: Kirloskar Ferrous Industries Limited, Koppal** • **IIM NF Best Performance Awards [NF]** A] CATEGORY: Large Integrated Manufacturing Plants **First Prize: Hindustan Copper Ltd.** B] CATEGORY: Secondary Processing/ Fabrication Plants [Other than casting & Forging] **Winner: Hindalco Industries, Hirakud** C] CATEGORY: Casting & Forging **Winner : Jain Resource Recycling Pvt Ltd**
II	IIM Best Chapter Award	**Large Category:** 1st Prize: **Kalpakkam** 2nd Prize: **Bhubaneswar** **Medium Category:** Winner: **Chennai** **Small Category:** 1st Prize: **Kanpur** 2nd Prize: **Bokaro**
III	IIM Dr AK Bose Gold Medal	**Reddi Jaswanth Sai** Department of Metallurgical and Materials Engg., IIT Kharagpur Thesis: Comparative study of laser surface melting and laser surface cladding of h13 tool steel using h13 tool steel powder
IV	IIM Vidya Bharathi Prize	**Swarnendu Das** University of Pennsylvania, USA (PhD starting Aug 2023) BTech from IIT BHU Varanasi (May 2023)

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Seminars & Conferences

Second International Conference on Advances in Minerals, Metals, Materials, Manufacturing and Modelling (ICAM5-2023)

The second International Conference on Advances in Minerals, Metals, Materials, Manufacturing and Modelling (ICAM5-2023) was organised by the Department of Metallurgical and Materials Engineering (MMED) at the National Institute of Technology, Warangal, in association with the Indian Institute of Metals, Hyderabad Chapter, during 22nd & 23rd September 2023.

The conference was inaugurated by the Chief Guest, Dr. Sanjay Kumar Jha, Chairman & Managing Director of Mishra Dhatu Nigam Limited (MIDHANI), along with the Guest of Honour, Prof. G. Madhusudhan Reddy, Adjunct Professor at the National Institute of Technology, Warangal, and Former Director at DMRL, Hyderabad.

The inaugural function started with the national song 'Vande Mataram,' followed by lamp lighting. Prof. N. Kishore Babu welcomed the delegates to the conference and briefed them about MMED. Prof. C. Vanitha, Organising Secretary of ICAM5, introduced the conference theme and scope to the delegates, highlighting the sessions planned for the two days of ICAM5. Prof. Bidyadhar Subudhi, Director, NIT Warangal, congratulated the organizing team for conducting the conference with a very relevant and focused theme, 'Advanced Materials for Sustainable Development.' The Guest of Honour, Prof. G. Madhusudhan Reddy, outlined the importance of innovation in materials processing and design in national development and prosperity. He also mentioned that technological advancements and their reach are revolutionizing the functioning of almost every organization, irrespective of their domain of operation. Chief Guest Dr. Sanjay Kumar Jha outlined the need for the development of cutting-edge manufacturing processes such as additive manufacturing (3D printing), advanced machining, and nanofabrication. He also stated that the above technologies are revolutionizing the way we produce components and structures. He emphasized that this conference provides a platform to exchange ideas and discuss the challenges in the field of metallurgy and materials for researchers from academia, research, industry, and government organizations. Dr. S. K. Jha also emphasized that the present generation of scientists and technologists should take up new challenges and find solutions to modern-day problems.

Plenary Talks by Dr. S.K. Jha (MIDHANI) and Prof. G. Madhusudhan Reddy (NITW) have outlined the indigenous development of materials for strategic applications in India. Dr. Arup Dasgupta (IGCAR, Kalpakkam), Dr. Laura Silvestroni (CNR - ISSMC Institute of Science Italy), Dr. Venugopal Rao (DMRL), Dr. Anirbhan Bhattacharya (IIT Bhubaneswar), Sri M. Venu Madhava Rao (RINL, Visakhapatnam) have delivered keynote talks and critically assessed the developments in the field of materials engineering. More than 70 contributory talks were presented during the two days, discussing important aspects of materials development and sustainability.

The dignitaries on the dais released the ICAM5 -2023 Conference Souvenir booklet.

Crude Steel Production September 2023 (World)

Crude Steel production by region

	Sep 2023 (Mt)	% change Sep 23/22	Jan-Sep 2023 (Mt)	% change Jan-Sep 23/22
Africa	1.3	-4.1	11.9	6.6
Asia and Oceania	110.7	-2.1	1,055.7	1.6
EU (27)	10.6	-1.1	96.2	-9.1
Europe, Other	3.5	2.7	30.7	-9.3
Middle East	3.6	-8.2	32.6	-0.6
North America	9.0	-0.3	82.2	-3.3
Russia & other CIS + Ukraine	7.3	10.7	66.3	2.0
South America	3.4	-3.7	30.9	-6.2
Total 63 countries	**149.3**	**-1.5**	**1,406.4**	**0.1**

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

	Sep 2023 (Mt)	% change Sep 23/22	Jan-Sep 2023 (Mt)	% change Jan-Sep 23/22
China	82.1	-5.6	795.1	1.7
India	11.6	18.2	104.1	11.6
Japan	7.0	-1.7	65.4	-3.6
United States	6.7	2.6	60.6	-1.4
Russia	6.2 e	9.8	57.1	4.8
South Korea	5.5	18.2	50.4	-0.4
Germany	2.9	2.1	27.2	-3.6
Türkiye	2.9	8.4	24.5	-10.1
Brazil	2.6 e	-5.6	24.0	-8.0
Iran	2.4	-12.7	22.1	-0.6

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)

	Sep'23	Aug'23	Jul'23	2022 - 23	2021 - 22
ALUMINIUM					
National Aluminium Co Ltd	0.36	0.38	0.37	4.60	4.60
Hindalco Industries Ltd*	1.13	1.13	1.12	13.22	12.94
Bharat Aluminium Co. Ltd	0.48	0.49	0.49	5.69	5.80
Vedanta Ltd	1.45	1.48	1.50	17.22	16.92
TOTAL	**3.42**	**3.48**	**3.48**	**40.73**	**40.26**
*Renukoot, Hirakund, Mahan, Aditya					
ZINC (One major producer)					
Hindustan Zinc Ltd	**0.64**	**0.63**	**0.58**	**8.21**	**7.76**
COPPER (Cathode)					
Hindustan Copper Ltd	0	0	0	0.000073	0.62
Hindalco (Birla Copper)	0.36	0.35	0.31	4.07	3.59
Vedanta Ltd.	0.13	0.12	0.11	1.48	1.25
TOTAL	**0.49**	**0.47**	**0.42**	**5.55**	**4.85**
LEAD					
Hindustan Zinc Ltd	**0.21**	**0.20**	**0.16**	**2.11**	**1.91**

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

Prices in India (as on 28th October, 2023)

(Mumbai Local Price in Rs. / kg)

Product	Rs. / kg	Product	Rs. / kg
Copper Armature	672	Aluminium Ingot	209
Copper Cathod	719	Aluminium utensil	164
CC Rod	728	Zinc Ingot	224
Copper Cable scrap	694	Lead ingot	189
Brass Sheet Scrap	495	Tin Ingot	2187
Brass Honey Scrap	453	Nickel Cathod	1580

Source : https://mtlexs.com/

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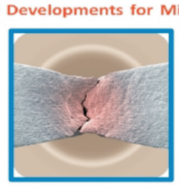

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