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Thermal Spray Coating an Alternative Coating Solution in Place of The Traditional Hot Dipped Galvanizing Process in Present Industrial Scenario

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Abstract

In present scenario the Thermal Spray Coating is prestigious alternative solution to replace traditional Hot Dipped Galvanizing Coating as an alternative solution for new and existing structures in industries and offering a range of benefits for long durability and maintenance free solution for more than 25 years in service. There is no weld life for site application in case of Hot Dip Galvanized Structure and may customers have issue with coating performance and applicability of liquid coating or cold spray application on Hot Dip Galvanizing for repair application. Thermal Spray Coating can apply very safely, maintenance can be possible at site, easy application as compared to Hot Dip Galvanizing and excepted by many Customers Specifications as an alternative solution to the traditional Hot Dip Galvanizing Coating. Thermal Spray Coating is an anti-corrosive protection used for very long life of the coating for onshore and offshore structures, equipment's and piping. Thermal Spray Coating is the only coating system recognized by international code and standards having desired service life of more than 25 years to its first maintenance cycle time in very aggressive environment like offshore platform where aggressive corrosive environment is the great challenge to the end users. This paper covers the comparison of Thermal Spray Metallic Coating with traditionally used Hot Dipped Galvanized Coating and summarizes the merits of using a more advanced coating system. Thermal Spray Coating can be applied by anyone of the following coating methods, Arc Spray, Flame Spray and High Velocity Oxygen Fuel, High Velocity Air Fuel, Atmospheric Plasma Spray, Vacuum Plasma Spray, Cold Spray, etc. Many more thermal coating methods can be considered to optimize the cost of Coating Application for Oil & Gas Refineries, Petrochemical Complex, Marine, Shipping Industries, Power Sector including Nuclear Plant. Thermal Spray Coating can be applied with the help of filler material starting from pure metals, alloys, ceramic, composite, etc. in the form of wire and powders. Thermal Spray Coating can be applied to any metal and non-metal surface with, or little surface preparation based on the type of coating thickness to be applied [2].

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INTRODUCTION

For over a century Hot Dip Galvanizing has been the most accepted process for adding a zinc- based water protecting coating to equipment's, piping and structures of steel. However, it has its own limitations including possible heat distortion, need to drill sealed holes in complex structure section and piping, suspend the items for getting desired coating thickness, etc. [6],[9]. Like Hot Dip Galvanizing, Thermal Spray Coating can be used with Aluminum for Carbon Steel and Stainless-Steel metals and

Zinc and Aluminum-Zinc Alloy for Carbon Steel metals. Thermal Spray coating provides protection against general environmental corrosion, pitting corrosion and stress corrosion cracking to a large extent. It also acts as scarification cathodic protection or provides barriers against severe corrosive environments like sea water. Thermal Spray Coating can be considered as one of the metallizing processes out of many high temperatures coating in present scenario of coating which is also used for erosion resistance over and above corrosion protection applications in the world. That's the reason Thermal Spray Coating popularity increased as an alternative solution to Hot Dip Galvanizing Coating because no dross formation is produced and there is no need for fettling operation which can invalidate the warranty of customer.

Also, in case of Thermal Spray Coating structures, Equipment's and Piping fabrication activities are not going to have adverse effect on the coating performance in case of site activities as compared to Hot Dip Galvanizing which was challenge for the applicators to meet the desired service life of the Structure item [5].

Thermal Spray process can be applied as molten zinc, aluminum or its alloy with a handgun application which offers exceptional long-term durability, Long Service Life with very high-performance anti-corrosive protection to the system. By comparing Hot dip Galvanizing to Thermal Spray Coating can produce a superior powder coat finish at very high accuracy with respect to coating thickness uniformity over a metal surface as shown in Figure 1 [1].

One of the key advantages of Thermal Spray Coating is that it is a low heat process compared to Hot Dip Coating with no potential for heat distortion especially in thin-walled type construction of steel structure as well as corners and edges can be eliminating the risk of razor, spikes and Health and Safety issues on these structure items. (i.e. Handrails, Walkways, etc.) [5].

Thermal Spray can also use for decorative purpose as well as applying coating on monuments for long lasting coating application. With the use of low heat input to the process, Thermal Spray Coating resulting impact on the environment and helps reducing the Coating Applicator carbon footprint towards the common goal of ecosphere. Zinc as a recyclable material and the metallizing process produces zero volatile organic compound emissions so its demand is growing in the world as an alternative solution to Hot Dip Galvanizing [2].

