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Experimental Investigation on Corrosion Resistance by Using Thermal Spray Coating with Different material

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***Abstract*— Today's trends in mechanical has long been characterized by very stringent requirement s, on one hand customer require high performance, light weight and long life components on other with use of minimum assets and cost. To increase the life of metal components environment effect on parts should be reduced. And this can only possible by coating.**

There are many methods of coating are available in market for iron composite material like Painting, Galvanizing, electroplating, thermal spray coating and many more. There is continuous research is going on all the methods. But now days to improve corrosion resistance thermal spray metal coating is widely used which gives better performance and corrosion resistance.

Here on steel components three metals (Al, Zn, Al-Zn alloy) are thermal spray coated and analyze for corrosion resistance.

***Index Terms*— Coating, Thermal spray, Corrosion, Salt spray test**

I. INTRODUCTION

The Advantages of Coating technology in general is that it combines two different materials to improve, in a synergistic way, the performance of components. The coating provides protection against environmental degradation process including Wear, corrosion, erosion Biological and thermal attack.

Coatings are not a new technology, for times immemorial, wood and metal have been painted with organic or inorganic pigments to improve their esthetics appearance and their environmental stability. Corrosion Wear and abrasion resistance of the substrate materials were significantly improved by the paint coatings.

Modern High performance Machinery and structure are subject to extremes of temperature and mechanical stress needs surface protection against high temperature corrosive media and mechanical wear and tear. For such coatings highly versatile, low cost technique must be applied that can be performed with a minimum of equipment investment and does not require sophisticated training procedures for the operator. Such a technique has been found in thermal spraying.

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II. THERMAL SPRAY COATING

Thermal spray is define as Thermal spraying is a group of processes in which finely divided metallic or nonmetallic surfacing materials are deposited in a molten or semimolten condition on a prepared substrate to form a spray deposit. The surfacing material may be in the form of powder, rod, cord or wire or molten material. Thermal spray processes are grouped into three major categories: Flame spray, electric arc spray and plasma arc spray. These energy sources are used to heat the coating material to a molten or semi molten state. The resultant heated particles are accelerated and propelled toward a prepared surface by either process gases or atomization jets. Because of high impact force, a Bond forms with the surface, with subsequent particles causing thickness buildup and forming a lamellar structure.

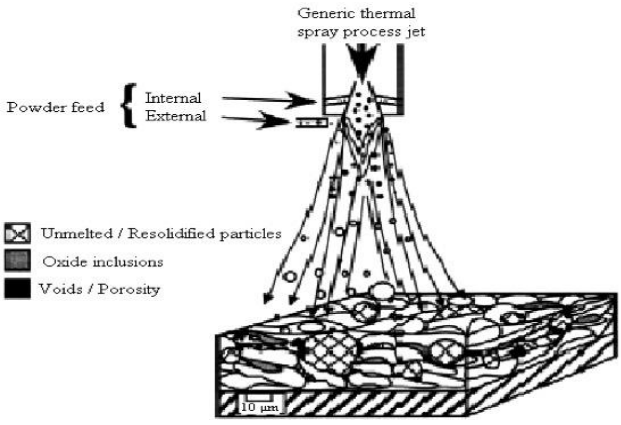

Fig.1 Thermal spray powder process [1]

A major advantage of thermal spray processes is the extremely wide variety of materials that can be used to produce coating. Second major advantage is ability of most thermal spray processes to apply coating to surface without much heat transfer to surface and avoid distortion of the surface. There are four main thermal spray coating process. [15]

Electric Arc Coating he coating material, in wire form, is electrically charged, and then contacted creating an arc. The molten droplets of metal wire are then sprayed onto the substrate using a high velocity air stream to atomize and propel the material.

Flame Spray coating: Flame spray coating employs combustion of gases to melt powder, wire or rod material and propel the molten droplets onto a surface to create a coating. Its gas velocities are much slower than HVOF. Flame

spraying can create coatings out of a wide range of materials from plastics to oxide ceramics.

Plasma-Arc Spray Coating: The plasma spray process (non-transferred arc), uses inert gases fed past an electrode inducing the "plasma" state of the gases. When the gases exit the nozzle of the gun apparatus and return to their normal state, a tremendous amount of heat is released. A powdered coating material is injected into the plasma "flame" and propelled onto the substrate. Ceramic Coatings are most often applied using plasma spray due to their high melting temperatures. (Often > 3500F)[15]. several types of ceramic coatings can be applied using plasma spray.

