Investigation of Mechanical Behavior of Al2O3 Coating on AISI - 316 Steel

S. Jeevabharathi

Abstract--- *In this work the micro structural description and mechanical properties of alumina coated AISI 316 austenitic steel were examined. The microstructure of both coated and un coated specimens of AISI 316 austenitic steel are captured and studied. The corrosion resistance of the materiel is found out using salt spray test and the hardness of the specimen has been found by using Rockwell hardness principle and equipment.* *Alumina has an excellent ability to hinder the inward diffusion of oxygen and especially above 1000 degrees centigrade. Alumina is the most effective oxide against environmental attacks. When high temperature metallic coating is exposed to an oxygen containing environment, a protective oxide scale is expected to form on the surface of the coating to slow down or even avoid the depletion of alloying elements by hindering the diffusion of metal ions and oxygen through the oxide scale*

Keywords--- *Thermal Spray Coating, Alumina, Austenitic Steel, Corrosion, Salt Spray Test, Rockwell Hardness Test.*

I. INTRODUCTION

Coatings have historically been developed to provide protection against corrosion and erosion that is to protect the material from chemical and physical interaction with its environment. Corrosion and wear problems are still of great relevance in a wide range of industrial applications and products as they result in the degradation and eventual failure of components and systems both in the processing and manufacturing industries and in the service life of many components. Various technologies can be used to deposit the appropriate surface protection that can resist under specific conditions. They are usually distinguished by coating thickness: deposition of thin films (below 10 to 20 µm according to authors) and deposition of thick films. The latter, mostly produced at atmospheric pressure have a thickness over 30 µm, up to several millimeters and are used when the functional performance and life of component depend on the protective layer thickness. Both coating technology can also be divided into two distinct categories:”wet” and ”dry” coating methods, the crucial difference being the medium in which the deposited material is processed. The former group mainly involves electroplating, electroless plating and hot-dip galvanizing while the second includes, among others methods, vapor deposition, thermal spray techniques, brazing, or weld overlays.

Thermal spray is a surface treatment process that the subtle and dispersed metal or non-metallic coating material like wire or powder in a melt or semi-molten state, deposits on the substrate surface to form a sort of deposited layer. Thermal spray material is heated to a plastic or molten state and then accelerated. While these particles hitting the substrate surface, they are deformated due to pressure, form layered sheet, and adhere to the substrate surface. The

---

S. Jeevabharathi, Assistant Professor, Department of Mechanical Engineering, BIST, BIHER, Bharath Institute of Higher Education & Research, Selaiyur, Chennai.

Received: 19 Feb 2019 | Revised: 07 Mar 2019 | Accepted: 02 Apr 2019

plasma coating process is basically a high frequency arc, which is ignited between an anode and a tungsten cathode. The gas flowing through between the electrodes (i.e., He, H2, N2 or mixtures) is ionized such that a plasma plume several centimeters in length develops. The temperature within the plume can reach as high as 16,000° K.

The sprayed material (in powder form) is injected into the plasma plume where it is melted and propelled at high speed to the substrate surface where it rapidly cools and forms the coating.

II. Materials Used

AISI 316 austenitic steel bars of dimension 1) 20*20mm for sample coated specimens, 2) 20*5*5mm coated specimens for testing

III. Coating Process

Thermal spray is a generic term for a group of coating processes used to apply metallic or nonmetallic coatings. These 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 (in powder, wire, or rod form) to a molten or semimolten state. The resultant heated particles are accelerated and propelled toward a prepared surface by either process gases or atomization jets. Upon impact, a bond forms with the surface, with subsequent particles causing thickness buildup and forming a lamellar structure. The thin "splats" undergo very high cooling rates, typically in excess of 106 K/s for metals.

A major advantage of thermal spray processes is the extremely wide variety of materials that can be used to produce coatings. Virtually any material that melts without decomposing can be used. A second major advantage is the ability of most thermal spray processes to apply coatings to substrates without significant heat input. Thus, materials with very high melting points, such as tungsten, can be applied to finely machined, fully heat-treated parts without changing the properties of the part and without excessive thermal distortion of the part. A third advantage is the ability, in most cases, to strip off and recoat worn or damaged coatings without changing part properties or dimensions. A disadvantage is the line-of-sight nature of these deposition processes. They can only coat what the torch or gun can "see." Of course, there are also size limitations. It is impossible to coat small, deep cavities into which a torch or gun will not fit. The article "Introduction to Processing and Design" in this Handbook provides a more complete discussion of the advantages and disadvantages of thermal spray processes..