Thermal Spray Coating is the coating system recognized by may International Standards (i.e. Section-g, Table 1 of EN ISO 14713) for more than 20 years of performance to first maintenance, even in the challenging environment such as Marine Splash Zone [1],[3].

With the use of Thermal Spray coating, applicator can achieve far superior bond strength for sealer coat paint system as it provides an excellent profile unlike very shiny surface which can be achieved by Hot Dipped Galvanizing. Comparing to Hot Dip Galvanizing, Thermal Spray Coating components coating finish with a thin coat of sealer at a low viscosity polyurethane, epoxy or vinyl resin will produce a super aesthetic finish [2].

Thermal Spray coating application include but not limited to use metallic powder or solid wire metal to have high corrosion resistance as well as excellent surface appearance. Thermal Spray Coating can be applied with a much more-dense coating thickness (approx. up to 350 microns) as compared to Batch type of Hot Dip Galvanizing where coating thickness control is not possible. Thermal spray coating can be overcoated by any liquid coating as it is porous in nature and can be applied with or without primer application. In Thermal Spray Coating Zinc metal can be applied to achieve a coating thickness accuracy in the range between 250 microns to 350 microns as it can be controlled by operator very easily with controlling operating parameters to a far greater extent as compared to Hot Dip Coating. [5] Thermal Spray Coating having very broad areas of application include but not limited to Anti Corrosion Coating, Heat Shielding, Erosion Corrosion and Insulation for Onshore equipment's, piping and Rigs, Jetties for Offshore Platform.

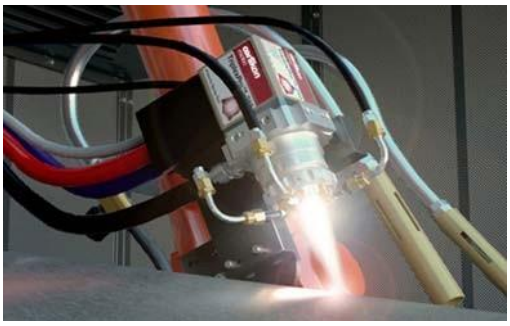

Figure 1. Thermal spray coating [10].

Figure 2. Hot Dip galvanizing process [11].

APPLICATION DIFFERENCE BETWEEN THERMAL SPRAY COATING AND HOT DIP GALVANIZING

Application of each coating is unique in its type. Hot dip Galvanizing does not require very high surface roughness and cleanliness. It requires only removal of oil, grease, weld slag or varnish from the steel surface with the help of caustic soda, pickling and flux as cleaning process and then dipping the steel into molten zinc kettle to establish the zinc coating by reacting zinc with steel surface. With this process Zinc layers are established with intermetallic alloys in between steel surface to pure Zinc layer. Hot dip galvanizing, where entire steel assembly is completely submerged into the Molten Zinc Kettle which include all corners, edges, threads, hollow sections, complex geometry having variation in thickness, etc. fully covered in the galvanized bath completely. Hot Dip galvanizing process can be carried out at shop to achieve coatings having impervious and adherent barrier type of Zinc layer with optimized sacrificial action. Hot dip galvanizing is independent of environmental condition requirements, which is normally the requirements for Thermal Spray Coating as shown in Figure 2. Hot Dipped Galvanizing temperature can be considered based on the metal and alloys used for coating and it can be further improved by the addition of alloying elements in kettle. Addition of alloying elements can improve the properties of coating. Such controls are difficult for wire type Thermal Spray Coating considering limitation of filer metal oxide formation during coating application, but it can be well maintained with the help of powder coating to a large extent. Temperature of Hot Dipped Coating can be around 450 Deg. C based on the metal and alloy used and its melting point temperature limit. Whereas Thermal Spray Coating temperature can be wary based on type of thermal spray methods as well as metal and alloys used of coating [6], [7], [9].

For improving the fluidity of molten zinc many time lead and other low melting point metals are added based on the productivity needed. However, the addition of zinc is prohibited for food grade storage vessels considering health and safety as well as environmental regulations issues, i.e. carcinogenic properties of lead. Hod Dipped Zinc and Lead use is ban in many countries including United States and Europe. If we consider the advantage of adding such element in zinc kettle for proper heat distribution, advantage over draws formation due to lighter density product over zinc, dross recycling can be managed nicely, to a large extent then small quantities of addition of lead can be justified by the Hot Dipped Galvanizers [8].

Considering corrosion mechanism in exposed to the atmosphere with the Zinc coating application, Zinc oxide is formed when it reacts with oxygen and carbon dioxide, zinc carbonate is formed over a steel surface. Such oxides underneath insulation may affect the coating color changes to the large extent due to temperature effect on coating and color shade can be dull gray due to such thermal effect [9].

