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Thermal Spray in India - Opportunities and Challenges

Subramaniam Rangaswamy

Oerlikon Metco (Retired), Rochester Hills, Michigan, USA.

ABSTRACT

This paper explores the growth of Thermal Spray (TS) technology in India from around the 1950's. It tries to explain the relatively slower growth of this technology in the earlier years but finds optimism in the potential for significant growth in the next few years. Applications in the industry sectors of power generation (both Hydro and Thermal), Steel industry and Aviation MRO (both Civil and Military) are identified as attractive areas for significant growth. Along with growth opportunities, potential challenges and likely roadblocks are also highlighted.

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Introduction

Thermal Spray is a widely used process in many industrial applications around the world. It is used for surface enhancement in more than 30 different industries and some estimates put the market size in excess of US$7.5 billion. This is a mature technology in many countries including North America, Europe and Japan. On a relative basis, growth of this technology in India has been somewhat sluggish until the early 2000's.

History of Thermal Spray in India

Thermal Spray probably started in India around the 1950's.For nearly 3 decades it was mostly focused on wire arc and flame spray metallizing. The first couple of air plasma systems came to India in the late 70's and early 80's. Plasma spray activities gradually grew in both military aviation and commercial job shops between 1980 to 2000 and beyond. HVOF activities began to pick up from the early to mid 1990's. From 2000 till date there has been a moderate growth of Thermal Spray in power generation and several industrial applications.

Why slow growth ?

It would be worthwhile to see why such a slow growth of TS in India compared to elsewhere in Europe and North America. There are a couple of major reasons. Although there is an estimated total of 150 systems (Plasma + HVOF) in India currently, there is apparently a widespread lack of 'awareness'about this technology and its benefits for many applications. Second, there has been no central organization to bring the practitioners of this technology under one umbrella. Recent formation of ITSA is definitely a step in the right direction. Third, there is a major issue regarding the non availability of locally manufactured powders and advance spray equipment. Therefore imported powders, advanced spray equipment and technology transfer become prohibitively expensive for many Indian customers. Also, In US and Europe, the aerospace/aviation /IGT and MRO activities have spurred the growth of this technology into many other areas; but there has been very limited aero MRO activity in India. Finally one cannot overlook the serious bureaucratic and compliance issues that exist in India.

What could be some growth areas?

Coming to areas of growth, I have 4 areas have been identified where there might be significant opportunities for growth in the next few years. They are coatings for a) Hydroelectric power generation, b) Thermal Power generation, c) Steel industry coatings and d) Aviation MRO sector. In terms of other areas, Automotive industry has competing technologies (PVD, Chrome plating) and needs *Bharat Stage 6* standards to grow. Cylinder Bore coatings using rotating plasma devices (Oerlikon Rotoplasma) is a potential growth area and could be an exception. Other general Industries (Pulp/Paper, Sugar, Cement, Oil and gas, printing) will likely grow at an organic rate or by replacement of welding processes. Anilox Rolls are seeing significant growth as well as valve coatings (Praxair/FMC, Cameron, Aramco, Flowserve). Hard chrome replacement coatings are popular in EU and US. However, lack of Environmental and Health/Safety legislation in India will be a determining factor.

Electric Power Generation in India

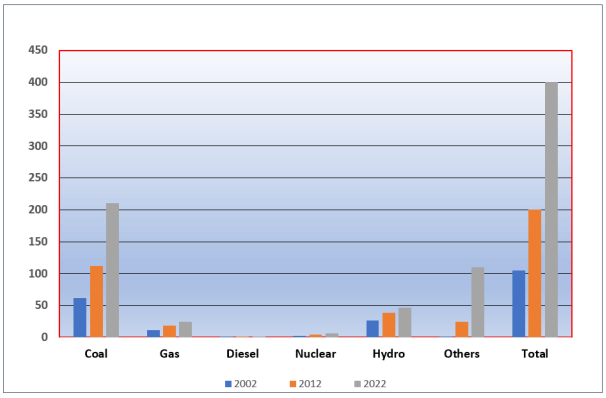

Figure 1: Growth of Overall Installed Capacity of Electric Power Generation in India from 2002 to 2022

Corresponding Author: S Rangaswamy, Tel: *+1-248-464-1601*
Email: Bullu@aol.com
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If one looks at electric power generation in India, Fig 1 shows that the total installed capacity has grown from approximately 105 GW in 2002 to about 400 GW in about 20 years.

