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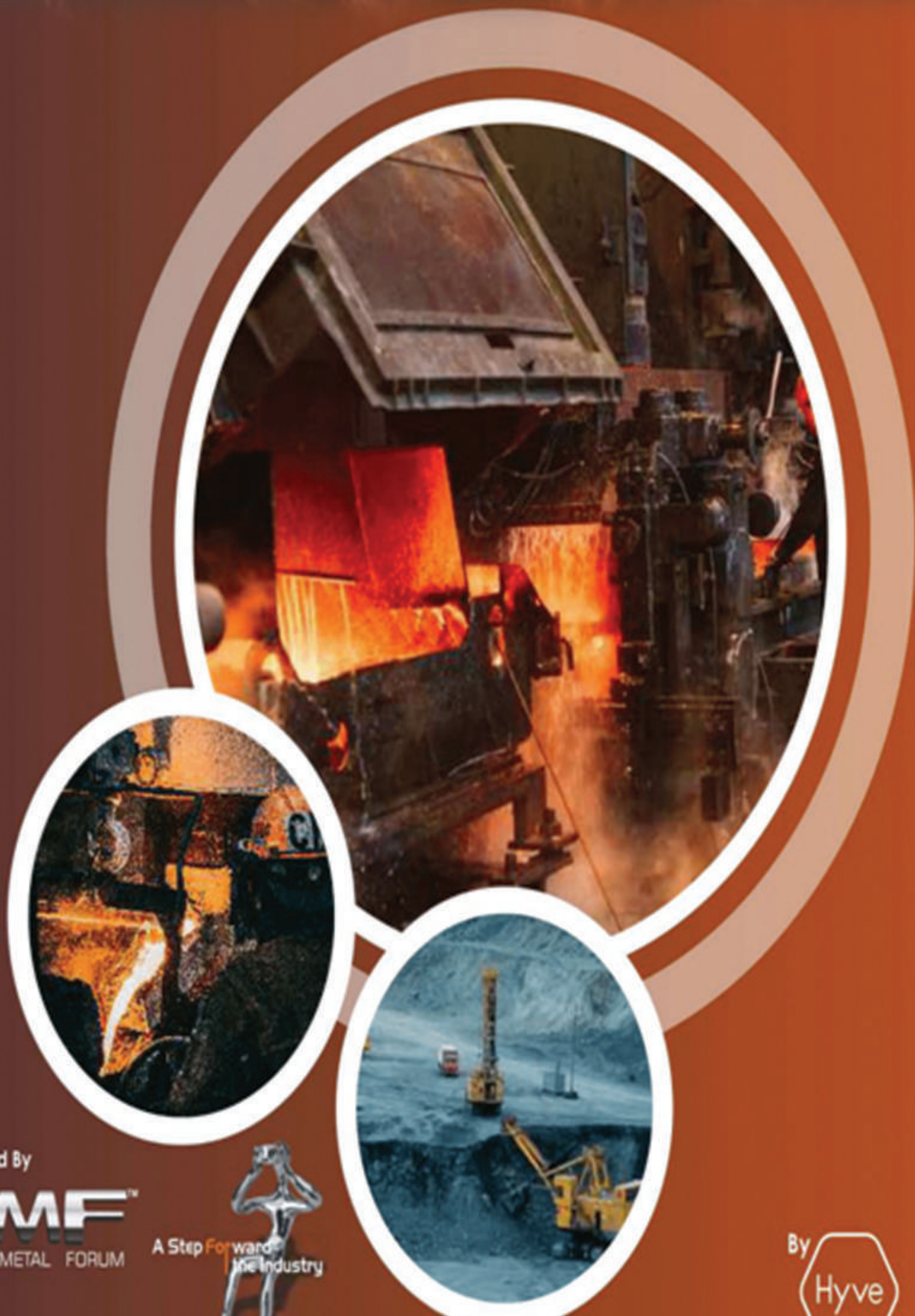

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Chief Editor
Prof K Bhanu Sankara Rao

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E-mail: secretarygeneral@iim-india.net
publications@iim-india.net
Phone: 033-2367 7089 / 2367 5004
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Technical Article

Using Advanced Surface Engineering to Improve Efficiency of Coal based Power Generation

K Anand

Abstract

Thermal power continues to meet nearly 75% of energy needs despite the growing foot print of Renewables across the world. Given the advent of climate change, managing emissions from thermal power plants through more efficient Brayton and Rankine cycles have taken centre stage. Advanced ultra-super critical (AUSC) steam turbines generate power at an efficiency of 48-50% using coal as fuel. HA.03 gas turbines along with steam turbines in a combined cycle power plant generate energy at efficiency that exceeds 63% with natural gas as the fuel. Yet, the power plants are susceptible to degradation due to several surface damage mechanisms which in combination can reduce efficiency by as much as 3 to 6%. Efficiency loss occurs because of three predominant factors: a) Aerodynamic drag because of rough surfaces resulting from erosion, corrosion and fouling, b) Clearance increase caused by rubs between rotating and stationary surfaces leading to leakage flows, and c) Heat transfer losses caused by fouling and deposition of insulating deposits leading to reduced heat transfer between combustion gases fluid medium pumped through tubes. These three mechanisms contribute to as much as 6% of efficiency losses in a large thermal power plant; with 200GW of installed thermal power capacity, this represents enough fuel to burn generate an extra 12000 MW of power into the grid. Technologies to address surface damage and clearance increase are available and can in principle be retrofitted on existing designs. Technologies to combat heat transfer losses are at varying degrees of maturation and needs further validation. This paper presents both tried and tested approaches as well as new ideas to protect components from surface damage when exposed to stringent operating conditions to meet efficiency and output requirements as well as combat surface degradation.

Coal Based Thermal Power

Heat rate 0.7Kg/KWh of power
5% efficiency loss – 0.035 Kg per KWh
35 ton for 1000 MWHr – 2450000 Tons per year
for 1000 MWh plant

For a 200GW thermal power economy it is 49 million tons of additional coal being burnt – or 125 million tons of CO_2 additional emissions being released

GE Retiree and Consultant
E-mail : anandmapr@gmail.com

1.0 Introduction

Thermal power has remained one of the main sources of energy across much of the world, with the energy being fuelled predominantly by combustion of coal and or natural gas. Coal, unless gasified, is typically pulverized, burnt in a boiler to generate steam at high pressure and temperature, which in turn drives a steam turbine. Depending on the pressure and temperature of the steam as it enters the steam turbine high-pressure section, the power plant is called as sub-critical, super critical, ultra super critical or advanced super critical. The increase in steam pressure and temperature improves the plant efficiency from 35% for sub critical to 42% for ultra-super critical to 48% for advanced ultra super critical steam turbines. Similarly, with gas turbines depending on the compression ratio of the compressor and hot gas path firing temperature and turbine inlet temperature of the combustion plume the efficiency of the simple cycle gas turbine can vary from 38% to 48%. When the hot exhaust gases from a gas turbine are passed through a Heat Recovery Steam Generator (HRSG) and the steam is passed through a steam turbine, one has a combined cycle gas powered plant with an efficiency ranging from 52% to 63% (See Figure 1).

It must be noted that natural gas-powered combined cycle turbines offer significantly higher efficiency compared to coal fired Rankine cycle steam turbines. However, the entitlement efficiency as described in Figure 1, drops rapidly within the first thousand hours of operation because of several surface degradation modes. Since the mechanisms are different for coal and gas fired thermal power plants these are covered separately.

2.0 Efficiency Loss in Coal Fired Thermal Power Plants

The operation of a coal fired thermal power plant is described below. Blocky coal pieces are fed into the coal pulveriser mill wherein the coal is ground between a rotating annular disc and conical rolls to a size where d_{75} is 75 microns or below. The crushed coal particles along with ash, constituting often 35 to 50% of the mix are fed into the combustors. The combustors, typically numbering four or more create a large fire ball in the boiler stack. The hot flue gases flow past the water wall panels where the water gets converted to steam and then past super heater reheater and economiser boiler tube bank. The hot flue gases as they exit, heat up the incoming ambient air in air preheater system so that the combustion efficacy (and efficiency) of solid coal particles is improved. Water fed through the boiler stack becomes steam is progressively heated through economiser, reheater and super heater banks till it reaches temperature and pressure that can fire the steam turbine. Depending on the

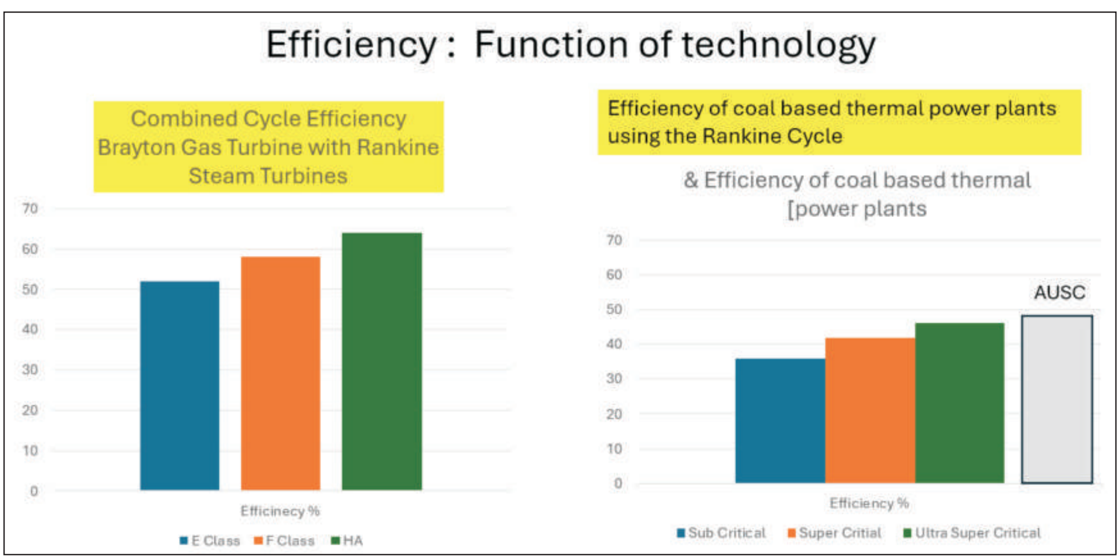


Fig. 1 : Efficiency of New Thermal Power Installations Based on the Brayton and Rankine Combined Cycle (Left) and Rankine Cycle (Right).

pressure and temperature of steam as it enters the steam turbine the system is classified into subcritical, super critical, ultrasuper critical or advanced ultra super critical with increasing efficiency. The efficiency of power generation varies based on input steam – temperature and pressure cycles which is outlined in Table One. Major degradation modes include wear of coal mill rolling elements leading sub-optimum size distribution, high temperature wear of combustor nozzles leading to skewed flame orientation, deposition of ash and slag on boiler tube elements leading to reduced heat transfer, and deposition of soot, heavy hydrocarbons on air preheater seals. Efficiency losses due to surface degradation of coal mill elements, combustor, boiler tubes and air preheaters can total to about 4%.