High Velocity Oxy-Fuel Coating (HVOF): High-velocity, oxy-fuel, (HVOF) devices are a subset of flame spray HVOF utilizes confined combustion and an extended nozzle to heat and accelerate the powdered coating material. Typical HVOF devices operate at hypersonic gas velocities, i.e. greater than MACH 5. The extreme velocities provide kinetic energy which help produce coatings that are very dense and very well adhered in the as-sprayed condition.

Literature Survey

BU QIAN WANG and GANG QIANG GENG[12] Found from research with Nine thermal spray coatings on 1018mild steel, including hard tungsten carbide—cobalt and softer, more ductile metals that are supposed to provide wear protection, were eroded—corroded at elevated temperature using 250 µm fluidized bed combustor bed material and quartz particles. And found from that all the coated material had lower erosion-corrosion, and has longer life than bare materials.

J.E. Cho,S.Y. Hwang and K.Y. Kim[4] found from experiment that A series of the electrochemical and long-term immersion tests was carried out in a strong sulfuric acid (5 wt.% H2SO4) solution on thermal sprayed WC cermet coatings having various kinds of metallic binder in order to examine the effect of composition of binder materials on the corrosion behavior. In the present study, the coatings were processed via a high velocity oxygen fuel (HVOF) spraying technique. The experimental results revealed that a considerable galvanic corrosion occurred between WC particles and metallic binders in the aerated 5 wt.% H2SO4 solution. The corrosion resistance of the coatings containing Cr was better than that of the coatings without Cr.

Z. Glogovic, V. Alar, Z. Kozuh, I. Stojanovic, S. Kralj[5] found from study that Thermal sprayed aluminium (TSA) coatings are widely used for the protection of steels from aqueous corrosion in seawater environments e. g. offshore structures, risers, pipe components and ship structures. This study has investigated the influence of parameters of flame spraying aluminium on structural steel for corrosion protection. The powder supply has the biggest influence on the thickness of the sprayed coating. The application of a larger quantity of powder results in a thicker layer being obtained. The only significant effect on the corrosion rate of the sprayed coating is exerted by powder supply, while all other parameters have no effect on the corrosion rate.

D. Toma, W. Brandl, G. Marginean[6] found from experiment that In order to protect machining parts against wear and corrosion, they are coated by cermet coatings. The coatings consist of WC or Cr C particles in a metal binder, which can be a pure metal or a mixture consisting of Ni, Cr, Co. The examined coatings were produced by high velocity oxy-fuel HVOF spraying and were investigated with regard to erosion and corrosion resistance. Combined erosion and corrosion tests of HVOF sprayed cermet coatings have shown that a coating with highly corroding matrix will suffer a much greater weight loss than a coating with a less corroding matrix. Among the tested materials the WC-Co coating was the least resistant.

Joseph G. Radzik[7] found from comparison of hot dipped galvanizing with thermal spray Zinc. Hot dipped galvanizing has been used in various markets for over 100 years as a method of corrosion protection. An alternative to the hot dipped galvanizing process is the use of Thermal Sprayed Zinc. Representative samples of Thermal Sprayed Zinc and Hot Dipped Galvanized ductile iron castings were subjected to a 5% salt spray test, and found that after 120 hours exposure the hot dipped Galvanized sample got red rust. And on thermal sprayed Zinc sample signs of rest rust found after 192 hours.

Experimental Procedure

In experimental work EN9/070M55 steel are used as base material and wire thermal spray coating apply on this materials. Different materials Aluminum, Zinc and Zinc-Aluminium (85%Zinc, 15%aluminum) are apply on the base material.

Aluminum coated to base material: Sainte-Claire Deville observed that aluminium had good resistance to atmospheric corrosion, which included the particular atmosphere of gas lamps (used for street lighting in the Second Empire), an atmosphere laden with hydrogen sulphide (H2S) recognized the very good resistance of aluminium in contact with water. The Aluminum is one of the most resistive materials against the corrosion. When oxygen is present (in the air, soil, or water), aluminum instantly reacts to form aluminum oxide. This aluminum oxide layer is chemically bound to the surface, and it seals the core aluminum from any further reaction.

This very good resistance to corrosion, as much as lightness, explains the development of numerous aluminium applications and offers users a number of major advantages [8]

- Equipment and components can have a very long service life.
- Maintenance is minimal, even when no extra protection (painting, anodising) is provided
- Appearance is preserved longer, because of the very good resistance to corrosion.