Table 1: Growth of Installed capacity (in GW) by various categories (Coal, Gas, Hydro, Renewable, Nuclear etc)

	2002	2012	2022
Coal	62.13	112	210.7
Gas	11.1	18.4	24.9
Diesel	1.1	1.2	0.5
Nuclear	2.7	4.8	6.8
Hydro	26.3	39	46.7
Others/Renewable	1.6	24.5	109.9
Total	**105**	**200**	**400**

If one looks at power generation based on the types of fuel (Table 1) , Coal by far has the biggest share for power generation in India. Hydroelectric power generation has a decent share; but interestingly the renewable sector seem to growing faster than most. Some of the issues with this scenario is that the traditional fuels like coal/lignite/biomass etc, there are significant pollution issues, but many other challenges such as growing economy, rising exports and infrastructure development also represent opportunities for growth. Some of the major players for power generation in India are NTPC, NHPC (both state owned) , Tata's, Reliance, Adani (Privately owned).

Hydroelectric Power and Thermal spray

It is estimated that the current potential for Hydroelectric power generation in India is approximately 149 GW (Utility) plus about 6.8 GW for smaller Hydro projects. Installed capacity is around 46 GW (Utility) and 4.6GW for smaller projects. Major players are NHPC (National Hydro Power Corporation); NEEPCO (Northeast Electric Power Corporation); SJVNL (Sutlej Jal Vidyut Nigam Ltd); THDC (Tehri Hydroelectric Corp); JSW; Teesta (Sikkim) and NTPC (National Thermal Power Corporation). Among active OEM's are BHEL-Bhopal; GE Renewable Hydro; Voith and Andritz. There are also several smaller Indian fabricators who supply coated components.

Why Thermal spray

Many of the rivers used for Hydropower generation in the Himalayan region of India contain a high amount of Silt (fine dust like mineral sediments). These minerals cause havoc on the turbine runners during operation and can degrade the runners by solid particle erosion and cavitation erosion. When turbine runners are severely eroded, the efficiency of the turbines decrease to unacceptable levels. In some cases, these damages can be so severe that a turbine runner cannot be used beyond a single monsoon season. To minimize the erosion and extend the life of the runners, several types of hard coatings were tested on the runners. Shown below (Fig 2a) is a picture of a 150 Ton Francis Turbine. Fig 2b shows the effect erosion on the runners of a Pelton Turbine runner.

Some of the earlier coatings that were tried unsuccessfully included a) Boronizing b) Wire Arc Spray c) Weld overlays of cobalt hardfacing alloys d) Ceramic Oxide coatings and e) Plasma Sprayed WC-Co Coatings. Current state of the art coatings of WC-Co-Cr materials applied by High Velocity processes offer some level of protection for these applications. Various commercial spray equipments such as HVOF or HVAF with Liquid Fuel or Gas Fuel models provide the desired relief. Coatings with low porosity (less than 0.5%); hardness in the range of HV 1100- 1300 and coating thickness up to 300 microns are the industry standard. (see Fig 3 for typical coating microstructure).