The oxides on the tube ID, reach critical thickness and spall off after several thousand hours of operation during shut downs, and are carried into the steam path impacting turbomachinery as the exfoliated oxide scales are very erosive. The steam flow path components are subject to erosion, leading to increased roughness levels, chord loss, causing aerodynamic losses. Also, the MSV valve stem is subject to erosion which can lead to leakage flows when the valve is seated. The steam as is traverses past the High Pressure and Intermediate section loses its pressure and temperature, where it enters the Low Pressure (LP) turbine. The gaseous steam sheds temperature and pressure till it reaches condensation point. Thus at the exit of the last stage of the LP (Last Stage Bucket), the flow is partly steam

Table 1: Steam Pressure, Temperature and Efficiency of Different Steam Turbine Power Generation Systems.

Turbine System	Turbine Inlet Steam Pressure (Kg/cm^2)	Turbine Inlet Steam Temperature	Entitlement Efficiency %	Kg Coal/ MWh
Sub Critical	170	535-565	35	593
Super Critical	250	565-593	39	554
Ultra Super Critical	270	600-650	42	
Advanced Ultra Super Critical	310	610-730	46	511

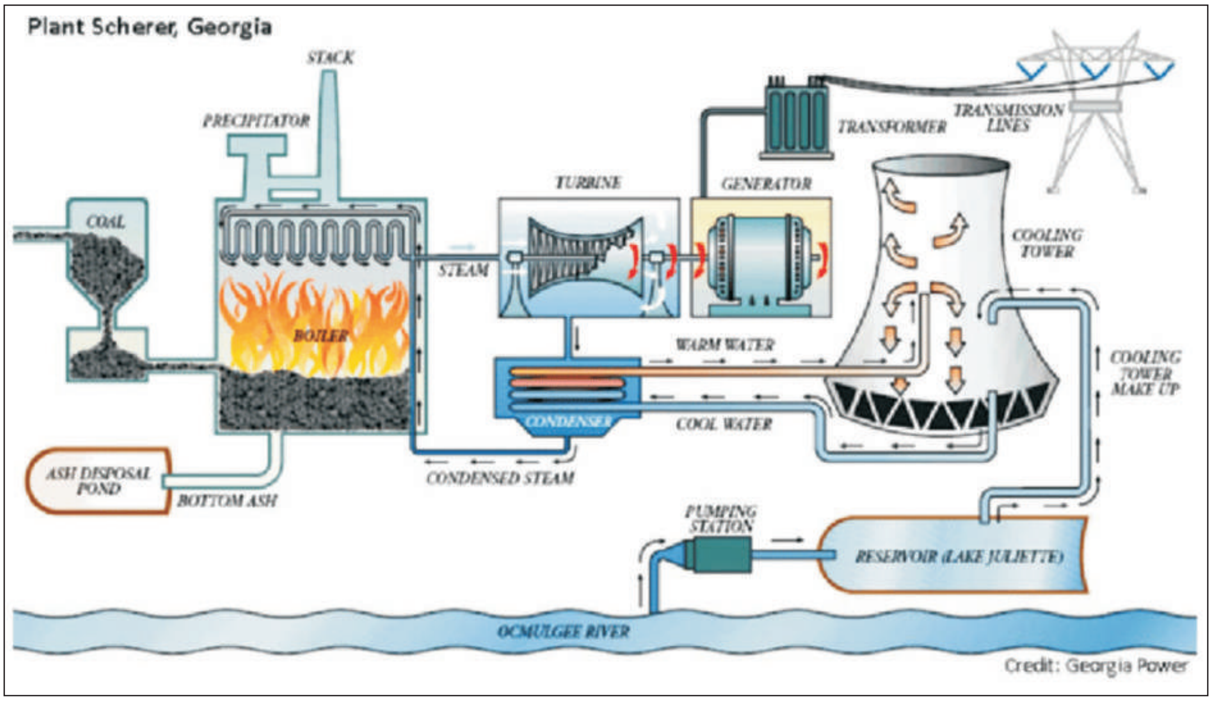


Fig. 2 : Schematic Illustration of a Coal Fired Thermal Power Plant.

in the vapour phase and partly water droplets. The droplets as they nucleate homogenously in the flow path are too small (~10 microns) to cause water droplet erosion. However such droplets often contact stationary surfaces upstream (Last Stage Nozzle or Vane), where they form a continuous film. When the film thickness reaches a critical level, it detaches itself from the nozzle surface releasing as large slivers of water – which break up into large enough diameters to be extremely erosive. Indeed the water droplet erosion is very severe.

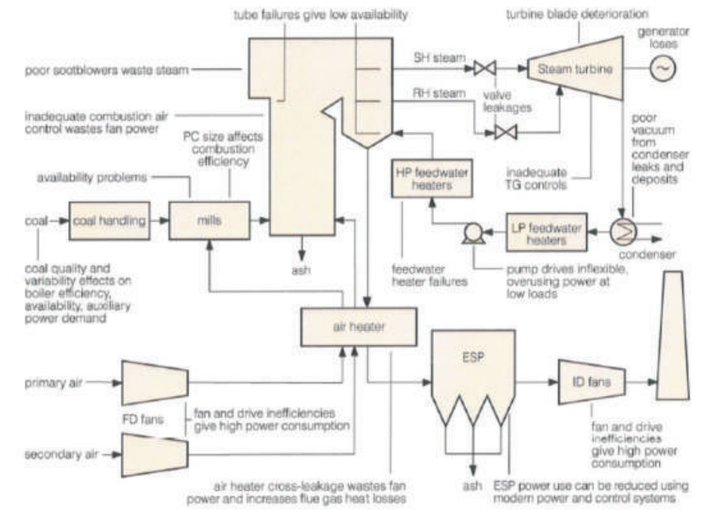
The steam turbine island has many seals to maintain pressure heads and direct flow – such as end packing seals, interstage seals, and bucket tip – casing flow path seals where rubs can occur between stationary and rotating surfaces. Such a damage can be severe, leading to disproportionate loss to thin-walled seal tips especially on the rotor. The increased gaps lead to leakage flows and loss of efficiency.

The combined efficiency losses in a steam turbine due to chord loss, surface roughness increase, and higher clearances can exceed 2 to 2.5%.

Lastly, as the condensing steam flow exits the last stage bucket it is drawn into the condenser. The condenser consists of tube bundles through which cooling water is passed. Scaling along the tube ID is well known, which requires periodic cleaning. Another interesting nuance is that steam tends to form a film on the tube bundles which is an insulator; in other words the heat transfer coefficient between steam in the vapour phase with a metal tube is better than when there is a film covering the copper tubes. A hydrophobic coating on the ID and OD of the tubes would lead to better heat transfer characteristics. An efficient condenser creates a suction pressure in the LP steam – condenser circuit which promotes LP section efficiency [1,2].., The efficiency losses in the condenser due to reduced heat transfer is about 1%.

The propensity for degradation in performance increases significantly with increased temperature and pressure of the steam flow path. With higher pressure, temperature, and flow of steam in ¬boiler tubes the exfoliation rates of the hard oxide scale would increase; with higher flame temperature and flow in the boilers, erosion and deposition issues would increase. With higher combustor temperatures and flow erosion and corrosion would increase. If any, the problems of performance degradation for advanced ultra super critical turbines would only increase. The above modes of degradation have a profound impact on overall plant efficiency.

With growing concerns on climate change, and power plant economics, there have been several studies on power plant efficiency. These are succinctly summarized Figures 3 and 4 and drawn from International Energy Agency.



Source: International Energy Agency (IEA), Clean Coal Centre. Upgrading and Efficiency Improvement in Coal-fired Power Plants. Clean Coal Reports at http://www.iea-coal.org.uk/site/2010/publications-section/reports.

Fig. 3 : Sources of Energy Loss in a Coal Based Thermal Power Plant Operation.

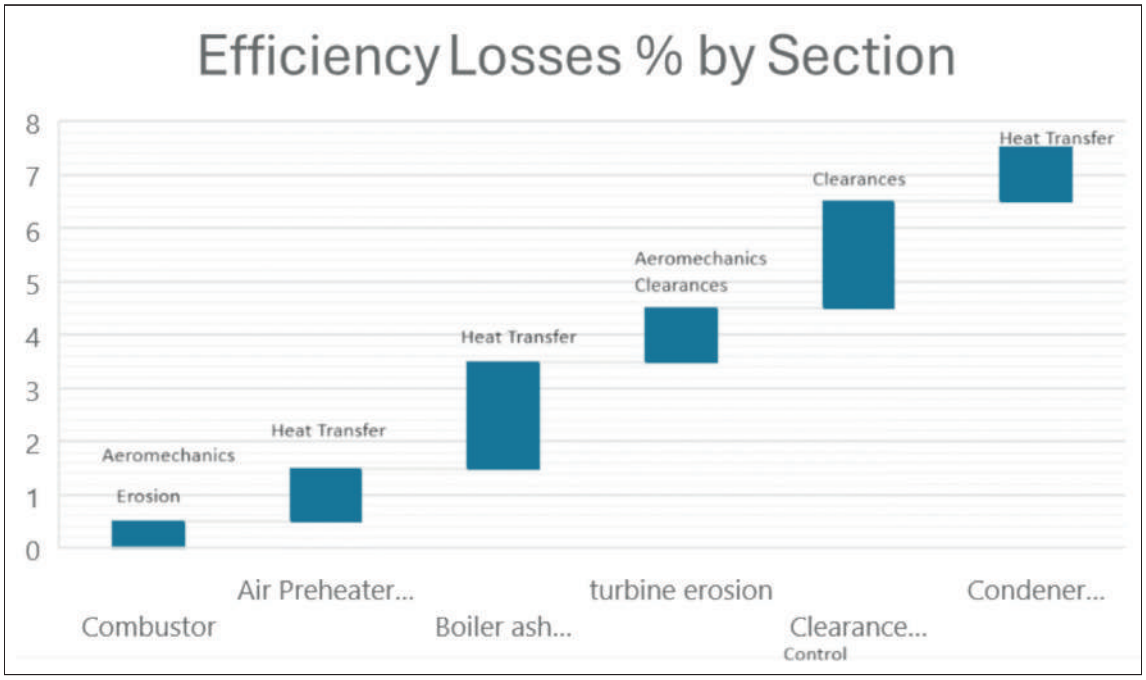


Fig. 4 : Efficiency Losses in Different Sections of the Coal Fired Thermal Power Plant Based on International Energy Agency.

3.0 Surface Engineering Solutions to Combat Efficiency Loss

Coatings technologies to combat wear, oxidation and corrosion have improved tremendously over the last decades. This applies to both thermal sprayed and PVD coating technologies, in India, and includes spray processes (HVOF, HVAF, ID Guns, suspension thermal spray processes). However, the deployment of such technologies has been largely confined to measures that improve plant reliability and up-time rather than technologies directed at improving efficiency. In the following section both coatings that are readily available and those that need validation or further development will be described.

Coal Mill and Coal Combustion

Coal mill components undergo extreme abrasion and gouging by ash particle entrained in the coal and by pebbles and granite pieces entrained along with coal. Even tool steel rolls made of D2 HCHCR steels reportedly undergo 75mm of wear within 2500 hours of operation. Proprietary HVAF coatings have been developed that combat extreme abrasion in a coal crushing environment have been developed which may be licensed and implemented in India. The advantage of such technologies lies in operation for extended periods of time without a shut down, and more importantly a stable hap between rolling elements leading to a uniform particle size distribution through out.

