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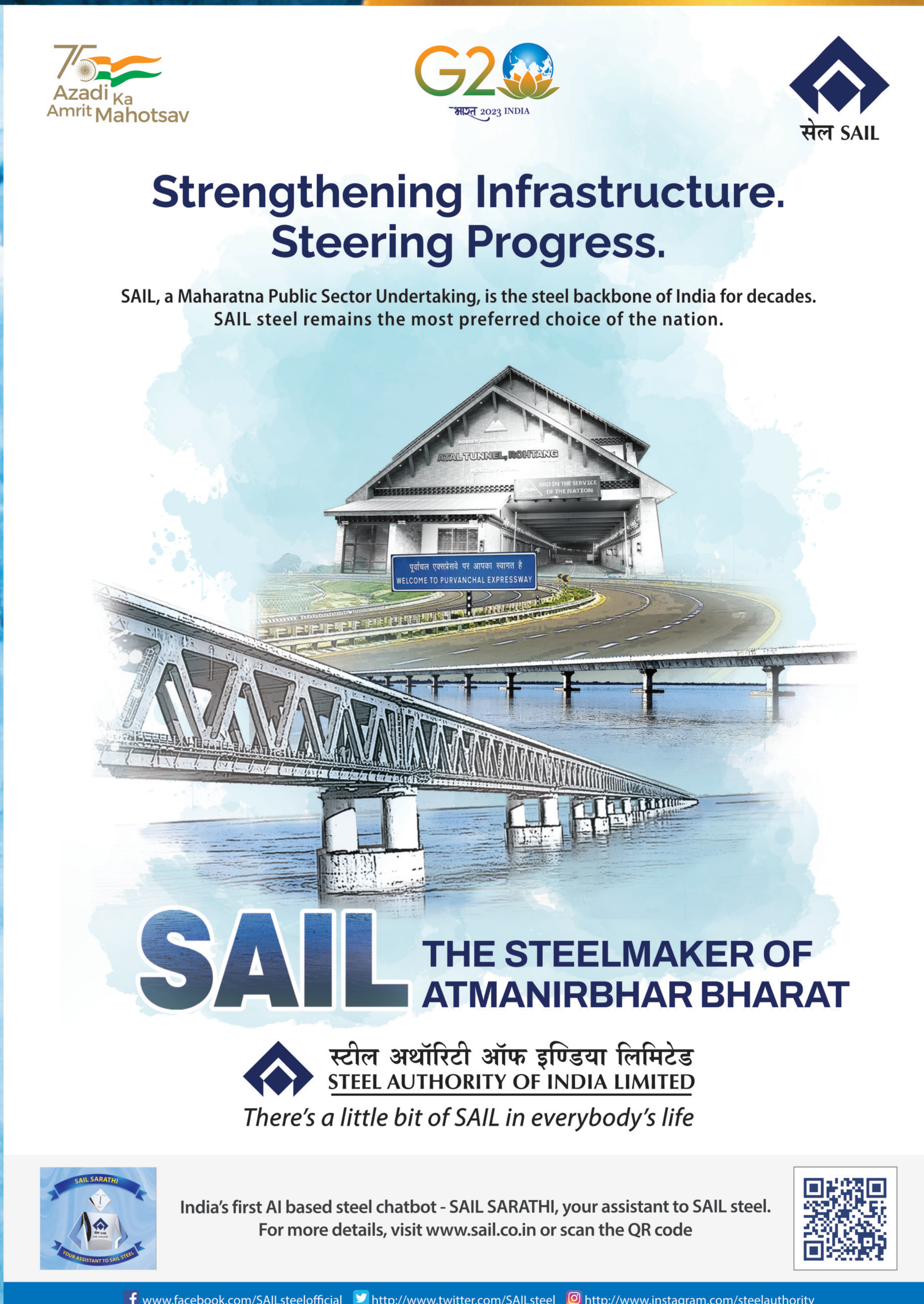

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E-mail: secretarygeneral@iim-india.net
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Phone: 033-2367 9768 / 2367 5004
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Group Snap to conclude the 6th Baldev Raj Memorial Lecture held on 9th April 2024 @ CSIR-NIIST Trivandrum

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Technical Article

Creep–Fatigue Interaction Behaviour of Thermally Aged 316 LN Stainless Steel Weld Joint

T Suresh Kumar[1*], A Nagesha [2,3]

Abstract

Thermally aged (923 K/5000 h) AISI 316 LN austenitic stainless steel weld joint (WJ) is investigated under mechanical strain-controlled isothermal low cycle fatigue (LCF) and peak tensile strain hold (60 s and 300 s) creep-fatigue interaction (CFI) at different temperatures between 823 K - 923 K. The cyclic stress response (CSR) and fatigue life of the joint decreased with an increase in temperature and duration of hold. Cyclic softening occupied major part of the CSR in all the tests. The failures were initated mostly in weld metal region of the joint, though the mechanism of failure was found to depend on the testing conditions. Initiation and propagation of microcracks were observed to be a combined effect of microstructural embrittlement and creep damage, as identified through extensive microscopic examinations. The detrimental role of the microstructural embrittlement in the weld region which caused extensive secondary cracking along the interfaces of austenite/σ-phase and their coalescence, was more pronounced with an increase in the hold time and temperature. The variation in life was seen to be consistent with the severity of cracking under different testing conditions.

Key words : Weld joint, thermal ageing, low cycle fatigue, microstructural embrittlement, fatigue-creep interaction.

1.0 Introduction

Large structural components of sodium-cooled fast reactors (SFRs) are subjected to a combination of cyclic thermal loadings and steady state or fluctuating stresses during start-up and shut-down operations in combination with the in-service transients and trips following unexpected events [1, 2]. As a result, creep, low cycle fatigue (LCF) and creep-fatigue interaction (CFI) become important life-limiting damage mechanisms in high temperature SFR components. The accumulation of damage under CFI is generally more severe compared to that developed from either creep or fatigue mechanism acting independently. Weld joints (WJ) which are vulnerable to the accumulation of local strains, are unavoidable in the large structures of SFRs. Thus, the resistance of the WJ to the above loading has been recognised as an essential design criterion for the assessment of SFR components intended for a service life of 40 to 60 years [1-3]. Nitrogen-added type 316 LN austenitic stainless steel (SS) is used to construct many components in out-of-core regions of SFRs due to an optimum combination of corrosion resistance and mechanical properties at elevated temperatures [4]. Austenitic SS is known to exhibit substantial reduction in fatigue life when a dwell period is applied at the peak tensile strain of the cycle compared to compression and symmetric (tensile + compression) holds [1, 5-7]. Therefore, tensile hold CFI testing is the most conservative practice for obtaining relevant design data for the material. The WJ yielded significantly lower cyclic lives compared to the base metal (BM) due to significant strength and microstructural gradients across the joint, which results in premature failures either at the weld metal (WM) or the heat-affected

[1] **Department of Materials Science and Engineering, National Institute of Technology Calicut, Kozhikode, Kerala – 673601**
[2] **Mechanical Metallurgy Division, Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu, India – 603102**
[3] **Homi Bhabha National Institute, Mumbai, Maharashtra, India – 400094**
Corresponding author E–mail : *tsk030@gmail.com

zone (HAZ) of the joints [8, 9]. The δ-ferrite which is introduced to minimise the problem of micro-fissuring and hot cracking in austenitic SS welds undergoes a series of metallurgical transformations that result in different carbides and intermetallic phases, depending on the temperature, the time of exposure and chemical composition of the weld [10-12]. As these microstructural changes can significantly affect the behaviour of welds, especially at elevated temperature, studies pertaining to the influence of such transformations on the fatigue behaviour of the 316 LN SS joints under LCF and CFI conditions are very important towards ensuring the structural integrity of the complete WJ. With this background, the current investigation was undertaken to evaluate the influence of thermal ageing-induced microstructural transformations on the cyclic deformation, and failure behaviour of a type 316 LN SS weld joint under LCF and CFI loading.