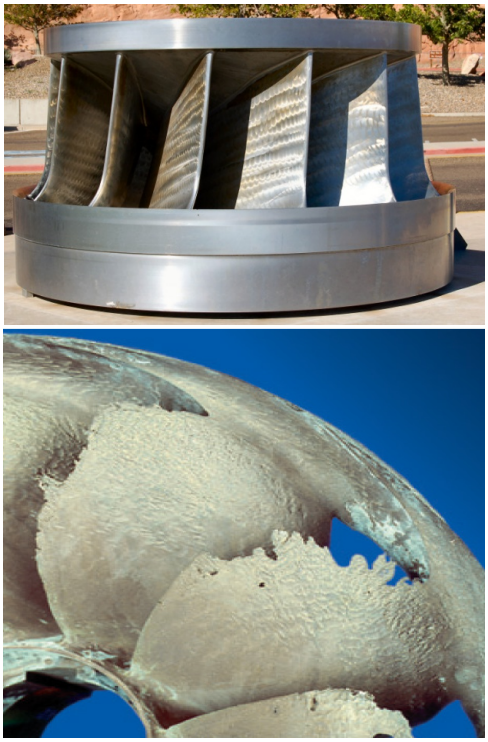


Figure 2: (a) A large 150 Ton Francis Turbine, (b) Silt erosion damage (Pelton runner)

Using this technology, many applicators are successfully applying coatings on the shop floor (when possible) and on site depending on the logistics. The complex contours of the runners are coated using robotic manipulation systems to achieve a uniform thickness.

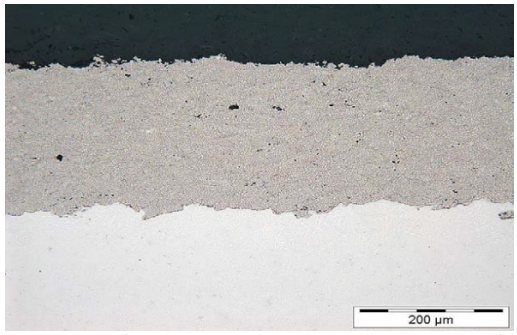


Figure 3: Typical Coating microstructure of HVOF sprayed WC-CoCr coating

Notwithstanding the success of the HVOF applied WC-CoCr coatings, there are some technical challenges to be overcome. In many instances, transportation/logistics to remote areas for onsite work pose their own challenges. When the turbines are very large (for e.g.: 80T or 100T or 150 T), they will need very sophisticated handling systems to apply uniform coatings on the intricate profiles of large runners. It is reported that several local (Indian) coating applicators are providing coating services with locally

made HVOF (MEC) systems and specially designed Handling equipment.

Thermal Power Generation (India)

Thermal Electric Power and Thermal Spray

Major sources of fuel for Thermal Power generation in India are: a) Coal/Lignite (57%) b) Natural gas (10%) c) Petroleum products (1%) and d) Agricultural waste and domestic trash. Major types of Power plants are: a) Steam cycle (large utilities) b) Gas Turbines (moderate size peaking facilities) c) Co-gen and Combined cycled (Gas turbines/IC engines with heat recovery) d) IC Engines (remote locations)

The major problem with Coal/Lignite in India is the very high ash content (up to about 50%) and consequently very low calorific values.

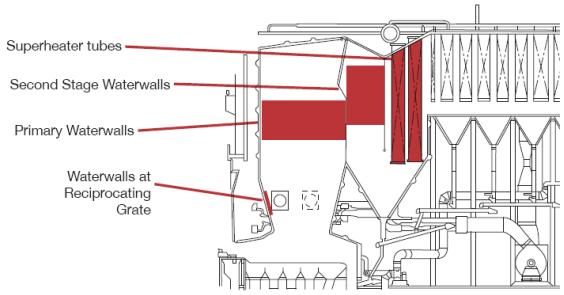
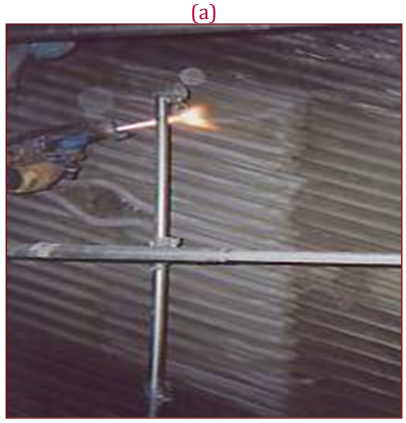


Figure 4: Cross section of a typical Thermal Power Plant

Fig 4 shows a schematic of a typical thermal power plant and the various components such as water wall tubes, super heater tubes that require protection from corrosion and erosion. Pictures 5a and b below show thermal spray process used to apply coatings on water wall tubes.