Whereas Thermal Spray Coating process needed abrasive blast cleaning to nearly white metal surface finish (i.e. SSPC SP 10 or NACE No. 2) as minimum. Zinc or its alloy then applied to the blast surface with the help of high-pressure combustion gases using very high-capacity compressor with heating gun to the steel surface within four hours of abrasive blast cleaning process to avoid moisture contamination

on to the surface which will create the corrosive product on the blast surface. Entire process shall be done in the control environmental condition as per approved quality control inspection and test plan meeting applicable code and standards requirements as minimum. As in case of Hot dip galvanizing there is increasing in the temperature of steel surface during hot dipping operation and very high-quality Zinc coating layer can be established forming intermetallic alloy layers which is not the phenomena in Thermal Spray Coating. Also, corners, edges, threads, hollow sections, complex geometry having variation in thickness, etc. can be excluded if not required to coat using Thermal Spray process as per customer requirements which is practically not possible in Hot Dip Galvanizing [11].

Thermal Spray process quality depends on applicator skill and needed Operator qualification before using them on actual job work. Thermal Spray Coating surface preparation requirement as well as general requirement of coating is like the liquid coating requirement with respect to environmental requirement like humidity, due point, metal temperature, etc. Steel surface should be 3 Deg. C above the dew point to avoid expected condensation at the time of coating application. Like liquid coating thermal spray coating can be performed in shop as well as at site under control environmental condition which includes control of wind during blasting and coating application based on NACE 12 Standard requirements [6].

If we compare the adhesion test results of thermal spray coating over hot dipped coating, then hot dipped coating adhesion properties are much better as compared to thermal spray coating considering metallic bonding as compared to adhesive bonding strength (approx. 1500 psi). Hot Dipped Galvanizing adhesion strength can be almost double (approx. 3500 psi) as compared to Thermal Spray Coating. There are many other properties that shall be considered other than coating strength like abrasion resistance which is adherence to the steel surface requirements in case of scratch. Also, hardness value for Hot Dip Galvanizing is 2.5 to 3.5 times high compared to Thermal Spray Coating as Zinc and even higher compared to bare steel in general due to hot dipping in molten zinc bath [4].

Hot Dip galvanizing coating thickness requirements shall meet ASTM Standard requirements as minimum i.e. 1.4 to 3.9 mils based on thickness of steel to be galvanized. As Hot dip galvanizing is normally having higher coating thickness due to dipping process limitation. Whereas in case of Thermal Spray coating the coating thickness in the range starting from 3.3. to 8.3 mils. Based on comparison of hot dipped to thermal spray coating with respect to density, hot dipped coating having more density considering less porous coating. Density of coating is directly corelate with design life or durability of coating. Thermal Spray coatings have pours and it is rough compared to Hot dip galvanizing [4].

Depending upon the huge requirements with respect to corrosion, fluctuating temperature from very high to very low, the demand in material selection for Thermal Spray coating including Zinc, Aluminium, Steel, Tungsten carbide, Chrome carbide, Ceramics, Plastic or composite coating but not limited to many more challenges there in industries can be address by Thermal Spray process very easily as compared to Hot Dip Galvanizing. Thermal Spray Coating can be applied to any material surface with the use of any metal combination as coating surface cools very rapidly and form unique crystalline structure as shown in Figure 3.

Thermal Spray Coating is available in different composition of Zinc, Aluminium and its alloy which is not possible by Hot dipped Galvanizing process. Hot Dip Galvanizing is hazardous in nature due to use of acids, water, molten Zinc Bath, etc. as compared to that Thermal Spray Coating is generating metal dust which is recycle in shop very easily at very high accuracy up to 99.99%

Comparison Of Metals and Alloy Used for Thermal Spray Coating and Hot Dipped Galvanizing.

Thermal Spray Coating is available in pure metal, metallic alloys, plastic, composite as well as ceramic material categories. In general, Thermal Spray Coating materials available in rod, powder and wire, etc. forms with very wide material range start from pure metals (i.e. Zinc, Aluminium, etc.), Alloy (Ni-Al, Cr-Al, Cr-Al, etc.), self-fluxing metal (FeNiBSi), steel (Fe- Cr), Nickel Graphite (NiC), oxides

(Al2O3, Cr3C2, etc.), carbides (WC) and many more combinations are available and it can be applied to any substrate materials starting form Ferrous Metals, Non-Ferrous Metals, Non Metals (i.e. plastic, concrete, etc.) whereas Hot Dip Galvanizing process use only Zinc and its alloy up to 2% alloying elements addition (i.e. Pb, Al, Sn, etc.) as per ASTM B6 standard requirements with three different grades of Zinc combination and it can only use for metal structures only. [12],[13][14].