2.0 Experimental details and Initial microstructure

Multi-pass shielded metal arc welding (SMAW) technique was used to produce the weld pads of 316 LN SS base metal plates with 22 mm thickness employing a double-V shaped groove joint geometry as shown in Fig. 1 (a). The chemical composition of the BM and WM and the procedure and parameters followed during welding are reported elsewhere [13]. The blanks from the sound regions of the weld pads (Fig. 1 (a)) following Xay-radiography inspection, were thermally aged at a temperature of 923 K for 5000 h with a view to capture the long-term effects at normal operating temperatures (823 K to 873 K) of the reactor. Tubular specimens with optimised geometry (1.4 mm wall thickness and a 25 mm gauge length) [13], were machined from the aged blanks and used for both LCF and CFI tests. A completely reversed triangular waveform was used to perform axial strain-controlled LCF tests at temperatures of 823 K, 873 K and 923 K employing a strain rate of 6.4×10^{-5} s^{-1} and mechanical strain amplitude ($\Delta\varepsilon_{mech}/2$) of ±0.4%, while the CFI tests were conducted with hold durations of 60 s and 300 s imposed at the peak strains during tensile deformation. All the tests were terminated following the failure criterion of a 20% decrease in the maximum tensile stress with reference to the half-life / stabilised value. Microstructural features of the samples following electrolytic etching at 1.6 volts in a solution prepared with 60 percent HNO_3 and 40 percent water were examined using optical microscope and field emission scanning electron microscope (FESEM) to gain insights into the microstructural transformation and the mechanisms of crack initiation and propagation.

The untested microstructure of the aged weld metal of joint is presented in Fig. 1 (b), which shows both δ-ferrite and σ-phase in an austenitic matrix. The important consequence of thermal ageing is seen to be the breakdown of the continuous network of the δ-ferrite (Fig. 1 b), which was attributed to the formation of carbides and intermetallic σ-phase and morphological chages due to continuous exposure to high temperature [10-12]. In addition, ageing also impareted a softening in the weld region and decreased the gradient in hardness distribution across the joint. The transformation of metastable δ-ferrite in austenitic SS welds following ageing is known to increase the stability of the microstructure [10-12] though at the expense of strength [13]. The difference in microhardness distribution across the joints in the thermally aged and as-welded conditions is presented elsewhere [13]. Previous thermal ageing studies on the 316 SS welds at different temperatures confirmed the presence of σ-phase either at the interfaces of austenite/δ-ferrite or within the δ-ferrite due to a high concentration of Cr and Mo and their faster diffusivity in the δ-ferrite [10-14]. The authors' earlier study [13] compared the substructural dislocation density of the weld region in the as-welded and thermally aged joints, calculated using the kernel average misorientation (KAM). A considerable reduction in the dislocation density was observed following the ageing, which was attributed to the temperature-induced annihilation of dislocations of opposite sign, imparting a softening in the weld region.

3.0 Results

3.1 Cyclic stress response and fatigue life

The variation in peak tensile stress of the aged joint with cycling during LCF and 300 s tensile hold CFI tests are plotted at different temperatures and presented in Fig. 2(a). The cyclic stress response (CSR) comprised of an initial cyclic hardening followed by a gradual cyclic softening, which culminates in a quick drop in the tensile stress owing to the formation of macrocracks (Fig. 2 a). The region of softening is seen to occupy a large portion of the total life. With an increase in the temperature, the CSR and fatigue life are found to decrease for both continuous cycling and hold time tests (Fig. 2 a), which was attributed to an increase in thermal recovery effects and creep damage with temperature [5-7]. Besides, the number of cycles required to reach the maximum stress (hardening) is higher at the temperature of 823 K compared to 923 K (Fig. 2 a). This behaviour is more evident under continuous cycling tests.

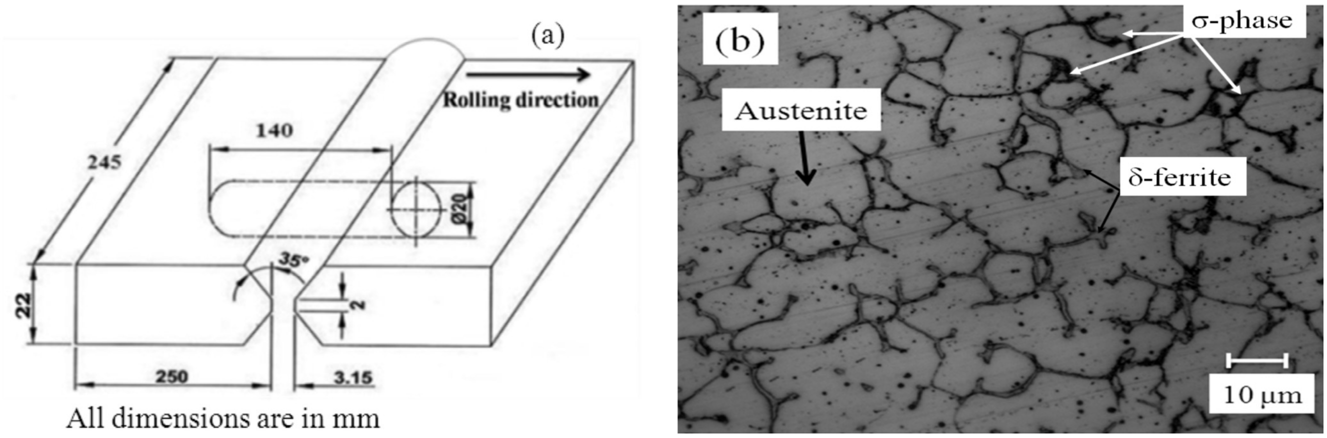

Fig. 1 (a) : Configuration of the weld pad, (b): optical microstructure of the weld region contains δ-ferrite and σ-phase in the austenitic matrix following thermal ageing.

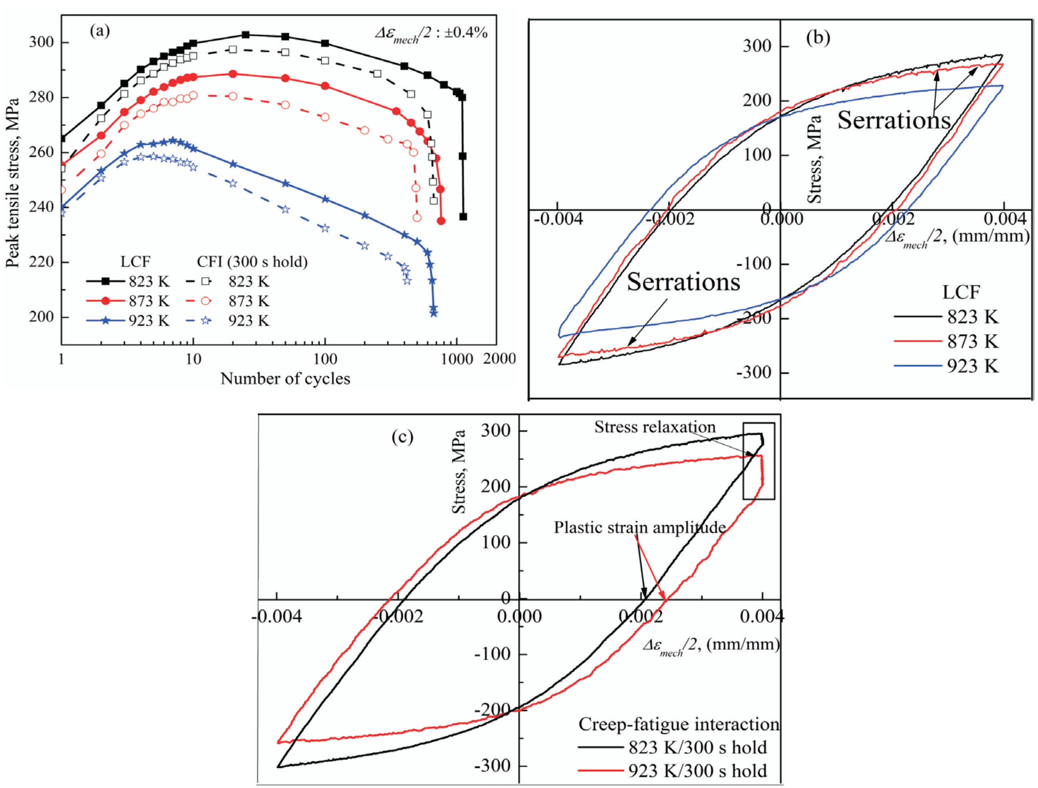

Fig. 2 (a) : Cyclic stress response of the aged joint, (b): variation in stress-strain behaviour during tensile and compressive regimes under LCF at different temperatures, (c): hysteresis loops showing increase in stress relaxation and accumulation of plastic strain with temperature under CFI (300 s hold) cycling.