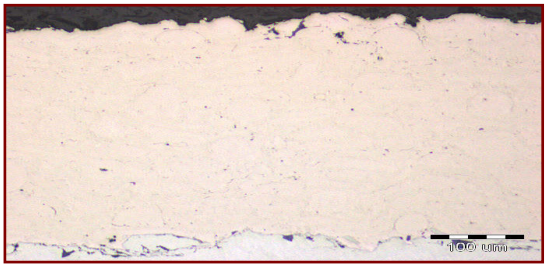
(a)



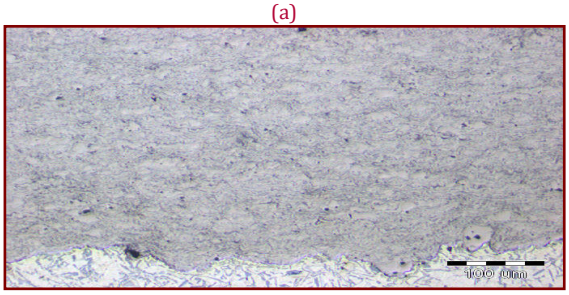
(b)

Figure 5: Thermal Spray coatings being applied on Water wall tubes

For HT corrosion resistance, powders or wires of Nickel based, high Chrome based alloys are used (see typical microstructure in Fig 6a. Coatings up to a thickness of 250 microns with a hardness HV 600 to 700 are employed. This type of coatings are typically used in the incinerator areas (superheater, screen tubes and water wall), BLRB (superheater, Water walls) and Crude Oil (Water wall) areas. In areas where high erosion is anticipated, harder Chrome Carbide-Nichrome composite powders are applied using HVOF process (see typical microstructure in Fig 6b). These coatings typically have hardness's of around HV 800 – 900 and are applied to a thickness of about 200 microns.



(a)



(b)

Figure 6: Coating cross sectional microstructures of a) Nichrome alloy b) Chrome Carbide-Nichrome composite

There are of course some challenges associated with the application of Thermal Spray coatings on boiler components. For example, there will be wide variations in the types of hot corrosion and erosion at various locations in the inside of the boilers. Second, the onsite application of these coatings is not trivial. It is not known if there are experienced spray contractors for large scale on site applications in India, although it may be noted that there are a few local applicators (especially in the state of Gujarat) that are providing limited coating services to Indian thermal power plants as well as a few neighboring countries.

Finally, the variability in the quality and ash content of Indian sourced coal will be a factor to predict the success of these coatings.

Steel Industry Applications for Thermal Spray

What drives the growth of steel sector in India?

The per capita consumption of steel in India is currently estimated to be around 70 kg. When compared to world average (228kg), developed nations (350kg) and China (690kg), this is relatively low. However, with an annual growth rate of 7%, this number is projected to increase to about 160 kg by 2031. It may be noted that China is on the decline and the rest of the world is concerned about CO_2 emissions.

Figure 7: Outlook for steel production in India (to 2030)

The Government of India is doing its part to grow the steel sector. It has rolled out the National Steel Policy in 2017. It's liberalized policies are attracting significant private and foreign investments. Huge government investments for infrastructure developments (approx. $500 million) are also contributing to grow the industry. All of these are resulting in the modernization and increased capacity of steel production (Brownfield and Greenfield expansions).