Erosion of combustor nozzle plates has been a frequent issue. Technologies are now available to reduce erosion – and this take the form of ARCI developed aluminide coatings or commercially available CrC-NiCr coatings which can be deposited by ID torches to reduce erosion.

Boiler Section

Water walls: Water wall panels line the boiler walls closest to the fireball created by the combustors working in tandem. While the skin temperature is moderated by the water rather than steam flowing through the panels, there remains the danger of large spits of fire or ash / slag falling on the panels, However the baseline temperatures for Super critical systems are 370 to 4200 C. Table two summarizes the approach to combat surface degradation in water wall panels. **However, none of them address squarely heat transfer debits because of ash deposition.**

Table 2 : Coatings Technologies to Address Surface Degradation in Water Wall Panels.

Coating Solutions for different mechanisms – water wall panels

Damage mechanism	Extent of damage	Typical solutions	Processes	Caveats
Hot corrosion (S /Cl containing coal). pO2 under the deposits are lower, iron sulfiates formation is facilitated,. If coal contains chloides the problem is compounded .	Severe corrosion attack, perforation in weeks	Thick corrosion resistant overlays such as C276, C22, IN625., NiCrBSi, NiCr(50%) Wire sprayed solutions such as AMSTAR 888	Laser cladding for OEM parts, Hardfacing and wire spray for onsite solutions	Such materials are not robust when it comes to solid particle erosion., Thick porous coatings inhibit heat transfer Wire spray works as an on site solution but porosity is a factor in hot corrosion
Fire side corrosion pO2 under the deposits are lower, iron sulffde formation is facilitated,. If coal contains chloides the problem is compiounded .	The problem can be acute when there is a high flux of the combustion plume (often misdirected)	Thick corrosion resistant overlays such as C276, C22, IN625., NiCrBSi Wire sprayed solutions such as AMSTAR 888 If feasible use an ash pile as an insulator	Laser cladding for OEM parts, Hardfacing and wire spray for onsite solutions	Balance between corrosion resistance, heat transfer. These siluations are not best for erosion protection Wire spray works as an on site solution but porosity is a factor in hot corrosion
Solid particle erosion by ash particles	Severe damage,, especially with Indian coals containing 35 to 50% ash	Wire sprayed coatings ((eg Metco 8294 and 8453), HVOF NiCrCrC	Wire arc spray and HVOIF spray	While wire spray is thicker its porosity is higher and can driver hot corrosion.

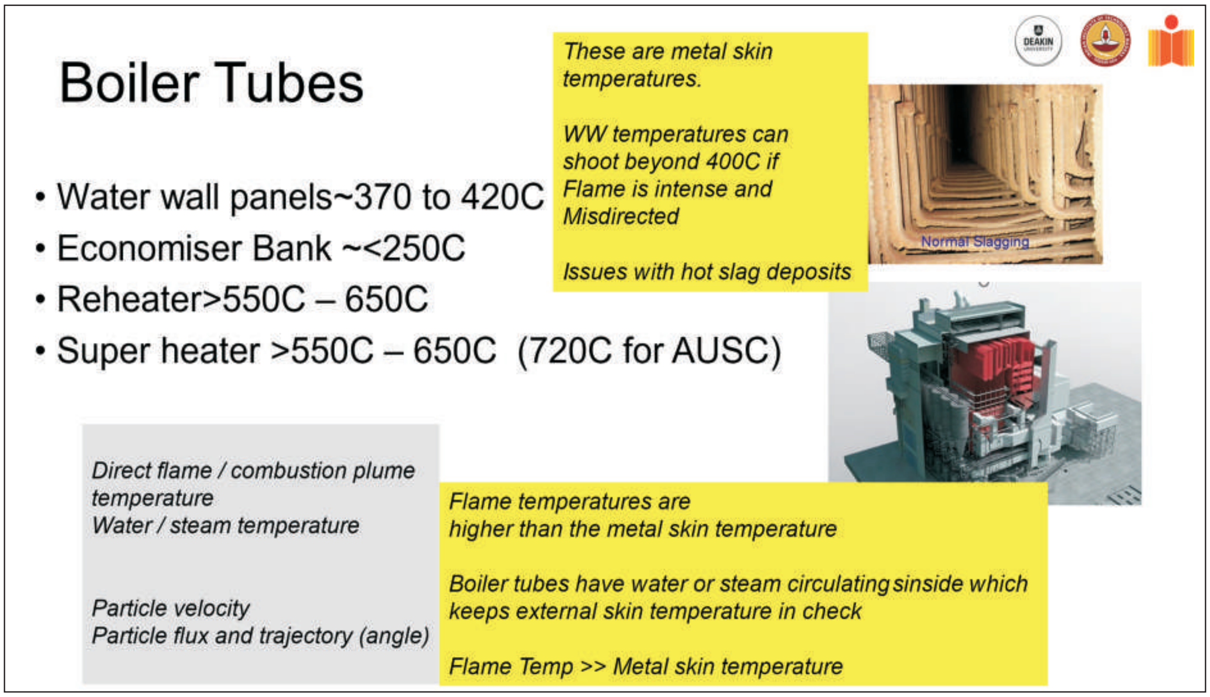
Super Heater/ Re-Heater/ Economise Banks: The combustion plume rises up propelling ash particles at velocities in the range of 15 m/s, losing temperature as it flows past super heater to reheater and economiser. Figure Five summarizes the metal skin temperature at each section of the boiler along with examples of erosion and deposition. In the hotter zones the primary surface degradation mode is high temperature oxidation and under deposit corrosion. AT lower temperature such as the economiser the problem is more of solid particle erosion.

Once a new boiler is commissioned, the initial wall thickness is designed such that erosion losses are tolerated, But once the residual wall thickness reaches 2.5mm approximately (and with 2.5mm thickness loss), stress levels increase to levels wherein the tube is susceptible to rupture. When there are large scale leaks, in kilometres of tubes, finding the leakage location and redressing the problem takes enormous time and effort. For a 600MW plant, generating Rs 30 lakh rupees an hour of revenue, a week long shut down implies a revenue loss of more than Rs 50 crores.

Another issue is one of ash deposition. Most power plants use exhaust flue gas temperature as a metric to estimate the energy transferred to the boiler -steam-water circuit. If the exhaust gases exceed a threshold for a given coal-air mix, then that indicates inadequate heat transfer because of excess ash deposition along the exposed boiler tubes. Most power plants employ a variant of a soot blower to remove the ash from the tubes while it is working. Often the soot blower comes on once a day and operates for a few hours to remove accrued ash. The losses because of ash deposition alone are in the range of 0.5 to 1%. **While this has a significant impact on carbon emissions, the interventions from a**

surface engineering perspective have been more to control erosion and corrosion. Developing robust solutions with the intent of reducing ash deposition remains work in progress and this is an area where both academia and industries can work towards a solution.

Coating solutions that need deployment needs to be customized based on metal surface temperature in different sections of the boiler. A summary of operating conditions and nature of surface degradation is shown in Figure 5. Commonly used coating solutions are shown in Figure 6.



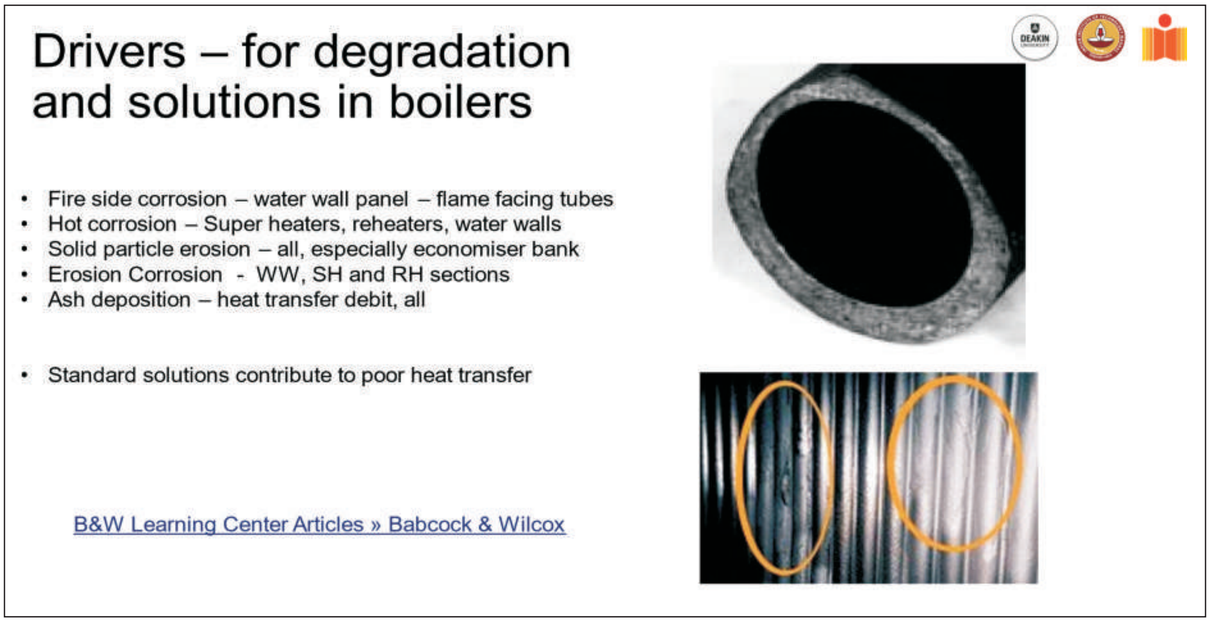
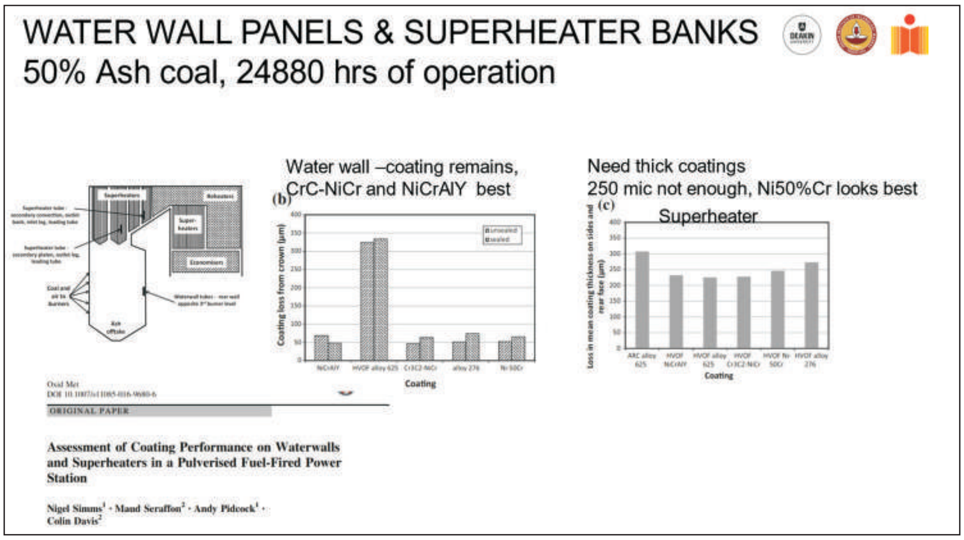


Fig. 5 : Typical Operating Conditions along with Nature of Ash Deposition (Top) and Erosion Damage Showing Thinning of Boiler Tubes (Bottom).