The stress-strain hysteresis loops pertaining to the hardening period (20^{th} cycle) under LCF cycling at different temperatures are presented in Fig. 2 (b). The hysteresis loops obtained at temperatures of 823 K and 873 K are comparatively similar with serrations along the plastic portions, one of the manifestation of dynamic strain ageing (DSA) during LCF cycling (Fig. 2 b). On the other hand, the loop obtained at 923 K is considerably different in terms of the magnitude of CSR. Also, serrations were absent unlike the observations at the lower temperatures of 823 and 873 K, signifying that that the phenomenon of DSA plays an important role in the cyclic deformation behaviour at 823 K and 873 K. The hysteresis loops recorded under 300 s hold CFI cycling at 823 K and 923 K are presented in Fig. 2 (c). The magnitude of plastic strain amplitude ($\Delta\varepsilon_p/2$) is significantly increased with temperature under CFI cycling. (Fig. 2 c). With the introduction of hold at the peak tensile strain, the role of stress relaxation and thermal recovery in controlling the CSR of the joint can be seen from a decrease in the stress response. Also, a more pronounced plastic strain accumulation takes place in the tensile parts of the hysteresis loops, indicating an increased contribution from creep damage to the failure of the joint. Further, the increase in the $\Delta\varepsilon_p/2$ with the hold time was an indication of the accumulation of creep damage in the form of grain boundary cracks and voids in the material [5-7]. A more pronounced reduction in the CSR during the the tensile compared to the compressive deformation of the cycle leads to an asymmetric stress response, resulting in the development of a compressive mean stress under CFI. Though compressive mean stresses were developed in the CFI tests, a significant decrease in the fatigue life of the joint (Fig. 2 a) could be attributed to the detrimental influence of microstructural heterogeneity, creep and surface oxidation damages.

3.2 Microstructural aspects of failure

The location of failure and mechanisms of crack initiation and propagation under both LCF and CFI loadings varied with temperature of cyclic loading. During continuous cycling and 60 s hold tests, the cracks mostly occurred at the HAZ or the interface regions between the HAZ and the WM of the jont. Optical image of the secondary cracks along the HAZ-WM interface under CFI at 873 K/60 s is shown in Fig. 3 (a). Secondary cracks and intergranular failure can be observed in the HAZ region of the joint (Fig. 3 a). With an increase in the hold duration to 300 s, the location of failure is shifted to the WM region at all the tempertaures. An important feature associated with the failure of the weld joint under hold conditions is seen to be the extensive secondary cracking coupled with crack deflections in the weld metal region. Figs. 3 (b and c) present the distribution of surface cracks under CFI cycling (873 K/300 s hold) wherein the failure took place in the weld region. More number of secondary cracks are observed in the vicinity of propagating cracks, in addition to crack deflections, as indicated with arrows in Figs. 3 (b) and (c). Though the secondary cracking was seen at all the temperatures, nucleation of many small cavities and delaminations at the austenite/σ-phase interfaces around the propagating cracks are higher under CFI at 923 K conditions, as can be seen from Fig. 3 (d). The detrimental role of the austenite/σ-phase interfaces towards nucleation and growth of microcraks with increasing temperature under CFI loading can also be understood from the decrease in the cyclic life. The strain accumulation along austenite/σ-phase interfaces during CFI is higher compared to LCF cycling due to additional creep damage in the former, which changes the deformation and damage behaviour with a raise in temperature. The difference in crystal structure, thermal and mechanical properties and chemical composition of the austenite and σ-phase is expected to result in higher stress concentration at the interface regions due to the strain incompatibility, thus providing sites for easy crack initiation [8-15]. Hong *et al.* [16] performed a series of investigations to understand the role of δ-ferrite morphology on the fatigue behaviour of 304L SS base metal under LCF and CFI loadings and found that the austenite/δ-ferrite interface region is the generally favoured location for the nucleation and growth of cracks. This was ascribed to the development of maximum tensile stresses and de-bonding of the interfaces due to impingement of slip bands on the δ-ferrite [16]. In the present study, an increase in the temperature for a given hold time resulted in an increase in the creep damage which augmented the stress concentration in the interface regions (or ahead of the growing cracks), thus promoting the coalescence of small cavities into secondary cracks (Fig. 3 (d) and leading to accelerated crack growth rate. Thus, a combined effect of creep damage accumulation and microstructural degradation could be the reason for the significant difference in failure mechanisms under CFI cycling, though failure location remains mostly unchanged (Figs. 3 b, c, d).