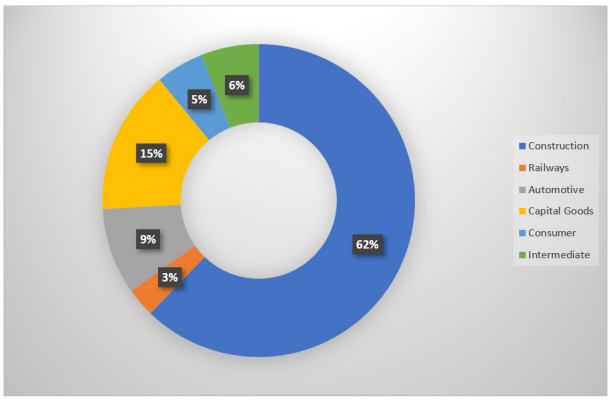


Figure 8: Sector wide demand for Steel

Thermal Spray Applications in Steel Industry

There are a vast number of applications for thermal spray in the steel industry from the Furnace areas (Hoods, Ducting, Tuyeres and Nozzles) to the Continuous Casting and Processing rolls (including Caster rolls, Wrapper and Process rolls, Bridle rolls, Deflector rolls, Annealing line rolls and Galvanizing Line rolls.

Figure 9: Fusing of Rolls with Self Fluxing NiCrBSiC alloys

Many of the transport rolls are hardfaced with NiCrBSiC based Self Fluxing alloys sometimes blended with WC -Co powders for increased wear resistance.

Continuous Annealing Line (CAL) rolls (also known as Hearth Rolls) are coated with specialized MCrAlY-Oxide strengthened composites by HVOF, but also need special heat treatment of the finished coatings to be fully effective. These coatings are especially useful to prevent iron oxide build up on the sheet metal during their passage through the annealing furnace lines. These coatings originally developed by Praxair (LCO-17) using oxide dispersion strengthened MCrAlY's are the industry standard. Some applicators in India (for example ATS with collaboration of Tocalo and SMS-Orissa) are spraying similar coatings to a limited extent.

Galvanizing Line rolls (also sometimes known as Sink Rolls) are coated with WC Cermet type coatings. The purpose of these rolls is to prevent Zinc dross from sticking to the metal sheets and the rolls.. Several new formulations are being developed in Korea/China using Borides and other compounds; but Indian applicators are HVOF spraying with low carbon WC-Co powders and subsequently using special sealants.

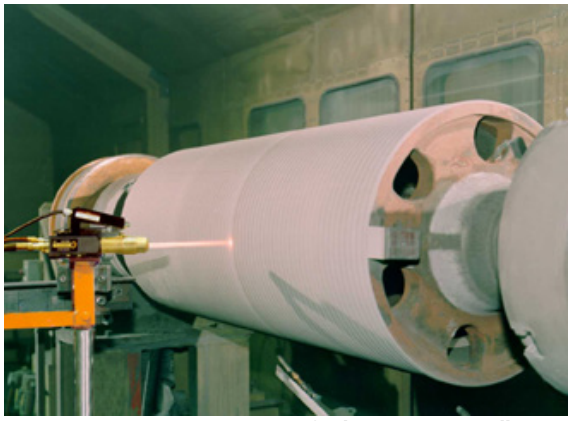


Figure 10: HVOF spraying of Galvanizing Line Rolls

Opportunities and challenges for Thermal Spray in the Steel industry

There are a number of opportunities to expand thermal spray in the industry such as a) development of replacements for Hard Chrome Plating b) Improved TBC's for furnace hardware c) Development of High Entropy alloys (HEA) d) New non skid coatings and e) multilayer coatings for Galvanizing Line hardware.

Among the challenges is the ability to develop fusing techniques for large size transport rolls when applying self-fluxing alloys. Not many applicators have developed expertise in this area. Another challenge is to develop coatings and application technology to meet the needs of CAL and CGL rolls. This technology is still in the early stages in India.

Thermal Spray for the Aviation Sector in India

Aviation sector in India can be viewed from the Civil Aviation sector and Military Aviation sector.

Civil Aviation -Opportunities and Challenges

In the Civil Aviation sector, consumer demand is constantly increasing resulting in increased fleet size. Currently the fleet size is estimated to be about 713 aircrafts whereas this is expected to double to about 1522 by 2031. Several Government policies such as the MRO Policy of 2021; National Civil Aviation Policy of 2016; Rationalization of GST and removal of GTO are incentives for the growth of MRO in the civil sector. Added to this will be redelivery maintenance and related work. Also helicopter MRO is another opportunity.