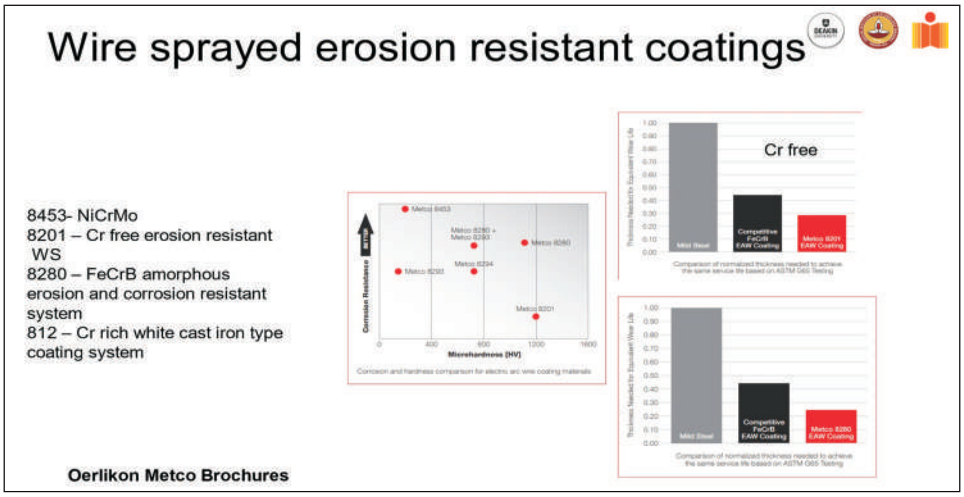


Fig. 6 : Erosion and Corrosion Resistant Coatings Deployed to Protect Water Wall Panels and Boiler Tube Bundles.

Ash Deposition Resistant Heat Transfer Enabling Coatings

Coatings currently deployed are typically combustion sprayed or wire arc sprayed to enable on-site application with high thickness, moderate porosity and some internal oxidation. While they may extend the life of the tubes they are not engineered to meet ash deposition resistance requirements. One needs a fresh approach to find solutions, some of which are outlined below:

- Flash Carbides: Flash carbides are highly dense and hard thin carbide coatings applied to a thickness of 50 microns approximately. The coatings have high volume fraction of carbides. The hardness and inertness of the carbides resistance resists deposition of ash particles as both embedment of hard ash and Vanerwaals / electrostatic forces of attraction are absent. Boiler tubes can be pre-coated with carbides – and welded – with welding methods requiring optimization.
- New Silicon Carbide Based Coatings: SiC reinforced hard particle coatings in a high Cr ferritic steel matrix is another alternative. SiC has the highest thermal conductivity and a hardness level that exceeds WC. The risk that needs to be managed is that free Si in the SiC particle can form low melting point eutectics (melting point in the range of 1000C) with Fe and Cr in the

matrix or base alloy. However, with HVAF and HVOF processes, the particles have a short dwell time in the flame and a fast-cooling rate upon impact. Such risks can be well managed. Given the abundant availability of SiC within India this could be an avenue for future.

On Site Coatings : With boiler tubes one needs to develop a robust on site coatings deposition platform. Much of it already exists in the form of wire sprayed coatings, wherein the feedstock is a prealloyed wire fed through an electric arc spray process. A variant to this is the use of a cored wire with the ID filled with particles whose composition can be tuned to meet the property requirements. This is schematically illustrated in Figure eight. An overarching technology summary for boiler tube coatings is provided in Table Three. For boiler tubes one needs to have a strategy for an off site OEM coating delivered before installation, and an on-site coatings strategy as a service option.

These Concepts are Shown in Fig. 7.

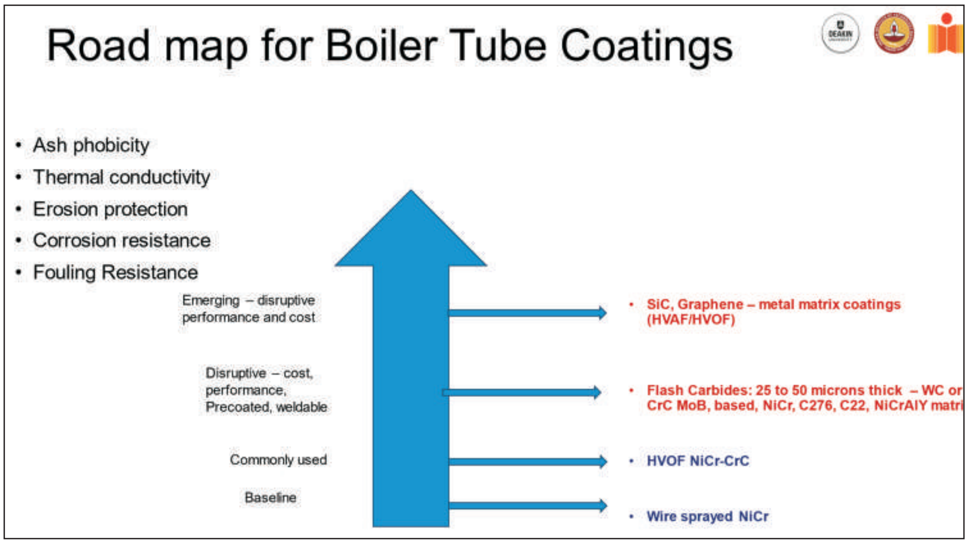


Fig. 7 : Current and Future Coating Materials Solutions for Boiler Tubes with Progression in Properties – Starting with Erosion and Corrosion Resistance to Ash Phobicity.

Table 3 : Technology Summary of Coating Offerings and Requirements for Boiler Tubes.

Parameter	Wire Sprayed Metallic	Onsite HVOF Carbides	Off Site Flash Carbides	Ashphobic Compositions
Erosion Resistance	Moderate	Good	Very good	Very good*
Oxidation Resistance	Good	Good	Very Good	Very Good*
Corrosion Resistance	Good	Good	Good	Good*
Heat Transfer	Poor	Moderate	Good	Very good*
Ash Deposition Resistance	Poor	Moderate	Good	Very good*
On Site Capability	Good	Average	Poor	TBD
Availability of Indigenous Powder / Wore Feedstock	Good	Low	Low	Opportunity to carve our future
TRL	9	6	6	3

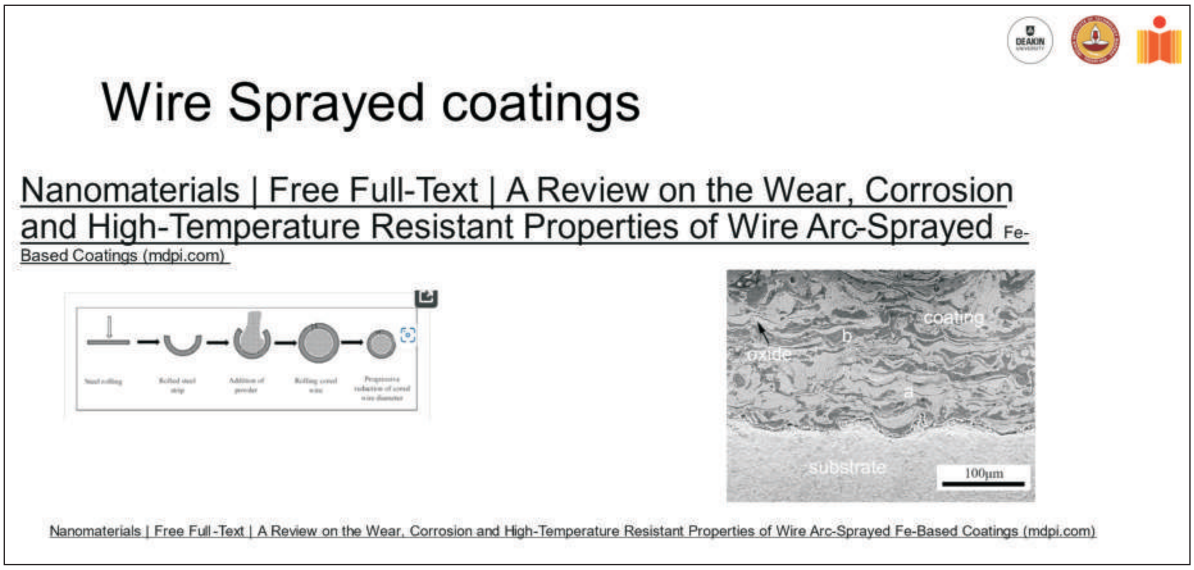


Fig. 8 : Cored Arc Wire Sprayed Technology wherein the Filler Wire is Filled with Hard Particle Metal Matrix Powder Composition to Meet Property Requirements.

4.0 The Steam Turbine

The heart of the power generation system in a coal based thermal power plant is the steam turbine island. The coatings technology required to address solid particle erosion, clearance control, droplet erosion, and fretting of dovetails and mid span dampers are well covered in the literature [4]. The critical aspects are discussed below. Figure 9 level illustrates at a high level the reasons for efficiency loss.

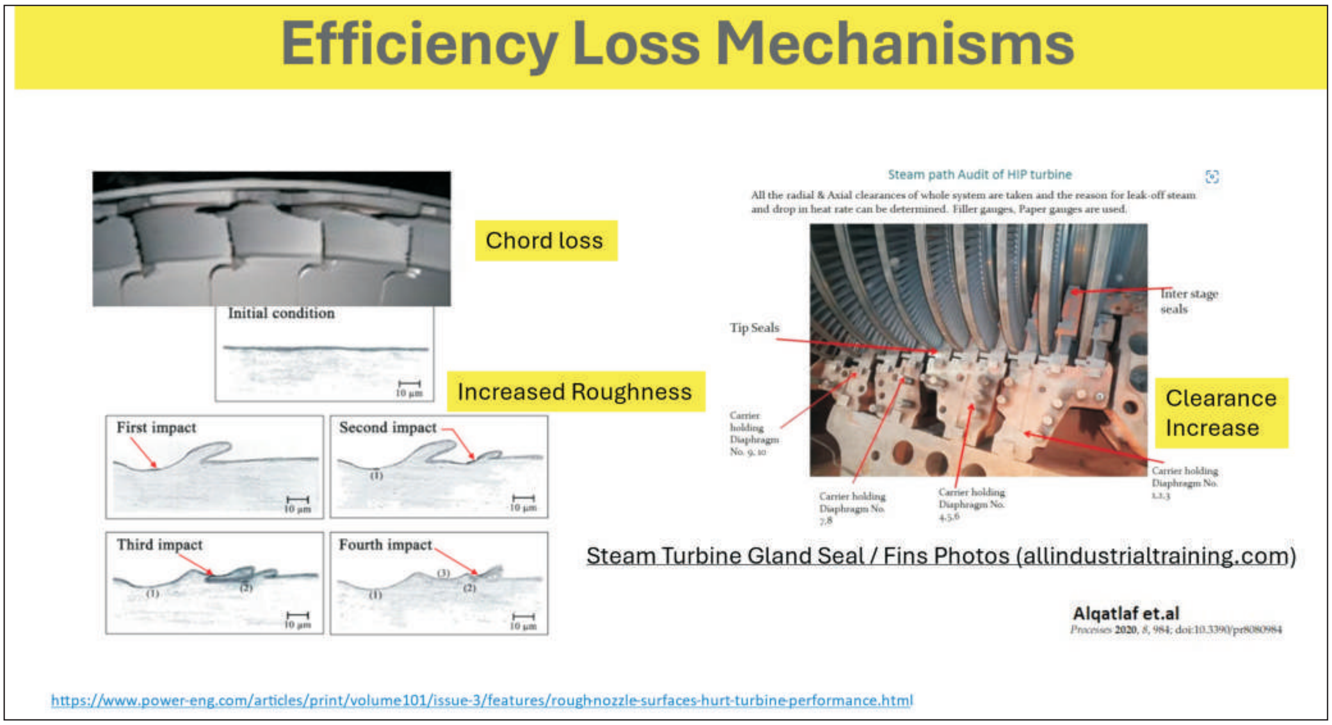


Fig. 9 : Chief Modes by Which Steam Turbine Efficiency is Lost.