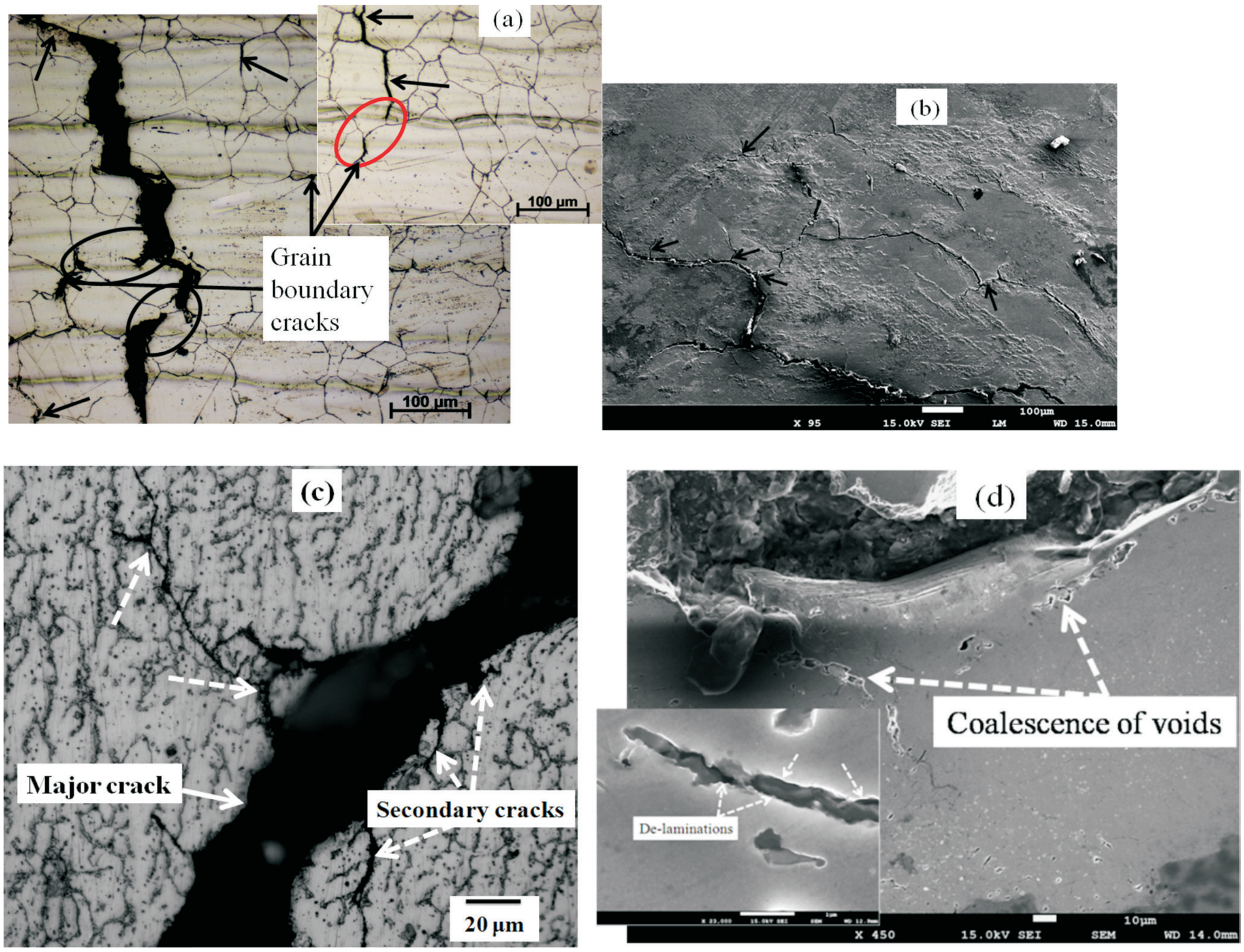

Fig. 3 (a) : Joining of the cracks in the HAZ region of HAZ/weld interface failure under CFI cycling at 873 K/60 s hold, (b), (c): weld metal failure showing distribution of secondary cracks and crack deflections under CFI cycling at 873 K/300 s hold, (d): cracks and microvoids in the weld metal and coalescence of microvoids around the major crack and delaminations at the austenite/σ-phase interface under CFI at 923 K/300 s.

4.0 Discussion

Different stages in the cyclic stress response of Type 316 LN SS weld joint under LCF and CFI cycling (Fig. 2 a) are due to difference in contribution from cyclic hardening and softening. The initial cyclic hardening is a consequence of dislocation multiplication and their pile-ups, dislocation–solute atom/precipitate interactions [5, 7, 13, 14, 17], while the cyclic softening is associated with the thermally-activated reorganization of random dislocation structure into cell/sub-cell configurations through dislocation annihilation and climb or cross-slip processes during their to-and-fro motion under cyclic loading [11, 13, 14, 17]. The contribution from the DSA to the cyclic hardening and the consequent increase in the stress response under cyclic loading was controlled by the diffusivity of the solute atoms (C, N, Cr, Mo) and their interactions with the moving dislocations [18]. The CSR is decreased with the duration of hold under CFI cycling which can be attributed to an enhanced substructural recovery which increases the probability of dislocation annihilations in the case of 316LN SS base metal as noted in earlier studies [5-7, 17]. In addition, when structures like weld joints are subjected to cyclic loadings, microstructural changes in the weld metal such as dislocation accumulation, subgrain formation, precipitation and possibly recrystallization also contribute to cyclic softening, depending on the loading conditions. Besides, the precipitation together with the formation of secondary phases will decrease the concentration of solute atoms responsible for the occurrence of DSA and matrix strengthening. Thus, a lower stress response under CFI compared to LCF tests (Fig. 2 a) is attributed to the combined influence of microstructural transformation, creep-induced softening and reduced DSA effects.

In the present study, the evolution of damage pertaining to different regions of the joint under LCF and CFI cycling are seen to be considerably different (Figs. 3 a-d). This is also supported by the observed differences in the stress response and fatigue life of the joint (Figs. 2 a-c) under the above cycling. In the case of high temperature cyclic loading of weld joints, inherent damaging mechanisms brought about by the metallurgical notch effect or microstructural embrittlement accelerate the microcrack formation [8, 9, 17]. The detrimental influence of the above mechanisms is strongly dependent on the temperature and hold duration, both of which have an important say on the failure location and fracture behaviour. Extensive microstructural examination following creep loading on 316 SS weld metal [15] demonstrated that the severity of cavitation damage and secondary cracking in the welds depends on the temperature and stress level. The effect of microstructural embrittlement becomes more pronounced with an increase in the duration of tensile strain hold, which together with the creep damage contributed to a reduction in the fatigue life. Though the WM failure was observed during both LCF and CFI conditions, the severity of localised deformation and the extent of secondary cracking was seen to be more complex under CFI with an increase in the temperature and hold time. The thermally activated motion of vacancies and their coalescence together with creep straining become significant at the interface regions with increasing temperature. Substructural evolution and void nucleation in weld joints become more complex during the creep part of CFI cycling because these mechanisms rely on the evolution of microstructural features such as secondary phase distribution, dislocation configurations, changes in the fraction of different grain boundaries (low angle, high angle, twin), grain boundary sliding, and interface regions. As a result, the availability of local sites for nucleation of microvoids increases with the hold duration, as evident from a large number of secondary cracks on the failed surface, tested under CFI with a hold time of 300 s (Figs. 3 b, d). Raske and Diercks [9] established that the resistance of 16-8-2 weld metal to creep-fatigue failure is directly correlated to its resistance to the interface cracking and the grain boundary damage. Thus, it can be deduced that addition of tensile hold into the fatigue cycle contributes to a significant damage in the HAZ or weld region of the joint. Therefore, the major factor that contributes to the failure in the weld region in the aged joint seems to be the local embrittlement associated with the nucleation of microvoids and their coalescence into secondary cracks/triple point cracks due to the development of deformation incompatibility along the interfaces with progressive cycling. Besides, an increase in the contributions from the creep mechanism can also be expected to aggravate the embrittlement in the joint. A series of investigations are in progress in the authors' laboratory to predict the lifetime of the weld joint under CFI by incorporating the microstructural factors into the existing life prediction models.

Conclusions

1. Cyclic softening is the dominant deformation mechanism in the aged weld joint under both LCF and CFI cycling. The stress response and fatigue life of the weld joint is decreased with an increase in the temperature and duration of the hold under CFI cycling.
2. Microstructural embrittlement in the weld region is an important damaging mechanism

that contributes to the early failure of the aged joint, in addition to creep damage.

3. The detrimental effect of microstructural embrittlement is found to promote the nucleation and growth of microvoids, delaminations, secondary cracking and crack deflections at interfaces of austenite/δ-ferrite/σ-phase, which increased with an increase in temperature and hold time under CFI.

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News Updates

Domestic

Adani makes metals debut as copper unit begins operations

Adani Enterprises commissioned the first unit of its copper refinery at Mundra in Gujarat, marking its debut in the metals space through subsidiary Kutch Copper.

Adani Enterprises will invest $1.2 billion to set up the first phase of the copper smelter, with an annual capacity of 500,000 tonnes. The second phase will also add 500,000 tonnes, making Kutch Copper the world's largest single-location custom copper smelter post completion of both the phases, the company said.

"With Kutch Copper commencing operations, the Adani portfolio of companies is not only entering the metals sector but also driving India's leap towards a sustainable and atmanirbhar (self-reliant) future," Gautam Adani, chairman of the group said. The project is likely to create 2,000 direct and 5,000 indirect jobs. It is also expected to have the lowest carbon footprint in its class.

"We believe the domestic copper industry will play a crucial role in achieving our nation's goal of carbon neutrality by 2070 by strengthening our green infrastructure hand in hand with mature environmental stewardship," Adani said.

The Economic Times (29.3.24)

Tata Steel India sales rises 6% to 20 Mt in FY24; production up 4%

Tata Steel India has reported a 6 per cent growth in deliveries to 19.90 million tonnes in FY24, supported by higher demand from retail, automotive and railway segments. In India, the company produced 18.85 Mt of steel during the preceding 2022-23 financial year, Tata Steel said in a statement.

Automotive and special products segment deliveries increased by 8 per cent in FY24 to 2.9 Mt, surpassing the previous record in FY23. Branded products and retail segment deliveries increased by 11 per cent in FY24 to 6.5 Mt. The industrial products & projects segment deliveries rose 6 per cent to 7.7 Mt.

Among sub-segments, engineering registered best-ever annual sales led by pre-engineered buildings and railways, among others, the company said.

The company in India produced a record 20.8 Mt crude steel in 2023-24, 4 per cent higher than 19.88 Mt in the previous fiscal.

The Economic Times (7.4.24)

India plans to raise steel production capacity three-fold by 2047

India is looking to enhance domestic steel production capacity threefold to 500 million tonnes per annum by 2047 with lower emission intensity, officials aware of the plan said.