Aluminium surface treatments can serve several purposes [8],

- protecting certain alloys if their natural corrosion resistance is deemed insufficient, often the case with copper-containing alloys of the 2000 and 7000 series,
- preserving the surface aspect, in order to avoid pitting corrosion or blackening,
- Modifying certain surface properties such as superficial hardness,

- Decorating the metal.

Zinc coated to base material: Approximately half of the world's production of zinc is used to protect steel from rust. Zinc coatings are probably the most important type of metallic coating for corrosion protection of steel.
Depending on the nature of the environment, zinc has the ability to form a protective layer made up of basic carbonates, oxides, or hydrated sulfates. Once the protective layers have formed, corrosion proceeds at a greatly reduced rate.
The best corrosion protection for steel is obtained with zinc. Zinc coatings on steel protect against corrosion in two ways [9]:

- By a barrier effect, i.e. they prevent oxygen and moisture from reaching the steel surface.
- By giving cathodic protection at scratches, chips, edges etc. Zinc is a metal with a relatively low galvanic potential and a small tendency to corrode. However, the corrosion rate is low in most environments, since the surface of the coating is quickly covered with corrosion products, which subsequently protect against further corrosion.

Property	Paints	Zinc Spraying
Ease of application	High	Medium
Thickness Control	Medium	High
Appearance	Low	Good
Adhesion	High	Very high
Corrosion Resistance	Low	High
Abrasion Resistance	Low	High

Table 1 Comparison of property for paint and Zinc thermal spray [10]

Zinc-Aluminium alloy Coated to base material: Uniform corrosion rates of zinc are not appreciably affected by the purity of the zinc. However, the addition of some alloying elements can increase the corrosion resistance of zinc.
Zinc allows an easy metallization and has a better adhesion to the steel substrate. The aluminium coatings have good mechanical properties and good resistance to abrasion in corrosive environment. Zinc is a strong electronegative metal in contact with the carbon steel, which has a potentially more electropositive, and it can provide protection against corrosion by cathodic protection effect. When these two metals add in different proposition resultant alloy will be more corrosive resistive than any individual.

Testing of Coated material: testing of all the parts Bare EN9/070M55 steel, Zinc, Aluminium and Zinc-Aluminium (85%-15%) Coated parts are done by Salt spray testing methods. In this experiment testing is done with ASTM B117 standard.

The ASTM B117 Salt Spray (Fog) Test is often used to evaluate the relative corrosion resistance of coated and uncoated materials exposed to a salt spray or fog at an elevated temperature. Test specimens are placed in an enclosed salt spray cabinet or chamber and subjected to a continuous indirect spray of a neutral (pH 6.5-7.2) salt water solution. This climate is maintained throughout the duration of the test.

Result:

From the above salt spray testing with all the four objects following result found.

1. EN9/070M55 steel: Test exposure time for bare bar is 72 hours. And during testing after 24 hours time duration small red rust, pitting found on the components and Pitting is increasing continuously. After completion of 72 hours there is heavy red rust found on the components as shown below image.

Figure 2 EN9/070M55 steel components after 72 hours

2. Aluminium Coated Component: Test Exposure time for Aluminium coated steel bar with 368.8µm thickness of coating is 72 hours. After completion of 24 hours no red or white rust found. After completion of 72 hours of test there is minor pitting of white rust found on the component as shown in below image.

Figure 3 Aluminium coated components after 72 hours.

3. Zinc Coated Component: Test Exposure time for Zinc coated steel bar with 356.5µm thickness of coating is 72 hours. After completion of 24 hours no red or white rust found but white rust shown on the components.. After completion of 72 hours of test there is heavy white rust found on the component as shown in below image.

Figure 4 Zinc coated components after 72 hours.

4. Zinc-Aluminium (85%-15%) alloy Coated Component: Test Exposure time for Zinc-Aluminium coated steel bar

with 352.5µm thickness of coating is 72 hours. After completion of 24 hours no rust found. After completion of 72 hours of test component is in same condition as before test as shown in below image.

Figure 5 Zn-Al coated Components after 72 hours.

Conclusion

There are many methods of coating are available for different metal components and machining as well as structural parts to reduce environmental effect like Corrosion, erosion, wear. Continuous research is going on coating methodology to improve life of components with cost effective methods.
Thermal spray coating is one of the less costly coating methods which improve considerable life of components by reducing corrosion effect.

In above investigation four steel components out of three are coated with Al, Zn, and Al-Zn alloy and one is bare component tested for corrosion. It is found that Al-Zn alloy has better corrosive resistance than other. Al and Zn coating are less resistive to corrosion. But all the three coating have higher resistance to corrosion compared to bare material.

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