Solid Particle Erosion Resistant Coatings (Efficiency Play – 1 to 2%)

With the advent of high kinetic energy coating processes such as D-Gun™ and HVOF processes the use of hard CrC-NiCr based coatings for HP and IP sections of the steam turbines have been well established. The decision to deploy the coating was largely techno-commercial, where the risks and rewards especially in terms of life and reliability was balanced, along with other levers to manage the problem (through design to control the trajectory and flux of particles). Steam turbine performance assumes centre stage in managing uptime and maintenance strategies; it is common to estimate steam turbine component damage and correlate the same to actual performance. As a part of the performance audit, surface finish, dimensional changes (chord loss for example) and clearances are measured, and the same correlated with efficiency debits by stage – covering HP, IP and LP sections. Given that even a 2% efficiency hit for a 660 MW turbine translates into an additional 1.4 lakh tons of CO_2 emissions per annum for a 0.58 Kg/KW heat rate machine, the sheer implications in terms of opportunity costs is coal savings and emissions increase is huge. Developing a robust coatings strategy to manage erosion, while countering fatigue debits if any is a must.

Therefore in selecting a coating system (apart from using legacy compositions where there is 2 decades of experience in the industry world wide), one needs to be cognizant of specific needs of the fleet. When the need to maintain chord dimensions and surface finish become important, typically a thicker thermal sprayed coating is desirable for the first two stages of HP and IP turbines, but beyond the first two stages as one goes aft, thick PVD nitride coatings can be considered too if they are cost efficient. And state of the art of the technology as it exists today worldwide is summarized in Table Three. The broad status of erosion coatings technology and its status in India is summarized in Table Four.

Clearance Control Coatings (Efficiency Play 1 to 2%) :

End Packing and Interstage Seals

There are two areas of relevance when it pertains to clearance control in steam turbines:

(1) Steam flow path between rotating bucket tips and casing, and stationary interstage seals between nozzle (vanes) and rotor.

(2) End-packing seals situated at either end of the shaft in HP, IP and LP sections.

End packing seals perform a vital function of preventing leakages from the shaft ends. While labyrinth seals are common, wherein labyrinth knife edge profiles are machined on the rotor, for it to rotate in close proximity to knife edges, they suffer from permanent loss in efficiency upon wear during rubs. With the growing footprint of renewables, even steam turbines could be called upon for frequent cycling, which transients and rubs more likely. In such a situation, brush seals perform better than labyrinths in end packing applications.

Table 4 : Summary of State of the Erosion Protection Technologies Used in Steam Turbines when Needed [4].

Material System	Proesss	Rationale	Outcome
CrC (80wt%) -NiCr, -Microstructure, carbide grain size optimized to ensure carbides do not crack, and deformation of binder is constrained.	HVOF/D-Gun	Industry bench mark for High T erosion and wear. Can be applied to 250 microns thickness. Life can be dialed through thickness and CrC-NiCr microstructure	Good Field experience Caveats – finishing on complicated geometries requires development. LCF / HCF debits are an issue that needs to be addressed on a case by case basis.
Thick PVD TiN based coatings - Residuakl compression - Ductile interlayers. - Ti alloyed for oxidatoon	PVD, PECVD	TiXN, with additional alloying elements added to improve temperature capability to 650C	Improved offerings with significant life extension and aero performance. However, erosion damage can increase if erodent particle size crosses a threshold. PVD coating thickness needs to be thicker than the norm Few vendors have this capability.

Table 5 : Criteria to Select Coating Materials and Processes for Deployment for Solid Particle Erosion Protection in Steam Turbines.				
	HVOF CRC	HVAF CRC	Suspension thermal Spray CRC	PVD TiALN
Surface Finish	Extensive polishing needed	Some polishing needed	Mild polishing needed	Best in class surface finish
Ability Maintain Sharp Profile (Trailing Edge)	Depends on blade design	Better than HVOF	Good	Excellent
Erosion Resistance	Good, ability to play with CrC content and matrix compositions to meet needs	Very good, decarbonization of CrC can be controlled. Higher kinetic energy gives better properties	Outstanding – because of microstructural control.	20 micron thick coatings needed. Global supply chain exists. But PVD remains a concern in the first stage of HP and MSV valve stems.
LCF / HCF Debits	Negligible for subcritical, Evaluation needed for USC/AUSC	Lower debits than HVOF	Least fatigue debits among thermal sprayed coatings	Minimal for PVD
Costs	Low	Low	Moderate	Moderate
Indigenous Coating Powder Feedstock	Low	Low	Low	Good
TRL	9 for subcritical	6	3	4

Material choices for sub critical machines are well established. HS25 based bristle pack as brush seals against coated or uncoated rotors combinations are well known. If the temperature is less than 500C in the end pack locations finely spaced WC-10Co4Cr has emerged as a coating of choice, if access to facilities where large rotors can be habdled are available. For Super Critical and Ukltrasuper critical machines, if temperatures exceed 500C at the end pack one could use Chromium carbide nickel chrome coatings. For AUSC machines one needs to understand the temperatures involved and take a call on whether HS25 in high temperature steam environments would have adequate like in terms of oxidation performance.

Interstage Seals: Often brush seals are used as interstage seals to manage clearances between stationary vanes and rotor. The criticality of managing clearances along the IDS needs to be assessed, given that the flow is higher along the radial tips away from the axis of rotation.

Bucket Tip – Casing Clearance Control: Casing clearances are often managed through the use of abradable coatings such as NiCrAl-Bentonite or Ni-Graphite running against bucket tips. When the option to use an abradable coating is not exercised, design engineers would tend to run the machines with higher clearances to minimize rub damage, that however reduces the starting efficiency. Therefore the use of abradable coatings is highly recommended, as it allows one to run the machines with tighter clearances, knowing that when rubs do occur the hardware is protected because of how abradable coatings are engineered.

The AUSC Challenge: Typically to maintain abradability a metallic coating consists of porosity (25 to 50%), soft abradable phases (20 to 30%) and lubricants (5 to 15%), when the temperature exceeds 650C, oxidation resistance requirements especially under steam environments become important. However, oxidation resistance is undermined by porosity. The use of relatively dense abradable phases becomes important. Therefore, the problem statement becomes the need to develop dense oxidation resistant abradable coating with soft additives that are capable of withstanding 750C that are oxidation resistant. The work horse high temperature coating – NiCrAl-Bentonite is rated to a maximum temperature of 650C. Another alternative is to stay with dense oxidation resistant and thick coatings for the shroud but apply abrasive tips on the rotating air foils. Tremendous work has gone towards developing abrasive tips. The best abrasive is cBN, and entrapment plating is a preferred method; but one needs to have MCrAlY as a plating combination which implies entrapment plating of cBN in a composite plating bath where Co or Ni has CrAlY particles in colloidal suspension while plating.

Table 6 : Coatings Availability and Requirements Chart for Clearance Control, within India

	End pack seals Labyrinth	End pack Brush Seals	Casing abradables	Bucket abrasive tips
Abradability	Moderate	Very good	Good	Very good
Erosion Resistance	Good	Average	Average	Good
>650C Oxidation Resistance	Average	Very Good	Needs development	Very good
Availability of Indigenous Feedstock in India	Honeycomb manufacturing required	Low – Carbide coating powders needs to indegenized	Low – abradable compositions needs to be manufactured	Good, Indigenous manufacture of cBN exists
TRL in India	9	4	5	3

Water Droplet Erosion

AUSC machines would tend to be larger and handle significant flows of condensing steam at the last stages. If there are no active measures to keep droplet sizes below the erosive threshold of about 60 microns, severe droplet erosion is bound to occur. Given the severe damage, it would have a bearing on both the reliability and efficiency of the last stage of the LP section. Stellite 6B has been one of the go to solutions. While cast stellite leading edges have been welded on to the blades, there may be limitations on this course of action based on weldability of the base alloy. Laser cladding of stellite has been a preferred solution.

Functional Anti-fouling and Hydrophobic Coatings

Hydrophobic Coatings (Efficiency Play: Up to 2% from Condenser and Last Stage Bucket Erosion Losses)

As described earlier, the Condenser positioned downstream of the LP turbine converts the condensing steam to water and feeds it back to the boiler circuit. In the process, because of the change of state from vapour to liquid, there is a huge reduction in volume which causes a pressure drop between the LP and the condenser. The pressure drop is advantageous for the system as the steam is pulled through the last stages of the LP creating additional thrust. Any back pressure because of poor evacuation of the steam is avoided when the condenser does its function well.

For efficient heat transfer through the condenser, the exposed metal surfaces needs to be free of any fouling or continuous film formation of water, as convective heat transfer through exposed metallic tubes is better. Similarly, the water flowing through the condenser pipe inner diameter needs to be clean and free of contaminants – any scaling of the tube ID will lead to heat transfer losses. For both these functions having a good hydrophobic surface is deisirable. The same can be accomplished through thin films which are hydrophobic, or surface textures which could be hydrophobic. In terms of coatings Ni-PTFE is reported to be hydrophoibic. The same can be applied as a composite plating, or PTFE can be applied as a thin spray (10 microns thick).

Hydrophobic Coatings upstream of Last Stage Bucket: When it comes to water droplet erosion control, keeping droplet size below the erosive threshold is a first line of defense which is often not followed. In a condensing steam flow path, in the absence of external surfaces for steam to deposit the primary mode of droplet formation is homogenous nucleation, which would produce droplets which are smaller than 30 microns. At such a droplet size erosion rates are negligible. However, in a steam turbine flow path, the last stage nozzle upstream with respect to the bucket provides a large area for steam to condense as droplets, which coalesce to form a film. The continuous water film, subsequently detaches itself and proceeds as large droplets which are very erosive. So while there is abundant work to produce coatings and cladding on leading edges to combat erosion, there has been minimal effort to develop hydrophobic coatings which stop the formation of large droplets. Choices include – Ni PTFE and PTFE coatings, DLC doped to achieve hydrophobicity.