The country also plans to reduce emission intensity to 2.25 tonnes of CO_2 per tonne of crude steel (2.25 T/tcs) production by FY29 from 2.50 T/tcs now, and even further by 2047, they said.

The new targets are more stringent than the goals fixed as per India's Nationally Determined Contributions (NDCs) for the steel sector.

Under the earlier goals, average CO_2 emission intensity of the Indian steel industry was projected to reduce from 3.1 T/tcs in 2005 to 2.64 T/tcs by 2020 and 2.4 T/tcs by 2030. This came to approximately 1% reduction annually. The country also targets to increase its steel-making capacity to 500 Mt in 2047 from around 161 Mt at present, a senior official aware of the plans being firmed up told ET. The plan takes forward the goals defined under the New steel policy (NSP), 2017, which aspires to achieve 300 Mt of steel-making capacity by 2030. NSP required an investment of around Rs 10 lakh crore for more than doubling the steel-making capability of the country from 2017 levels.

Domestic iron ore availability is pegged to improve from 226 Mt to 318 Mt in 2047.

In addition to these, the metals and mining sector can expect key reforms that allow more exploration, geological surveys and better data assessment, officials said. These goals are being finalised by sectoral groups of secretaries, along with action items to achieve them.

The Economic Times (9.4.24)

Shyam Metalics to invest Rs 650-750cr in stainless steel biz

Shyam Metalics and Energy Ltd announced that it will invest Rs 650-750 crore in its stainless steel business over the next few years. The company said it will establish a state-of-the-art stainless steel hot rolled coils (HRC) facility at its existing plant in Sambalpur, Odisha.

This facility, with a capacity of 0.3 million tonnes per year, will specialise in producing high-quality 200 and 400 series stainless steel hot rolled coils, as stated by the company in a statement. Shyam Metalics emphasised its commitment to leveraging captive raw materials such as direct-reduced iron (DRI), power, and ferro alloys for the project.

Additionally, the company plans to acquire a 20-acre land parcel at the newly merged Mittal Corp, now under its wholly-owned subsidiary Shyam Sel and Power Limited, officials said.

Sanjay Agarwal, Joint Managing Director of Shyam Metalics, said, "The entire project, expected to be commissioned by mid-FY 2026-27, will require a substantial capital outlay estimated to be in the range of Rs 650-750 crores."

The Economic Times (9.4.24)

India's steelmakers fall short of investment target due to delays linked to China

Leading Indian steelmakers fell short of an investment target for the fiscal year to March 2024 due to a delay in importing machinery from China and securing visas for Chinese experts, according to a government document reviewed by Reuters and sources.

Under a production-linked incentive programme, launched in 2020, 27 steelmakers including JSW Steel Ltd, Tata Steel Ltd, and ArcelorMittal Nippon Steel Ltd signed 57 agreements with the government, promising to invest Rs 21,000 crore ($2.52 billion) in the 2023/24 fiscal year.

But steel companies managed to invest only Rs 15,000 crore, according to two sources with knowledge of the matter, slowing down capacity expansion in the world's second-biggest crude steel producer even as domestic demand remained strong.

Steel companies have been facing difficulties in importing machinery from China and ensuring visa clearances for Chinese experts for more than six months, according to the government and the sources. Some of the steel mills that managed to get equipment on time failed to get experts from China to work on new projects, one of the sources said.

India's foreign ministry has issued guidelines to facilitate visa clearances for Chinese engineers, according to the document and one of the sources.

The Economic Times (15.4.24)

Jindal Stainless cuts 2.4 lakh tons of CO_2 emissions in last two fiscals

Jindal Stainless has reduced 2.4 lakh tonnes of carbon emissions between 2022-23 and 2023-24, according to a company statement. Jindal Stainless Ltd (JSL) is taking various measures to reduce the carbon component in its emissions to nil by 2050.

The company plans to generate over 1.9 billion units of clean electricity per annum with a target to reduce over 13.52 lakh tonnes of carbon emissions annually by the targeted year.

"In the last two fiscals (FY22 and FY23), the company has managed to successfully reduce 2.4 lakh tonnes of CO_2 emissions) taking it a step closer towards carbon neutrality and responsible manufacturing," the statement said.

The company said it has started using renewable energy sources for its operations. It has also started producing green hydrogen to be used in steel-making processes.

Besides, JSL has undertaken digitalisation and technology upgradation for energy efficiency and using EVs at its facilities in Odisha and Haryana.

The Economic Times (17.4.24)

Govt developing policy for low grade iron ore beneficiation: Steel secy

The government is working on a policy for low grade iron ore beneficiation, a move that will increase the usage of iron ore with less iron content in steel production.

Speaking to PTI, Steel Secretary Nagendra Nath Sinha said the Ministry of Steel along with the Ministry of Mines and the Ministry of Environment, Forest and Climate Change of India is working on the policy.

When asked about the timeline, he said the policy on the beneficiation of low grade iron ore is expected to be completed within three months' time.

"There may be some concessions on the royalty (on production of fines in the policy)," Sinha said without elaborating further.

While lump ore or high-grade iron ore contains 65.53 per cent Fe (iron), fines are inferior grade ore and have 64 per cent and less Fe content.

The use of iron ore with less iron content needs beneficiation which adds to the cost of steel production.

Business Standard (17.4.24)

Need to be watchful about steel imports: Tata Steel's T V Narendran

As steel imports continue to surge, Tata Steel CEO T V Narendran has said there is a need to be watchful about the situation. The comment comes at a time when India has reported a 38 per cent surge in steel imports to 8.319 million tonnes, becoming a net importer of the commodity during the 2023-24 financial year.

Speaking to PTI, the industry executive said, "It would be a pity if the situation continues in the long run. We have to be watchful about imports."

As long as it is unfair imports, the government needs to deal with it, Narendran said without elaborating further.

Steel consumption is expected to grow 8-10 per cent in the ongoing 2024-25 fiscal year, he said in reply to a separate question on demand.

Steelmakers have been raising concerns on increasing imports from certain countries, including China and seeking the government's intervention on the issue. Domestic players have also been demanding a curb on imports and review of free trade agreements (FTAs) with several countries.

"I don't think reviewing FTAs would be easy. But that's for the government to decide," Narendran added.

The Economic Times (28.4.24)

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NF Metals Statistics

Domestic Scenario

Prices in India (as on 25th April, 2024)

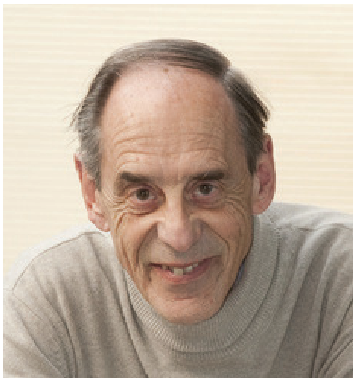
(Mumbai Local Price in Rs. / kg)

Product	Rs. / kg	Product	Rs. / kg
Copper Armature	828	Aluminium Ingot	248
Copper Cathod	884	Aluminium utensil	190
CC Rod	882	Zinc Ingot	253
Copper Cable scrap	844	Lead ingot	193
Brass Sheet Scrap	565	Tin Ingot	3040
Brass Honey Scrap	534	Nickel Cathod	1615

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

Achievements

Prof Dr Herbert Gleiter



Prof. Dr. Herbert Gleiter, the Honorary Member of IIM, is a German researcher in physics and nanotechnology. In 2023 two attractive new facet of his professional life have been started by the decision of the Chinese National Academy of Sciences (CAS).

The Chinese National Academy of Sciences offered him the opportunity of founding a new research institute of the CAS which will be given the name "Herbert Gleiter International Institute (HGII)". This HGII will focus its studies on the new atomic structures as well as the new properties of nanoglasses.

The HGII will be one of the four largest of the 14 National Institutes of the CAS.

The motivation of the CAS for this high ranking of the research on nanoglasses is the expectation that nanoglassy materials may open the way to a new world of technologies based on non-crystalline materials, similar to today's world of technologies that are primarily based on crystalline materials such as metals, ceramics or semi-conductors.