Life Cycle Cost and Maintenance Cost

Based on statistic data hot dipped galvanizing coating design life is as high as 75 years as compared to thermal spray coating which comes to 22 years which is one third of hot dipped galvanizing coating. Coating life needs to be evaluated based on the harsh environments to be addressed by the structures like marine, industrial, rural and urban based on ISO 12944 standard requirements of corrosive categories. For any project it is very important to consider a cost competitive solution for selection of appropriate coating process. Differences in initial cost and maintenance cost can have considerable differences between Hot dip galvanized and Thermal Spray coatings selection with respect to corrosive environments requirements.

Hot dip galvanizing is about half as expensive as compared to Thermal Spray Coating. Over the life cycle cost of the steel in corrosive environment with additional requirement of maintenance, Thermal Spray Coating can be cost competitive solutions and end up at 4-5 times as expensive as galvanizing in life-cycle costs consideration. However, maintenance of Hot Dip Galvanized Coating is not possible by same process (i.e. Hot Dip Galvanizing) at site due to its practical limitation and even if it will perform at site then also the life of structure is less as compared to Thermal Spray Coated Structure for repair application of Hot Dip Galvanized structure as well as other coating performed at shop or site.

Based on recent change in NACE 12 Standard life expectancy of thermal spray coating is minimum 25 years for its first maintenance. There is no intermediate maintenance needed for thermal spray coating when applying for critical marine application with the help of Zinc or Zinc-Aluminum Alloy coating. Thermal Spray Coating with 10 microns coating thickness in single coat will provide considerable medium high to high corrosion protection which includes areas where minor mechanical damage may have exposed the steel. Due to large anode to small cathode area ratio effect structure is protected even if there is minor mechanical damage during site erecting activities.

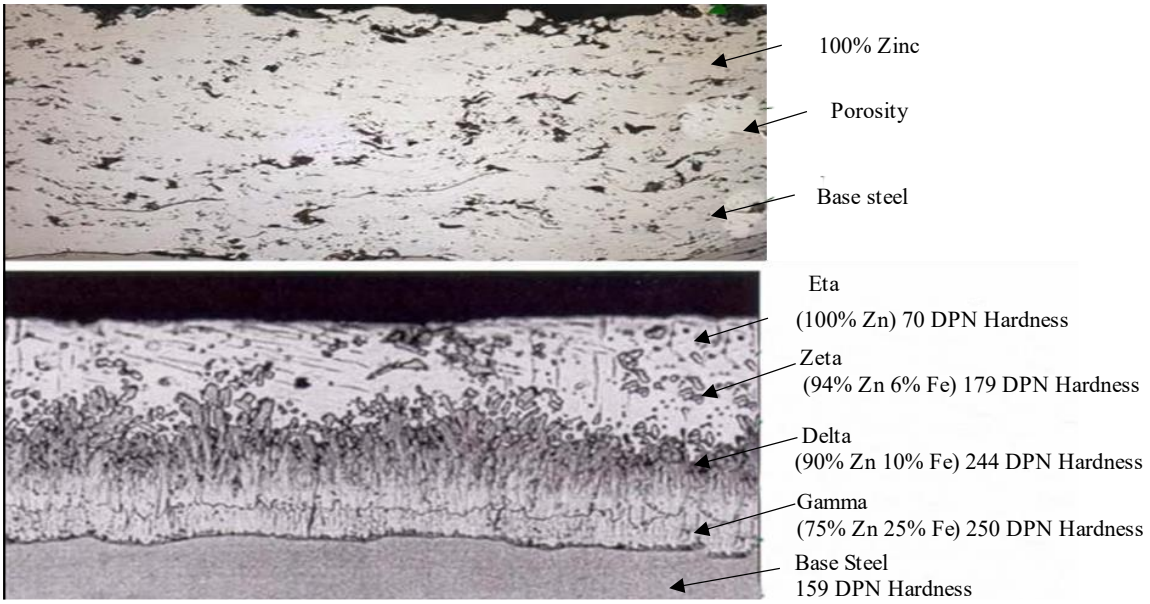

Figure 3. The micrograph comparison shows (a) Thermal Spray Coating thickness from 3.3 to 8.3 mils having rough surface with porosity around 3-5% as dark image (b) Hot dipped coating is dense in nature and very less porosity and coating sprade index and uniformity with the corners and edges are covered completely due to complete immersion of structure to be galvanized [4].