Fouling Resistant Air Preheater Basket coatings (Efficiency Play – 1 to 2%)

The coating requirement to improve the efficiency of the Air Preheater Seal remains the most complex. The hot flue gases that rise from the boiler are laden with ash particles and heavy organics as well as trace levels of NOX and SO2. When the temperature falls below the condensation or dew point of any of the constituents the air preheater seal basket can get fouled. Apart from that the ash particles can cause solid particle erosion. The temperature at entry can be as high as 400 0C which makes PTFE not plausible. One needs a robust materials discovery program to meet all requirements. A visual schematic of the Air Preheater section with operating conditions is shown in Figure Nine.

The technology chart for functional coatings is summarized in Table 7.

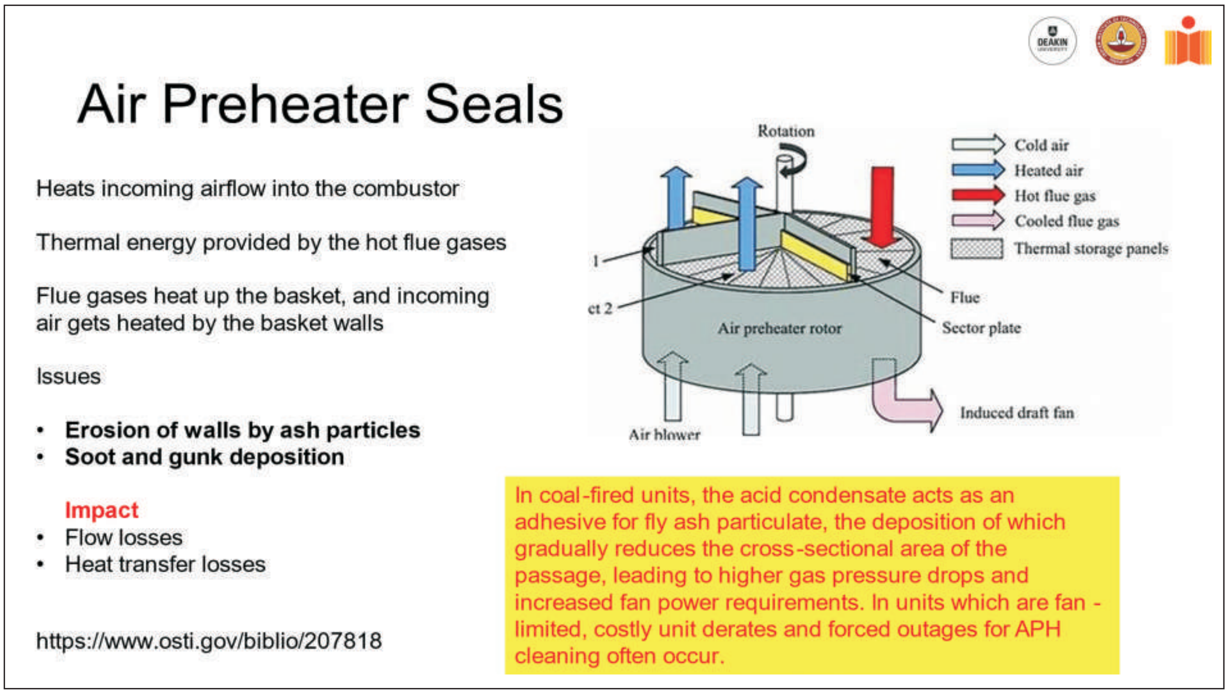


Fig. 10 : Schematic of Air Preheater Seal System Showing Component Shape and Functions.

Table 7 : Technology Requirements Chart for Functional Coatings for Coal Based Power Plant.

	Air Preheater Seal	Condenser	Last Stage Nozzle	Remarks
Corrosion Resistance Requirements	High – because of acid dew point concerns	Moderate	Moderate	Corrosion is not a major factor for condenser as steam is clean.
Oleophobicity	High – heavy organics can condense.	Low – not needed in steam flow path	Low not needed in steam flow path	
Hydrophobicity	Moderate	High	High	
Erosion Resistance Requirements	High	Low	Low	
Indigenous Availability of Feedstock and Coatings Technology	TBD	High	High	
Temperature Requirement	250-300C	<100C	<150C	
TRL Assessment	<3	6-9	6-9	

Conclusions

- There is an opportunity to recover 7 to 8% in efficiency in power generation **in the existing fleet** of thermal power plants through coating solutions that redress losses due to Aero Mechanics (flow losses), Clearances (Leakage flow), and Heat Transfer losses (Ash deposition, fouling, and moist film formation). These losses impact coal mills, combustors, boiler section, steam turbines, condensers, and air preheaters, and other balance of plant components.
- The knowhow to address these mechanisms are mature for steam turbines, and to a certain extent condensers. Heat transfer enabling coatings have a major play in boilers and need to be developed. Air preheater seal fouling requires new robust solutions.
- As one embarks on the AUSC product line, the need to deploy these solutions becomes even more critical, as all the problems get amplified – boiler tube scaling, turbine erosion, increased clearances, greater rubs due to deflections from large machines. While most of the coating technologies can be redeployed for AUSC, current abradable coatings are limited to 650C., New abradables need to be developed for AUSC applications.
- Finally, most of the coating technologies are available in India. However, much of the feedstock is imported. India needs to embark on a massive indigenization drive for its own energy security and ensuring that we are able to develop and deploy new customized solutions in a cost-effective manner.

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Technical Article

Indian Advanced Ultra Supercritical Programme for Thermal Power Plants

S C Chetal

India's total present installed power generating capacity of about 445 GW is predominantly coal fired (about 215 GW). Going forward, coal based thermal power generation is expected to continue to be the primary workhorse for the next few decades in spite of the nation's successful forays in the renewable energy. India has committed to reduction in carbon dioxide emissions and one important sub-mission under the National Action Plan on Climate Change is the development of the Advanced Ultra Supercritical (AUSC) technology for coal base thermal power plants. In this context, one of the ambitious project sanctioned by Government of India was R&D Project for development of AUSC Technology for Thermal Power Plants on a Mission Mode. On completion of the R&D project, technology demonstration plant of 800MW capacity has been planned to be set up. The R&D project is unique in several ways for the Indian thermal power sector, viz. a) being the first time a project of this magnitude has been undertaken; b) being the first time for such a collaboration between mega organisations having diverse interests such as BHEL, NTPC and IGCAR; c) for the first time indigenous design and manufacturing of key components of nickel-base superalloys has been undertaken.

The target for the plant efficiency has been set close to 46% and the steam parameters (with single reheat) of 310kg/cm2, 7100C/7200C have been selected.

The R&D project objectives included indigenous design, design review by external experts/organisations, material testing and evaluation of special alloys employed for boiler and turbine, indigenous production of key wrought and cast products, indigenous manufacturing technology development of key components in full scale prototype, and establishment of a few important experimental facilities for design validation.

Since the AUSC technology is not yet fully developed and demonstrated any where in the world, the R& D project has a number of challenges in design and manufacturing to be mastered. Considerable attention has been paid to result in an economical design and one such example is the selection of bimetallic rotor and casing to reduce the content of expensive Alloy 617M. All the challenging tasks envisaged have been successfully accomplished which include indigenous design of steam turbine in particular for the first time, production of boiler tubes in two nickel base alloys namely Alloy 617M and precipitation hardened Ni-25Cr-20Co (UNSN07740) by Midhani supplying the billets and tubes conversion by NFC, and advanced austenitic stainless steel22Cr-25Ni-3.5W-3Cu(304S31035), shot peening of tubes, forming and welding of boiler tubes, induction bending of nickel base alloys piping, manufacturing of superheater headers in nickel base alloys, manufacturing of high pressure bypass valve and safety valve by BHEL with nickel base alloys forgings supplied by Midhani, fabrication of evaporator panel by BHEL in grade 91 steel with indigenous tubes, and execution of rotor and casing bimetallic welds by narrow gap TIG welding and machining by BHEL with welding technology and NDT developed by IGCAR. Production of Alloy 625M casting for steam turbine casing of over 20 tonnes by BHEL is notable production of indigenous casting, the world' heaviest at the time of production. Another notable indigenous product is Nimonic 105 for steam turbine blades with flat material produced by Midhani and machining in advanced blade machining facility by BHEL.

Corrosion test facility at NTPC Dadri unit has given confidence in the usage of materials selected and manufacturing technologies of nickel-base alloys. The facility has logged more than 29000 hours of operation without any incident.

The 800MW demonstration plant is sought to be executed by a joint venture company between NTPC and BHEL. With the recent budget announcement of providing financial support to the project, the Ministry of Power will take further actions.

Ex-Mission Director-AUSC Project

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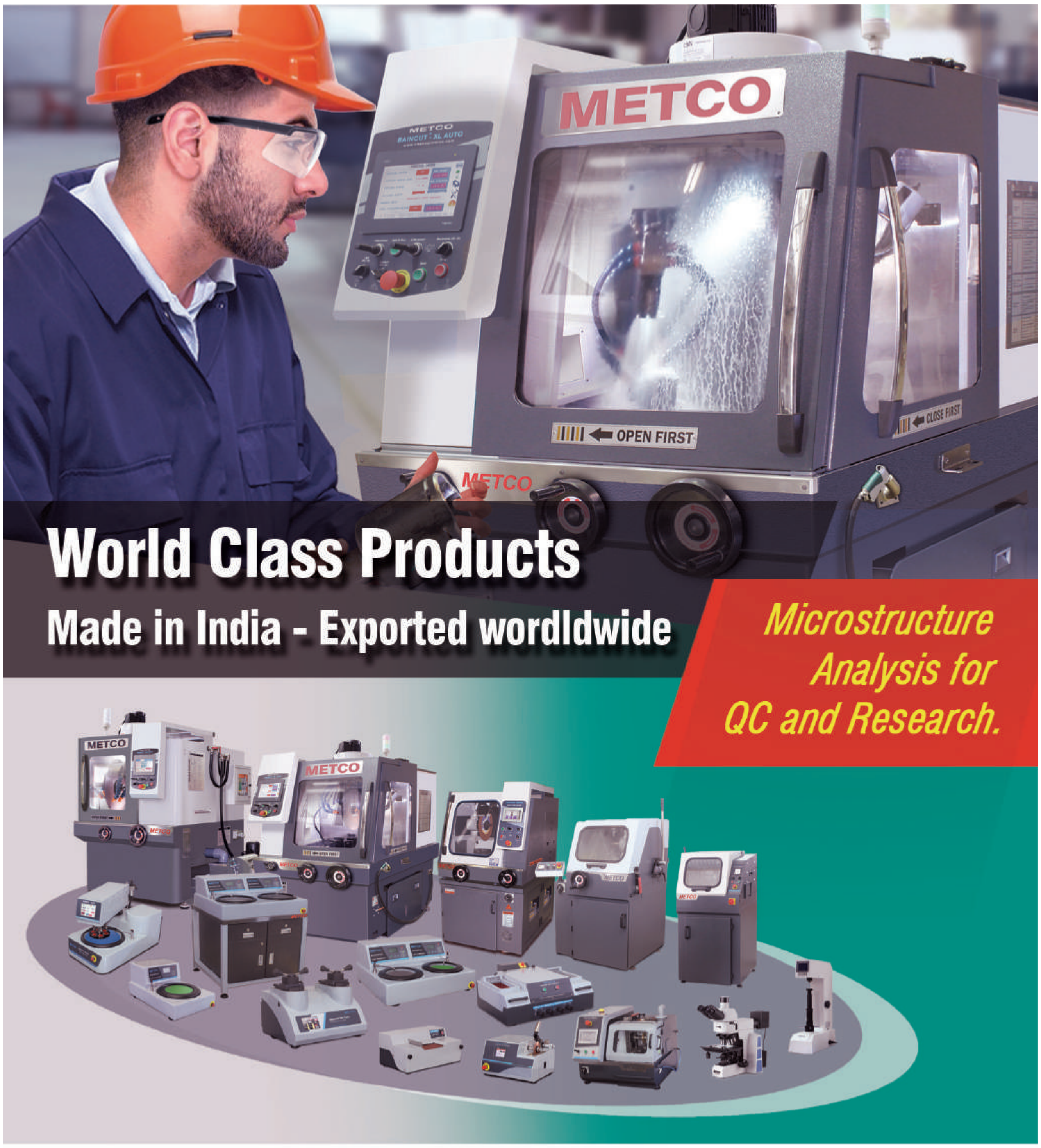
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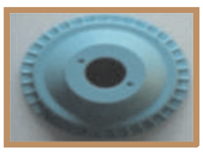
Process for making light weight Al-Si Alloy – SiC composite Manhole Cover