Due to their new atomic structures (different from the crystalline state as well as from the structures of today's glassy materials) nanoglasses exhibit new properties for numerous areas of science and technology. For example, the rate of the growth of ceölls deposited at the free surfaces of specific nanoglasses seems to be enhanced by up to several orders of magnitude, however, this is by no means the only new and surprising property of certain nanoglasses. They also were found to seem to permit the alloying of components that are immiscible in the crystalline state. For example the alloying of ionic and metallic components (e.g. the alloying of a metallic iron-based glass with a glassy material such as SiO2). Obviously, these new properties are likely to open the way to attractive new applications in the field of implantation medicine or by means of generating materials with novel electronic etc. properties.

The novel structures and properties of nanoglasses and nanoglass alloys were also the motivation for Lanzhou University to found in 2023 a new research center named "Gleiter Institute of Nanoscience (GIN)" working on new methods to prepare nanoglasses and nanoglass alloys as well as studies of their novel structure and properties.

It was also these new aspects of nanoglasses as well as of nanoglass alloys and the remarkable results reported for their structures and properties that motivated the Liaoning Academy of Materials, the Chinese National Academy of Science and the International Core Academy of Science and Humanities to elect me in 2023 as a new member. In fact, it were also these new aspects of nanoglasses and nanoglass alloys that motivated, the Lanzhou University to confer upon me an Honorary Doctor Degree in 2023.

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Achievements

Dr K L Murty

K. Linga (KL) Murty receives 2023-24 Alexander Quarles Holladay Medal for Excellence, the highest honor bestowed by NC State and the university's Board of Trustees

Dr. K. L. Murty, Progress Energy Distinguished Professor of Nuclear Engineering Department (and Professor jointly with Materials Science & Engineering) at NC State University. Murty joined NC State University in Aug 1981 following industrial experience at Westinghouse Research Center and Lynchburg Research Center of Babcock & Wilcox Co. Prior to that, he was an AINSE Research Fellow in the University of Newcastle (1972-75) and Research Metallurgist in Inorganic Materials Research Division (IMRD) in Lawrence Berkeley Laboratory (LBL) at the University of California, Berkeley (1970-72). He obtained his PhD in Applied Physics and Materials Science in 1970 from Cornell University following MS there in 1967. Prior to coming to USA in 1964, he attended Andhra University in Vishakhapatnam, India where he completed his B.Sc. (Hons) and M.Sc. in Physics with 1st rank in 1962 and 1963 respectively. He received many honors and awards for academic achievements during high school (M.H. School, Anakapalle), college (1957-58 - A.M.A. Lingamurty College, Anakapalle) and university: Lingamurthy Memorial Prize (1956, 1957, 1958), G.N. Murthy Memorial Medal (1958), Sripathi Medal (1962), S.B.P.V. Rao Memorial Prize (1962), Metcalfe Medal (1963) and Kothari Prize (1963).

Following his faculty appointment at NC State University in 1981, he received DAAD Fellowship (1987) in Germany, Alcoa Foundation Research Achievement Award (1988) at NC State, Gledden Senior Visiting Fellowship (1992) in Australia, and ANS Mishima Award (1993) for outstanding research in nuclear materials and fuels. He is a fellow of the American Society for Metals International and the American Nuclear Society. He is Honorary Member of the Indian Institute of Metals (IIM) and American Institute of Metallurgical Engineering (AIME). He served as the Program Director of Metals Research in the Division of Materials Research at the National Science Foundation on their IPA program during 2001-03. His recent doctoral students received the ANS Mark Mills Award for outstanding research paper from doctoral thesis: Dr. Ahmad Alsabbagh in 2014 (PhD, Nuclear Engineering) and Dr. Boopathy Kombaiah in 2015 (PhD, Materials Science and Engineering).

Murty is author/co-author of 384 technical papers and is a co-author of a text book on 'Introduction to Nuclear Materials,' published by Wiley & Sons. During the last 4 decades, he organized a number of technical symposia at the annual meetings of ASM, TMS and ANS. During his sabbatical at the Mechanical Engineering department of the Andhra University, Vishakhapatnam in 1987, he was instrumental in getting funds from the University Grants Commission of India for a separate Metallurgical Engineering department along with a new building and a number of faculty members at the Andhra University. Starting in March 2001, Dr. Murty instituted two awards in the newly established Metallurgical Engineering Department: (1) Lingamurty Gold Medal for Best student in Metallurgy, and (2) Kalaprapoorna Subbaraju Memorial Scholarship for Best upcoming senior, Metallurgy, in Andhra University. He and his wife, Ratnaveni instituted Murty scholarship in the College of Engineering at NCSU in 2012 and a scholarship in memory of his parents in 2018 (Kalaprapoorna Dr. K. subbaraju and Subhadramma Memorial Scholarship in 2018. A mini-symposium on 'Creep, Deformation, Texture, Nano and Nuclear Materials,' was held in his honor during the Plasticity2016 conference in Big Island, Hawaii. In addition, a symposium in his honor on 'Creep and Deformation of Advanced Materials,' was held during the TMS Annual Meeting in Feb 27 - Mar 2, 2017 in San Diego, CA.

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Chapter Activities

Kanpur, Roorkee

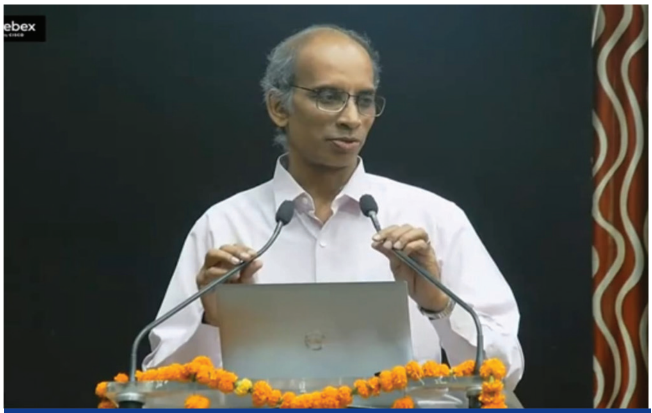
Kanpur Chapter

1) The Executive Committee (EC) Meeting of the IIM Kanpur Chapter was successfully held on April 17, 2024. Members gathered to discuss and strategize future activities and budgetary plans for the chapter. The meeting was productive, focusing on setting objectives and planning initiatives to further the chapter's goals. This collaborative effort is expected to drive the chapter's activities and growth in the coming year.

2) On April 19, 2024, the IIM Kanpur Chapter organised a talk on "Engineering Materials at the Atomic Scale for the Development of 3D-printed Complex Architecture for Sustainable Energy and Environment Applications." The talk was delivered by Prof. Chandra S. Tiwary of IIT Kharagpur which was well-attended by IIM members, students, and faculty members.

Roorkee Chapter

The 5th Prof. M L Kapoor Endowment Lecture was organised by the Metallurgical and Materials Engineering Dept., IIT Roorkee in collaboration with IIM Roorkee Chapter on April 29, 2024 at MAC Auditorium, IIT Roorkee. Dr. R. Balamuralikrishnan, Outstanding Scientist & Director DMRL-DRDO, Hyderabad delivered the lecture on "The Valley of Death in the Context of Advanced Materials". The lecture was well attended by the Audience which is available in youtube (https://www.youtube.com/live/1uEXSadLycg).



Dr. R. Balamuralikrishnan delivering the lecture

Lamp lighting ceremony

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BRML 2024

6th Dr Baldev Raj Memorial Lecture

IIM Trivandrum Chapter along with The Indian Institute of Metals HO, and IIM Human Resources Development Centre, Kalpakkam-Chennai organised the 6th Padmashri Dr. Baldev Raj Memorial Lecture on 9th April 2024 at National Institute of Inter-Disciplinary Sciences and Technology (CSIR-NIIST), Pappanamcode, Trivandrum. The lecture was attended by 150 participants in physical mode. The audience included several Senior Scientists from VSSC, LPSC, CSIR-NIIST, IIM Members and Research Scholars. More than 100 members participated in online mode as well. The programme started with lighting of the lamp and paying floral tributes to Late Dr. Baldev Raj by the dignitaries on the dias.