Bridge structures, interiors of water tanks and piping, compressor parts, aircraft components, marine application in many cases, over 30 years of service life without major repair activities with Thermal Spray Coating.

RESULTS AND DISCUSSION

Based on various parameters Hot Dipped Galvanizing and Thermal Spray Coating can be compared with following characteristic as descried in Table 1.

Table 1. Comparison between Hot Dipped galvanized to Thermal Spray Coating [4].

Hot Dipped Galvanizing (HDG)	Characteristic	Thermal Spray Coating (TSC)
Low	Initial Cost	High
Low	Life Cycle Cost	High
Yes	Cathodic Protection	Yes
No corrosion occurs when in contact with TSC	Compatibility	No corrosion occurs when in contact with HDG
Approx. 3600 psi	Bond Strength	Approx. 1500 psi
Yes	Inside Hollow Section coverage	No
Yes	Difficult to reach Corners coverage	No
1.4 to 3.9 mils	Coating Thickness	3.3. to 8.3 mils
Uniform	Coating informality	Based on Operator Skill
Based on Kettle Size	Size limitation	No limitation
Series of cleaning operations	Surface Preparation	Blast cleans to white metal surface
Approx. 100 Year Approx. 90 years Approx. 70 years Approx. 50 years	Durability (Service Life) Mild – Rural/ C2 Moderate – Industry/C3 Severe – Industrial/C4 Seacoast – Heavy Industries/C5, CX	Approx. 33 years Approx. 22 years Approx. 16 years Approx. 16 years
Independent of Weather	Application Condition	Depends on temperature and humidity
Less than 24 Hours	Process Time	Variable, Based on Blasting and Coating time
High	Abrasion resistance (Hardness)	Moderate
Shop only	Shop / Site Application	Shop & Site both
Recyclable	Sustainability	Recyclable
Not Possible	Rectification/ Post Erection at site	Possible

Based on cost, HDG can be used for all shapes, sizes and weights of steel with respect to the Galvanizing bath dimensions. This is the limitation of HDG over Thermal Spray Coating requirement. HDG cost is lower than compared to thermal spray coating but if we consider maintenance of HDG then its cost is very high for the non-productive hours. Also, there are hazardous and high temperature safety issues in industries. HDG and Thermal Spray Coating are considering as sacrificial type cathodic protection based on the metal and alloy used as specially for environmental protection requirement. As we are aware, thermal spray coating is more porous than HDG in terms of specific gravity data thermal spray is lesser in number i.e. around 6 whereas HDG is around 7. Metallizing can also perform on plastic and nonmetallic material where HDG have limitation. HDG bond strength is almost double that of thermal spray coating i.e. 1500 psi. HDG has no restriction for hard to reach areas and can coat internal surface of pipe or any hollow section whereas it is difficult to go with thermal spray coating due to its application limitations. Thermal Spray Coating can be considered up to 10 miles whereas HDG can be varied based on type of process i.e. continuous or batch type setup. HDG has size limitation due to kettle of molten zinc whereas metallizing has no size limit for steel pieces. Fabrications activities can be addressed together with metallizing which is not possible with HDG, and rework is also not possible after HDG makes metallizing more popular in resent industrial scenario [4].

CONCLUSIONS

Based on comparing Thermal Spray coating with traditionally performed Hot Dipped Galvanizing process which are mostly applied to all shapes and can applies to small size fasteners to large structures most commonly used for railways, road structure assemblies, marine structures, rebar coating, etc. There is a proven track record for hot-dip galvanized steel for a long maintenance free service life. However, there are times when Thermal Spray coating can be a good alternative solution to hot dip galvanizing in case where items cannot be galvanized due to size or on-site fabrication requirements. Thermal Spray Coating can be considered as a good alternative coating solution to galvanizing and can be used to overcome the issues of distortion for complex structures, no dimension limitation, can be performed at site easily, no risk of explosion. Distortion is one of the possibilities when hot-dip galvanizing process used because stresses induced into the steel during welding and fabrication process can be relieved in the molten galvanized kettle.

Thermal Spray coating is more popular now a days for cyclic service temperature as well as corrosion under insulation for temperature range starting form -45 Deg. C to 595 Deg. C. Temperature limits can be consider based on type of steel and process fluid requirement's including environmental condition to prevent corrosion under insulation. Thermal Spray coating is also applicable coating method for protecting against chloride stress corrosion cracking for Austenitic Stainless Steel in case of aqueous chloride environment like marine and corrosive industrial environment.

Thermal Spray Coating can be considered as best overall performance coating for repair and touch up for Hot dip galvanized as well as other coating products.

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