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TECHNOLOGY TRANSFER

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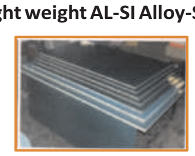
Ampricare - Face Mask



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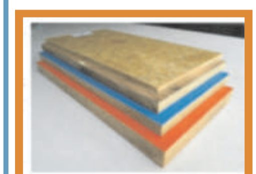
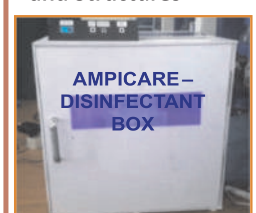


Parali Evergreen Hybrid Ply and Composite Wood

Bamboo Composites for Modern Housing and Structures



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For details please contact:
Dr. Avanish Kumar Srivastava
Director,
CSIR- Advanced Materials and Processes Research Institute (AMPRI), Hoshangabad road, Near Habibganj naka,
Bhopal - 462026 (MP), India

Chapter Activities

Trichy, Coimbatore, Delhi, Jamshedpur

Trichy Chapter

IIM Trichy Chapter organised eleven evening Lectures for their Members from April to June 2024. The list of the Lectures are:

Event Date	Type of Prog.	Event Name	Lecture by	Platform	Place	Organised by	No. of Participants
02.04.2024	Lecture	National Maritime Day 2024 theme "Sustainable Shipping : Opportunities and Challenges" Topic: Sustaining Shipping in 21st Century : Viability and Vision	Cmde (Dr) Johnson Odakkal, I.N. Retd., Founder & CEO Johnson Odakkal Initiatives, Faculty International Curriculum at Aditya Birla World Academy, Adjunct Research Faculty at Naval War College, Goa	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	36
09.04.2024	Lecture	Why there is a mystery around manufacturing ERP projects?	Er.S Vijay Venkatesh, Co-founder and MD, M/s Syscon Solutions Pvt Ltd, Electronic Complex, Kushaiguda, Hyderabad-500062.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	52
16.04.2024	Lecture	Universe Formation. (Physical and Dynamics of Galaxies, Comets, Planets, and Stars)	Er.Leelavinothan.A, Former Additional General Manger, Bharat Heavy Electricals Ltd., Public sector-India, Tiruchirappalli -620 014.	Offline, Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	61
23.04.2024	Lecture	Integration of Additive Manufacturing into Conventional Manufacturing Processes	Dr Vishvesh J. Badheka, IWE, Professor, Dept. of Mechanical Engineering, Dean Academic Affairs, Pandit Deendayal Energy University, Gandhinagar – 382426.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	40
02.05.2024	Lecture	Nanofluid and it's application in various fields	Dr. M. Muruganandam, Professor & Head, Department of Mechanical Engineering, Mohamed Sathak Engineering College, Kilakarai, Ramanathapuram - 623806 .	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	20
07.05.2024	Lecture	Possible defects, causes and remedies in heat treatment of steels	Dr. Vinothkumar G., Assistant Professor, Dept. of Metallurgical and Materials Engineering, National Institute of Technology, Tiruchirapalli-620 015.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	45

21.05.2024	Lecture	Local Crops, Varieties and Safe Food	Dr.V.Arivudai Nambi, M.Sc (Zoology), M.Phil (Ecology), Ph.D., (Futures Studies), Independent Expert on Biodiversity, Bolleneni Hillside, Perumbakkam Main Road, Nookampalayam, Chennai – 600 131.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	47
28.05.2024	Lecture	Exploring Horizons on Passion for Quality Excellence	Er. Kannan Rahavan, TQM Consultant, Visiting Faculty and National and International Jury for ICQCC, Tiruchirappalli - 620019, Tamilnadu, India.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	68
11.06.2024	Lecture	Carbon Credits in Agriculture	Mr.RM.Bhaskar, FPO consultant, Sammunati Agro Services, Hyderabad-500032.	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	52
18.06.2024	Lecture	Introduction to Generative AI	Dr.R.Saranya, Assistant Professor, Department of Computer Science, Central University of Tamil Nadu, Thiruvarur – 610005	Zoom Meeting	Tiruchirappalli	IIM Trichy Chapter along with IWS, IEI, IIW, CSI & IIIE	73
25.06.2024	Lecture	Occupational Hazards & Control Measures	Er.R.Krishnamoorthy FIE, Former General Manager, Oil &Natural Gas Corporation Ltd., Mumbai	Zoom Meeting	Tiruchirappalli	Offline, Zoom Meeting	49

Coimbatore Chapter

The Annual General Meeting of IIM Coimbatore Chapter held on April 29, 2024. The following points were discussed :

- Activities of 2023 - 24 report.
- The Income - Expenditure details and audited accounts for Financial Year 2023 - 2024 were presented and approved.
- The New Chapter Officer Bearers for the year 2024 - 25 assumed charges.
- Activity plan for the year 2024 - 2025 was discussed.

Annual General Meeting of IIM Coimbatore Chapter

Delhi Chapter

The 72nd Annual General Meeting (AGM) of IIM Delhi Chapter was held on 22nd June 2024 at the Chapter's premises.

The highlights of the AGM are :

- Activities undertaken by the Chapter in 2023-24.
- Adoption of Audited Accounts of the Chapter for 2023-24.

The 72nd AGM of IIM Delhi Chapter

- Preparatory Activities relating to MMMM 2024 Conference to be held from 27th to 29th September 2024 at New Delhi.
- Approval of the slate of Chapter Officer Bearers and Members of the Executive Committee for 2024-25.

Jamshedpur Chapter

1) The Annual General Meeting of the IIM Jamshedpur Chapter has been organised on June 27, 2024. The proposal for a few changes in Committee was placed and it was accepted by other Members.

2) Behind The Teacher's Desk (BTTD-2024) : The National Level Student Seminar on Materials and Metallurgical Engineering, "Behind the Teacher's Desk" (BTTD-2024) organised by the IIM Jamshedpur Chapter in association with CSIR-NML, Tata Steel Limited, National Institute of Technology (NIT) Jamshedpur, and the Academy of Scientific & Innovative Research (AcSIR) during June 19-21, 2024 at the CSIR-National Metallurgical Laboratory (NML) in Jamshedpur.

The Seminar was inaugurated by the Chief Guest, Dr. N.C. Murmu, Director of CSIR-CMERI, Durgapur. He was joined by Dr. Sandip Ghosh Chowdhury, Director of CSIR-NML Jamshedpur; Prof. Ashok Kumar, Chairman of IIM Jamshedpur; Dr. Chiradeep Ghosh, Chairman of the BTTD Programme; and Dr. Ammasi A., Convenor of BTTD-2024. The Dignitaries formally opened the event with the release of the Seminar Souvenir.

The Seminar aims to provide a platform for aspiring Metallurgists to engage with Experts from Industry, Research and Development Labs, and Academic Institutes. It offers Student Participants an opportunity to update their knowledge and share their Academic Achievements, Innovative Ideas, and Research in Metallurgy and Materials Technology.

Since its inception in 2011, "Behind the Teacher's Desk" has become a Prominent Event for Students across India. Dr. Sandip Ghosh Chowdhury welcomed the Chief Guest, Delegates, and Speakers, emphasizing the crucial role of Metals, Materials, and Minerals in National Development and the importance of Student involvement.

Dr. N.C. Murmu, in his address, praised the Seminar for fostering interest among Students in Metallurgy & Materials Science. Prof. Ashok Kumar highlighted IIM Jamshedpur Chapter's Activities, focusing on popularizing Metallurgy among Professionals in India.

Dr. Chiradeep Ghosh provided an Overview of the Event, noting that around 100 Students and Speakers from 28 Engineering Colleges and Institutes across the Country are participating, with 57 Technical Papers to be presented across three Parallel Sessions. The Seminar also includes a Metallurgical

Quiz and Industrial Visits. Participating Institutions include IIT Kharagpur, IIT Jammu, IIT Indore, IIT (ISM) Dhanbad, MGIT Hyderabad, VNIT Nagpur, NIT Durgapur, NIT Bhopal, MANIT Bhopal, BITS Pilani, NIAMT Hatia Ranchi, IIEST Shibpur, NIT Jamshedpur, and many others.

Dr. Ammasi A. expressed gratitude to the Chief Guest, Participants, and the Organizing Committee for their efforts in making the Seminar a success. He also thanked Dr. Sandip Ghosh Chowdhury and the Advisory and Organizing Committees for their continuous support.

The Seminar features five Keynote Lectures by Dr. Atanu Pal, Chief Technology Officer at TSL; Dr. Indranil Chattoraj, Adjunct Professor at IIT Jodhpur & Former Director of CSIR NML; Dr. P.K. Banerjee, Outstanding Scientist at CSIR-CIMFR, Dhanbad; Dr. S.K. Satpati, Chairman & Managing Director of Uranium Corporation of India Ltd.; and Dr. S. Sivaprasad, Chief Scientist at CSIR NML Jamshedpur.

The Valedictory Ceremony concluded at the CSIR-National Metallurgical Laboratory (NML) Auditorium.

Dr. Gopi Kishor Mandal, Secretary of IIM Jamshedpur, led a productive Feedback Session where Participants shared valuable suggestions for Future editions.

Expressing gratitude, Dr. Premkumar, Co-convenor of BTTD-2024, extended heartfelt thanks to all Participants and Organizers for their dedication in making the Event a resounding success. He announced that Industrial tours to Tata Steel Ltd. and Tata Steel Long Products are scheduled for June 21, 2024, providing Participants with practical insights into Industrial applications.