The Chapter Chairman Dr. S.V.S. Narayana Murty delivered the welcome address. Dr. U. Kamachi Mudali, Former President IIM & Vice Chancellor, Homi Bhaba National Institute, Mumbai presented the profile of Dr. Baldev Raj and also talked about the evolution of lecture Series. This was followed by the online message from Shri Satish Pai, President, IIM & Managing Director, Hindalco Industries. Dr. C. Anandharamakrishnan, Director, CSIR – NIIST, Trivandrum delivered a presidential address and welcomed the audience. A special address was delivered by Brig Arun Ganguli (Retd), Secretary General, IIM HO. Dr. K. Ramesha, Director, CSIR-CECRI, Karaikudi also graced the occasion.

The chief guest Dr. G. Madhavan Nair, Former Chairman, Indian Space Research Organization (ISRO) & Former Secretary, Department of Space (DOS), Govt. of India was formally introduced by Dr. S.V.S. Narayana Murty, Chairman IIM Trivandrum Chapter.

Dr. G. Madhavan Nair started his talk with his reminisces of Dr. Baldev Raj. He delivered the Lecture titled 'Space: The Next Frontier for Human Exploration'. Subsequently he had interaction with Students and members of the Chapter. His talk covered the evolution of launch vehicles and satellites of India, accomplishments of Chandrayaan-1, Mangalyaan and Chandrayaan-3 missions and the challenges being encountered in India's Human Space mission Gaganyaan. He stressed that the opportunities in Space are unlimited for the future generations.

The vote of thanks was proposed by Dr. V. Anil Kumar, Hon. Secretary, IIM Trivandrum Chapter. The meeting was followed by Lunch at Guest Dining facility at CSIR-NIIST Canteen.

Lighting the Lamp & Floral tributes to Dr. Baldev Raj

Dr. G. Madhavan Nair delivering the Lecture

Dignitaries with the Speaker

A Glimpse of the audience

Felicitation of Chief Guest Dr. G. Madhavan Nair by Dr. U. Kamachi Mudali

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Iron & Steel Statistics

World

Crude Steel production by region

	Mar 2024 (Mt)	% change Mar 24/23	Jan-Mar 2024 (Mt)	% change Jan-Mar 24/23
Africa	1.9	1.1	5.6	8.3
Asia and Oceania	118.3	-5.8	345.9	-0.4
EU (27)	11.6	-4.3	33.0	-1.4
Europe, Other	3.9	11.0	11.3	20.5
Middle East	4.8	4.0	13.7	12.1
North America	9.5	-1.4	27.2	-1.9
Russia & other CIS + Ukraine	7.8	1.5	21.8	1.6
South America	3.5	-0.2	10.6	3.2
Total 71 countries	**161.2**	**-4.3**	**469.1**	**0.5**

The 71 countries included in this table accounted for approximately 98% of total world crude steel production in 2023. Regions and countries covered by the table:

- **Africa :** Algeria, Egypt, Libya, Morocco, South Africa, Tunisia
- **Asia and Oceania :** Australia, China, India, Japan, Mongolia, New Zealand, Pakistan, South Korea, Taiwan (China), Thailand, Viet Nam
- **European Union (27) :** Austria, Belgium, Bulgaria, Croatia, Czechia, Finland, France, Germany, Greece, Hungary, Italy, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
- **Europe, Other :** Macedonia, Norway, Serbia, Türkiye, United Kingdom
- **Middle East:** Bahrain, Iran, Iraq, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen
- **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

	Mar 2024 (Mt)	% change Mar 24/23	Jan-Mar 2024 (Mt)	% change Jan-Mar 24/23
China	88.3	-7.8	256.6	-1.9
India	12.7	7.8	37.3	9.7
Japan	7.2	-3.9	21.5	-0.8
United States	6.9	0.0	19.9	-1.6
Russia	6.6 e	0.8	18.7	-0.2
South Korea	5.3	-9.5	16.2	-2.5
Germany	3.5	8.4	9.7	6.0
Türkiye	3.2	18.0	9.5	28.4
Brazil	2.8	5.6	8.3	6.2
Iran	2.8	2.0	7.6	16.3

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

Source : worldsteel.org


IIM-ATM 2024
Metallurgy
Materials Engineering
Steel
78th Annual Technical Meeting of The Indian Institute of Metals
20 – 22 November 2024
Bengaluru
Venue
Dr. Babu Rajendra Prasad International Convention Centre, Gandhi Krishi Vignan Kendra (GKVK)
University of Agricultural Sciences, Bengaluru
Organizers
IIM Vijayanagar Chapter, IIM Bangalore Chapter, IIM Dolvi Chapter, IIM Salem Chapter
in association with JSW Steel Ltd.
6366919274
iim.atm2024@jsw.in
www.iimatm.in

International Symposium on Transformational Technologies in Materials & Manufacturing

In today's dynamic industrial landscape, the convergence of state-of-the-art technologies within materials and manufacturing is indispensable for driving sustainable growth and maintaining competitiveness. Transformative advancements in materials and manufacturing represent a profound shift in how we conceive, develop, and utilize materials across various industrial sectors. From pioneering materials like nanomaterials and biomaterials to revolutionary manufacturing processes such as additive manufacturing (3D printing), robotics, and advanced automation, these innovations are reshaping the way we approach production.

At the core of this paradigm shift lies a shared pursuit of enhanced efficiency, sustainability, and performance across industries. By harnessing these transformative technologies, manufacturers can unlock unprecedented levels of precision, customization & cost-effective-ness in their production processes. This symposium serves as a focal point for industry thought leaders, researchers, and innovators to convene and explore the latest breakthroughs that are shaping the future of manufacturing.

With leading minds from around the world presenting their pioneering research and insights, this conference offers a unique platform for industry stakeholders to glean invaluable knowledge and perspectives. By showcasing transformative technologies and discussing their real-world applications, we empower industries to navigate the evolving landscape and make informed decisions about their technological investments.

Join us as we collectively chart a course toward a more efficient, sustainable & technologically-driven future for materials and manufacturing.

IIM-ATM 2024

Mark your calendars for the 78th Annual Technical Meeting of the Indian Institute of Metals (IIM-ATM), taking place from November 20th to 22nd, 2024. This event will be an unparalleled opportunity to delve into a wide spectrum of subjects, including mineral processing, ferrous and non-ferrous metals, advanced materials, digitalization, Industry 4.0, and sustainability practices.

Joining us will be a diverse array of professionals, including metallurgists, material scientists, engineers, students, and more, all eager to engage in extensive knowledge sharing and lively discussions. At the heart of the IIM-ATM, there will be an international conference featuring cutting-edge topics such as green manufacturing, strategic and rare metals, additive manufacturing, and accelerated materials development. Thematic sessions will delve into crucial and emerging areas, offering insights that will benefit the entire industrial community. Expect to connect with representatives from industries, Government bodies, research scholars, technical experts, and students.

In addition to the enriching discussions, the event will host a dynamic technical exhibition. This platform will showcase the activities, products, and innovative initiatives of enterprises across the metal, materials, and manufacturing sectors. Whether you represent a large corporation or a small-scale enterprise, this exhibition will provide invaluable opportunities for networking and discovering the latest methodologies and techniques shaping our industry's landscape.

Why Attend?

As the flagship event of the Indian Institute of Metals (IIM), the symposiums and annual technical meeting sessions have consistently stood as pillars of progress in the fields of metals, materials science, and manufacturing technology. Over the years, these gatherings have been instrumental in advancing discussions, presenting groundbreaking research, and fostering invaluable networking opportunities.

Past editions have witnessed the unveiling of pioneering research, engaging discussions, and memorable interactions for participants from diverse backgrounds. This year, the event is poised to continue its legacy by serving as a hub for collaboration, innovation, and cross-disciplinary dialogue. It promises to bring together academia, industry, and research institutions to explore new frontiers and chart the course for future advancements.

In essence, this cornerstone event of the IIM remains a beacon of knowledge and inspiration, driving the collective pursuit of excellence and progress in our shared domains.