Currently, the CAGR (India) is around 8.9% versus global average of 5.6%. In this scenario, current MRO market size of about $1.7 billion is projected to grow to about $4.0 billion by 2031.

India currently performs Airframe maintenance within the country whereas outsources Engine maintenance. Most MRO activity locally is centered around Air India (Mumbai) -AIESL. There are a few limited JV's for engine MRO's between AIESL – Pratt Whitney and Wadia Group – SIA Engg.

While there is potential upside to the growth of MRO activity and Engine maintenance work within India, there are many significant challenges as well. The ability to break into value chains cannot be trivial. Significant barriers will be present from OEM's, International MRO's, and many airline operators. Additionally, dealing with offset clauses, credit availability, Licensing/certifications, IPO controls and many other factors will not be easy.

Military Aviation - Opportunities

The repair and maintenance activities for Military aero engines in India is centered around HAL (Koraput for MIG and Sukhoi and Bangalore for SNECMA and RR) and Indian Airforce (BRD in Kanpur and Chandigarh). Routine Airframe maintenance activities and some plasma spray coatings are done for these engines in Indian overhaul shops. However, there appears no technology for the advanced repair of the critical engine components such blades, vanes etc.

More recently, there are several published reports about the French-Indian collaboration for the supply of Rafale fighter jets and engines to the Indian Navy and Airforce. Government of India plans to invest roughly $1 Trillion of funding in the next 25 years.

Approximately 36 fighter jets are already supplied to Indian Navy (INS-Vikrant) and there are plans to deliver 80 jets to the Indian Airforce. It is reported 50% of jets will be made in India and the rest assembled in India. As far as the engines are concerned, most M88 engines will be manufactured in India and there are plans to set up an MRO hub for Rafale in India. There are also reports about a proposed Dassault -Reliance JV in Nagpur.

Summary

Overall there are some positive signs for the growth of Thermal Spray technology in India. Some of the positive signs are:

Government of India through Department of Science and Technology has identified Surface Engineering as a thrust area and making funds available for R&D. Indian Government is also investing huge amounts in infrastructure developments (USD 500 Billion plus). Liberalized government policies are attracting FDI (Foreign Direct Investments)

Major shortage of electric power across the country is leading the growth of Hydroelectric power, Thermal power and renewable sources of power. Per capita consumption of steel in India will grow due to rising income of middle class, housing growth and infrastructure (bridges, highways) development.

Fleet size of airlines is increasing and opportunities for MRO will increase in both civil and aviation sectors.

Notwithstanding the opportunities, there are significant challenges to overcome. They are:

No Local powder manufacturing. Hence most powders are imported from either Europe or North America. Added costs of customs + duty+ freight + distribution is at least 50% more compared to similar materials in US and elsewhere. This will be further aggravated by fluctuations in currency exchange rates. Some local powder manufacturers are coming up in India, but they seem to be focusing on Laser Cladding or Additive Manufacturing or MIM powders; but none in Thermal Spray as far as I can tell.

Establishing Aviation MRO facilities and getting certification –this will be a long time effort and non-trivial.

Land acquisition troubles for major integrated steel plants in India. But things are apparently getting better since 2014.

Continued lack of awareness of the technology in many major industries. Also, there is very limited resources for demonstration facilities and application development. Bulk of R&D is focused on basic research and should be more Industry oriented and practical Applications. This requires significant financial support from the industry to academic institutions. Indian bureaucratic processes and compliance issues have a notorious history and are not friendly to foreign investors. Again, things are getting somewhat better since 2014.

Conclusions

India is a complex country; but the huge population, GDP growth, rising household income, infrastructure development all present some significant growth opportunities for the growth of thermal spray.

Significant among these opportunities are in the areas of Electric Power generation (both Thermal and Hydro); Steel industry and Aviation MRO work. There are significant challenges as well.

Indian government is doing its part and is trying to provide many incentives and help in several areas.

Overall, it depends on the Thermal Spray community in India to "take the bull by the Horn".

Acknowledgement
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