The winners of the Technical Sessions were honored with prestigious Awards, marking the culmination of yet another enriching Chapter of Academic Discourse and Professional Networking at BTTD-2024.

Glimpse of BTTD-2024

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IREL (India) Limited	32
Steel Authority of India Ltd	3rd Cover

News Updates

Domestic

JSW Steel Comes Out with a New Product for Green Energy Space

JSW Steel is looking at substituting the country's imports of a Coated Steel Product that finds application in highly corrosive environments in the renewable energy space.

The Country's Largest Steelmaker has started producing 'JSW Magsure', a zinc-magnesium-aluminium Alloy Coated Steel Product that had a demand of around 100,000 tonnes in India in 2023-24.

"Demand for this product is expected to go up to 250,000 tonnes this year, driven by renewable energy, and we are targeting a production of 145,000 tonnes," Ashwani Sharma, Executive President for JSW Steel Coated Business, told ET.

The Company is looking at supplying 120,000 tonnes of JSW Magsure in the Domestic Market and export the remaining 25,000 tonnes. It has already supplied 5,000 tonnes of this product to Adani Green Energy this year, and is negotiating for supplies of another 5,000 tonnes over the next three months.

While another of its products, JSW Galvalume also caters to the demand for corrosion-resistant steel, Magsure is expected to offer an even higher resistance to corrosion.

The Economic Times (1.6.24)

Welspun Corp Associate Company Signs Rs 3,670 Crore Contracts with Aramco for Steel Pipe Supply

Homegrown Welspun Corp Ltd said its associate entity EPIC has signed multiple agreements worth SAR 1.65 billion (about Rs 3,670 crore) with Saudi Arabian Oil Co. (Aramco) for the supply of steel pipes. The duration of the contracts is 19 months, and the financial impact of the contracts will be reflected from the fourth quarter of the financial year 2024-25 to the last quarter of the financial year 2025-26, Welspun Corp said in an exchange filing.

"Our associate company East Pipes Integrated Company for Industry (EPIC) announced multi contracts sign off with Saudi Arabian Oil Co. (Aramco) with value exceeding (Saudi Riyal) SAR 1.65 billion (approximately Rs 3,670 crore) inclusive of value added tax for manufacturing and supply of steel pipes," it said.

The Economic Times (3.6.24)

Vedanta Sees Sale of Steel Operations by October, to Spend $1.9 Billion on Capex

Vedanta Ltd. expects to monetise its steel and raw materials business in the first half of the current financial year, Chairman Anil Agarwal said.

The company had initiated a strategic review of these businesses in June last year, and had said that the demerger of this business would be completed by March 2024. Last month, though, Agarwal said that they would sell the business only at the “right” price.

The company had acquired Electrosteel Steels Ltd. through the insolvency process in 2018.

The plan to divest the steel business is a part of the company’s efforts to cut debt, Agarwal said in the company’s annual report for 2023-24 (Apr-Mar). At holding company Vedanta Resources, debt has been cut by $3.7 billion in two years, as against the company’s commitment of bringing it down by $4 billion.

“We seek to further deleverage Vedanta Resources by US$ 3 billion over the next three years,” he reiterated.

Vedanta Resources had a debt of $6 billion as on March 31, 2024. It also restructured bonds worth $3.2 billion last year, extending the maturity of these bonds up to 2028-29 (Apr-Mar).

The Economic Times (18.6.24)

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Employment generation
10K+
CSR beneficiaries
1.5K+
Industries supported in the value chain
1K+
Families rehabilitated
1.5K+
Acres of Green belt developed
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CORPORATE OFFICE:
PLOT NO. 1207, ECIL BLDG., VEER SAVARKAR MARG, OPP. SIDDHIVINAYAK TEMPLE, PRABHADEVI, MUMBAI-400 028
PHONE: 022-24211630, 24382042, 24220230 | FAX: 022-24220236 | EMAIL: CONTACTUS@IREL.CO.IN

Iron & Steel Statistics

World

Crude Steel Production by Region

	May 2024 (Mt)	% change May 24/23	Jan-May 2024 (Mt)	% change Jan-May 24/23
Africa	1.8	0.9	9.2	5.4
Asia and Oceania	122.1	1.6	586.2	-0.6
EU (27)	11.7	1.8	56.1	-0.1
Europe, Other	3.9	6.2	18.6	12.4
Middle East	5.2	4.6	24	7.7
North America	9.4	-0.9	45.2	-3.0
Russia & other CIS + Ukraine	7.7	2.8	36.7	0.1
South America	3.3	-8.2	17.3	-1.4
Total 71 countries	**165.1**	**1.5**	**793.2**	**-0.1**

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

	May 2024 (Mt)	% change May 24/23	Jan-May 2024 (Mt)	% change Jan-May 24/23
China	92.9	2.7	438.6	-1.4
India	12.2	3.5	61.9	7.7
Japan	7.2	-6.3	35.7	-2.3
United States	6.9	-1.5	33.4	-2.4
Russia	6.3 e	-0.9	30.9	-2.5
South Korea	5.2	-10.9	26.4	-6.3
Germany	3.2	-1.9	16.2	3.7
Türkiye	3.2	11.6	15.5	19.8
Iran	3.3	2.1	14.0	9.1
Brazil	2.6 e	-7.4	13.6	0.6

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

Source : worldsteel.org

NF Metals Statistics

Domestic Scenario

Production (unit : Lakh Tonnes)

	May'24	Apr'24	Mar'24	2023 - 24	2022 - 23	2021 - 22
ALUMINIUM						
NALCO	0.39	0.36	0.41	4.63	4.60	4.60
HINDALCO*	1.12	1.09	1.13	13.31	13.22	12.94
BALCO	0.50	0.48	0.50	5.84	5.69	5.80
VEDANTA LTD	1.54	1.49	1.54	17.81	17.22	16.92
TOTAL	**3.55**	**3.42**	**3.58**	**41.59**	**40.73**	**40.26**
*Renukoot, Hirakund, Mahan, Aditya						
ZINC (One major producer)						
HZL	**0.74**	**0.71**	**0.78**	**8.17**	**8.21**	**7.76**
COPPER (Cathode)						
HCL	0	0	0	0	0.000073	0.62
HINDALCO	0.27	0.38	0.38	3.68	4.07	3.59
SSL	0.05	0.06	0.07	1.41	1.48	1.25
TOTAL	**0.32**	**0.44**	**0.45**	**5.09**	**5.55**	**4.85**
LEAD						
HZL	**0.17**	**0.16**	**0.19**	**2.16**	**2.11**	**1.91**

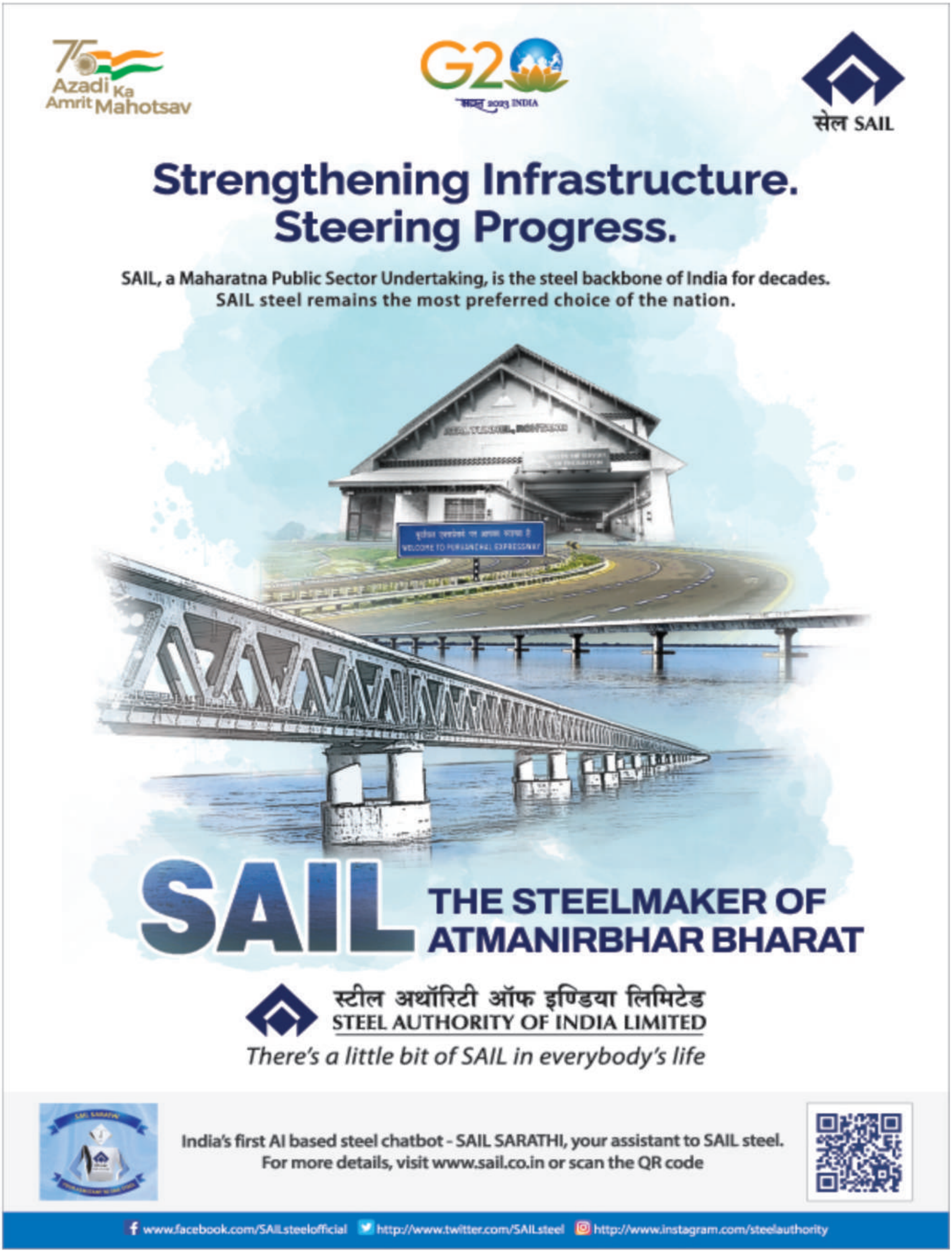
Source : https://mines.gov.in/

Prices in India (as on 6th June, 2024)

(Mumbai Local Price in Rs. / kg)

Product	Rs. / kg	Product	Rs. / kg
Copper Armature	831	**Aluminium Ingot**	247
Copper Cathod	894	**Aluminium utensil**	187
CC Rod	893	**Zinc Ingot**	269
Copper Cable scrap	859	**Lead ingot**	196
Brass Sheet Scrap	572	**Tin Ingot**	2866
Brass Honey Scrap	549	**Nickel Cathod**	1612

Source : https://mtlexs.com/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Correspondence
Shri K. R. Krishnakumar
Hon. Secretary
The Indian Institute of Metals – Delhi Chapter
Jawahar Dhatu Bhawan,
39, Tughlakabad Institutional Area
MB Road, New Delhi – 110062
e-mail: iim.delhi@gmail.com/ kuduvak059@gmail.com
Tel.: +91-11-21820057/29955084; Mobile +91 9818277840

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