Key Highlights

- **Explore Innovation:** Dive into the latest advances and emerging trends across materials science, manufacturing technologies and beyond
- **Expand Your Circle:** Connect with industry experts, peers, and potential collaborators to build valuable relationships and foster future partnerships
- **Exchange Knowledge:** Access cutting-edge research findings, real-world case studies and best practices to drive practical solutions and industry progress
- **Enrich Your Career:** Gain invaluable insights, mentorship and career guidance from seasoned professionals, empowering you to navigate your career path with confidence
- **Exhibit Your Impact:** Showcase your organization's products, services, and innovations to a diverse audience of industry leaders, researchers and decision-makers, amplifying your visibility and unlocking new opportunities

Glimpses of IIM-ATM 2023


Call for Abstracts

Prepare to seize a golden opportunity by submitting your abstract for presentation at the IIM ATM 2024. This prestigious event offers a platform to showcase your groundbreaking research and insights to an esteemed audience, including fellow researchers, academicians, industry experts, and policymaker. Whether you opt for an oral presentation or a poster display, your work will garner the attention it deserves, fostering collaboration, exchange of ideas, and potential partnerships. Abstracts are invited for technical sessions covering the entire spectrum of Metallurgy and Materials Science.

Your abstract, up to 500 words in length and written in English, can be submitted electronically in MS Word format. We do not accept submissions via mail or fax. Ensure adherence to submission guidelines by downloading the abstract submission template from our website.

Don't miss this opportunity to contribute to the advancement of metallurgy and materials science while engaging with peers and industry professionals. Submit your abstract today and be part of this exciting event.

The major topics will encompass a wide range, including but not limited to;

- Mineral Processing – Ferrous, Non-ferrous and Coal
- Ironmaking and Steelmaking
- Non-ferrous Metal Processing
- Solidification and Casting
- Metal Forming - Hot Rolling, Cold Rolling, Forging and Drawing
- Metal Joining – Ferrous and Non-ferrous
- Powder Metallurgy and Additive Manufacturing
- Bio-Materials, Smart Materials and Functional Materials
- Integrated Computational Materials Engineering (ICME), Modeling and Simulation
- Digitalization and Industry 4.0
- Structure Property Correlation
- Failure Analysis
- Environment and Sustainability
- Refractories, Ceramics and Composites
- Materials for Strategic Sectors – Defence, Nuclear and Aerospace
- Corrosion, Electrochemistry, Batteries and Fuel Cells
- Archaeo-metallurgy

Abstract Format

Font: Times New Roman
Size: 12
Title: Centered, Bold
Authors: Centered, Underlined the presenter, Single-space
Affiliation : Centered, Single-Space
E-mail address: Author's e-mail address
Contact Number: Author's contact number
Abstract: Single-space within paragraph, Double-space between paragraphs, Image inserts acceptable, 1 inch margin on four sides
Word limit: 500 words
Keyword: Maximum 5 words

Important Points

- To submit abstracts, please create an account in the website and upload your abstract in accordance with the submission guidelines
- Authors receive notification of acceptance in August
- All speakers and interested participants must register for the event by paying the prescribed registration fees through the registration link in the website
- To ensure a smooth process, we recommend early registration

Outstanding oral and poster presentations from each session and theme will be recognized and awarded during the event. More numbers of student participation is anticipated. Exciting prizes will be presented to PG/UG students for their distinctive work in materials and manufacturing sector.

Last Date for Submission of abstracts: 31st July 2024

Submit Abstract at www.iimatm.in

Sponsorship Opportunities

We are honoured to invite you to be a part of our upcoming conference as a sponsor. Don't miss this opportunity to elevate your brand and connect with industry leaders. Secure your sponsorship package today and position your organization as a key supporter of our conference. Details of various sponsorship opportunities and benefits are as below.

Sponsorship and Exhibition		Privileges	
Category (INR)	**Amount**	**Complimentary Registration**	**Others**
Platinum	₹ 15,00,000	10	~ Stall Area of 12 m^2 ~ One page colour advertisement in Souvenir ~ Banner publicity as Platinum Sponsor ~ Logo Display in the Website ~ Virtual Event Platform Access
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Silver	₹ 4,00,000	3	~ One page colour advertisement in Souvenir ~ Banner publicity as Silver Sponsor ~ Logo Display in the Website ~ Virtual Event Platform Access
Gala Dinner Sponsor	₹ 15,00,000	10	~ Banner publicity as Conference Gala Dinner sponsor
Gala Cultural Programme Sponsor	₹ 10,00,000	7	~ Banner and Backdrop screen publicity as Gala Cultural Programme sponsor
Conference Dinner Sponsor	₹ 10,00,000	7	~ Banner publicity as Conference Dinner sponsor
Conference Cultural Programme Sponsor	₹ 7,00,000	4	~ Banner and Backdrop screen publicity as Conference Cultural Programme sponsor
Conference Lunch Sponsor	₹ 10,00,000	7	~ Banner publicity as Conference Lunch sponsor
Delegates Bag Sponsor	₹ 10,00,000	7	~ Logo and company details printed in the bag
Technical Session Sponsor	₹ 3,00,000	2	~ Banner publicity during the session
Writing Pad Sponsor	₹ 1,00,000	1	~ Details of the sponsor printed in writing pad
Pen Sponsor	₹ 1,00,000	1	~ Details of the sponsor printed on pen

Souvenir

During IIM-ATM2024, a Souvenir will be unveiled at the Inaugural Function on 20th November 2024, in the presence of esteemed government officials, industry leaders, delegates from various sectors, and technical institutions. The 78th IIM-ATM Souvenir will feature messages from government representatives and renowned professionals, special articles, event details, committee information, awards, sponsors, supporters, and advertisements from both domestic and international entities. Soft copies of the souvenir will be provided to all event attendees, while limited high-quality hard copies will be printed for distribution to government agencies, industries, research and development laboratories, and academic institutions. Advertisements are welcomed for inclusion in the souvenir, with details regarding rates provided below.

Souvenir Advertisement Tariff
Back Cover - Colour : ₹ 1,00,000
Inside Cover (Back/Front) - Colour : ₹ 75,000
Full Page - Colour : ₹ 50,000
Half Page - Colour : ₹ 30,000

Technical Exhibition

A Technical Exhibition is planned during 20th – 22nd November 2024, in which various organizations, equipment suppliers, research institutions, consulting organizations and industries, both from India as well as from abroad, will get an opportunity to display their state-of-the art products and technologies to the largest gathering of Metallurgical and Material Engineering community.

Exhibition Stall

Stall Option	Price	Area	Includes
Standard Stall Option 1	₹ 6,50,000	12 m^2	Power Connection, Partitions, Front Desk and two chairs
Standard Stall Option 2	₹ 5,00,000	9 m^2	
Standard Stall Option 3	₹ 3,50,000	6 m^2	
Rate for additional space	₹ 60,000	per m^2	

Important Contacts

For any queries and Information contact the organizing committee members

Contact	Contact Number	Email ID
For General Queries		
IIM Secretariat	08395-243412 6366919274	iim.atm2024@jsw.in
Convenor Dr. Dhiren Kumar Panda	8884030210	dhirenkumar.panda@jsw.in
Co-Convenor Dr. D Satish Kumar	9449598273	satishkumar.dabbiru@jsw.in
For Registration & Website		
Mr. Ravindra Reddy	9480693062	ravindra.yeruva@jsw.in
Mr. Pranav Tripathi	9480694689	pranavkumar.tripathi@jsw.in
For Abstract & Poster		
Dr. Manjini S	9448286114	manjini.sambandam@jsw.in
Mr. Mrunmaya Pasupalak	9480693088	mrunmaya.pasupalak@jsw.in
For Sponsorship		
Mr. Pradeep Sikhile	9480693459	pradeep.sikhil@jsw.in
Mr. Pritesh Nesarkar	8971729697	pritesh.nesarkar@jsw.in
For Travel & Accommodation		
Mr. Praveen Kumar	9480693096	praveen.kumar@jsw.in
Mr. Ganesh K C	9480693744	ganesh.gagan@jsw.in

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