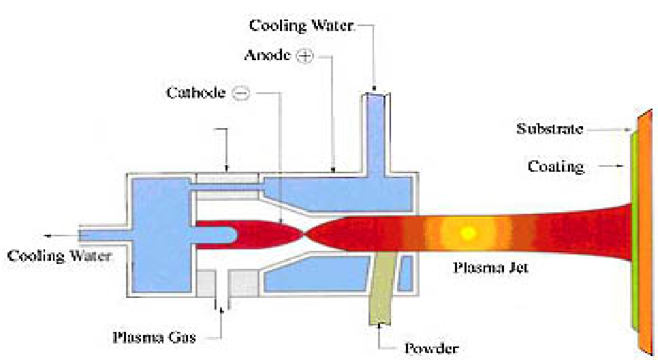

Fig 1: Plasma spray coating technique

IV. CHARACTERISTICS OF THERMAL COATING

4.1 Micro structural Characteristics

The term "thermal spray" describes a family of processes that use the thermal energy generated by chemical (combustion) or electrical (plasma or arc) methods to melt, or soften, and accelerate fine dispersions of particles or droplets to speeds in the range of 50 to >1000 m/s (165 to >3300 ft/s). The high particle temperatures and speeds achieved result in significant droplet deformation on impact at a surface, producing thin layers or lamellae, often called "splats," that conform and adhere to the substrate surface. Solidified droplets build up rapidly, particle by particle, as a continuous stream of droplets impact to form continuous rapidly solidified layers. Individual splats are generally thin (~1 to 20 µm), and each droplet cools at very high rates (>106K/s for metals) to form uniform, very fine-grained, polycrystalline coatings or deposits. Figure 2 shows a schematic of a generic thermal spray powder consolidation process, illustrating the key features and a typical deposit microstructure.

Sprayed deposits usually contain some level of porosity, typically between 0 and ~10%, some unmelted or partially melted particles, fully melted and deformed "splats," metastable phases, and oxidation from entrained air. Thermal spray process jets or plumes are characterized by large gradients of both temperature and velocity. Feedstock is usually in powdered form with a distribution of particle sizes. When these powdered materials are fed into the plume, portions of the powder distribution take preferred paths according to their inertia. As a result, some particles may be completely unmelted and can create porosity or become trapped as "unmelts" in the coating. Use of wire and rod feedstock materials produces particle size distributions because of non-uniform heating and unpredictable drag forces, which shear molten material from the parent wire or rod. The level of these coating defects varies depending on the particular thermal spray process used, the operating conditions selected, and the material being sprayed, as described later.

4.2 Flame spray process

Flame spraying includes low-velocity powder flame, rod flame, and wire flame processes and high-velocity processes such as HVOF and the detonation gun (D-Gun) process (D-Gun is a registered trademark of Praxair Surface Technologies Inc.). Flame Powder. In the flame powder process, powdered feedstock is aspirated into the oxyfuel flame, melted, and carried by the flame and air jets to the workpiece. Particle speed is relatively low (<100 m/s), and bond strength of the deposits is generally lower than the higher velocity processes. Porosity can be high and cohesive strength is also generally lower. Spray rates are usually in the 0.5 to 9 kg/h (1 to 20 lb/h) range for all but the lower melting point materials, which spray at significantly higher rates. Substrate surface temperatures can run quite high because of flame impingement. Wire Flame. In wire flame spraying, the primary function of the flame is to melt the feedstock material. A stream of air then atomizes the molten material and propels it toward the work piece. Spray rates for materials such as stainless steel are in the range of 0.5 to 9 kg/h (1 to 20 lb/h). Again, lower melting point materials such as zinc and tin alloys spray at much higher rates. Substrate temperatures often range from 95 to 205 °C (200 to 400 °F) because of the excess energy input required for flame melting. In most thermal spray processes, less than 10% of the input energy is actually used to melt the feedstock material.

Received: 19 Feb 2019 | Revised: 07 Mar 2019 | Accepted: 02 Apr 2019

International Journal of Psychosocial Rehabilitation, Vol. 23, Issue 03, 2019
ISSN: 1475-7192

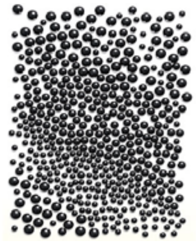

Fig 2: Steel grit used for pretreatment process

V. EXPERIMENTAL

5.1 Salt spray test

The salt spray test is a standardized and popular corrosion testmethod, used to check corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal.

5.2 Rockwell hardness

The Rockwell test consists of measuring the additional depth to which a carbide ball or Brale® diamond penetrator is forced by a heavy (major) load beyond the depth of a previously applied light (minor) load (SET point). The minor load is applied first and a SET position is established on the dial gauge or displacement sensor of the Rockwell tester. Then the major load is applied. Without moving the piece being tested, the major load is removed and, with the minor load still applied, the Rockwell hardness number is automatically indicated on the dial gauge or digital display. The Brale diamond penetrator is used for testing materials such as hardened steels and cemented carbides. The carbide ball penetrators, available with 1 /16 inch, 1 /8 inch, 1 /4 inch, and 1 /2 inch diameter, are used when testing materials such as steel-copper alloys, aluminum and plastics to name a few.

5.3 Microstructure

The concept of microstructure is perhaps more accessible to the casual observer through macro structural features in commonplace objects. If one ever comes across a piece of galvanized steel, such as the casing of a lamp post or road divider, one observes that the surface is not uniformly colored, but is covered with a patchwork of interlocking polygons of different shades of grey or silver. Each polygon (the most frequently occurring would be hexagons) is a single crystal of zinc adhering to the surface of the steel beneath.

5.4 Microstrucure

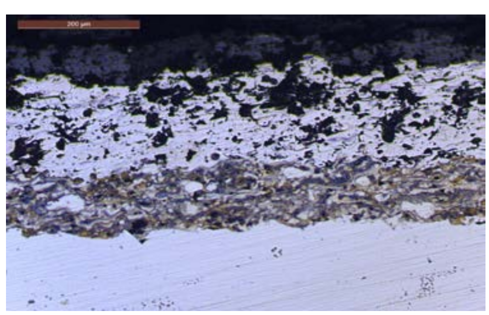

Fig 3: Microstructure of coated a AISI316 specimen mag: 200x

Received: 19 Feb 2019 | Revised: 07 Mar 2019 | Accepted: 02 Apr 2019

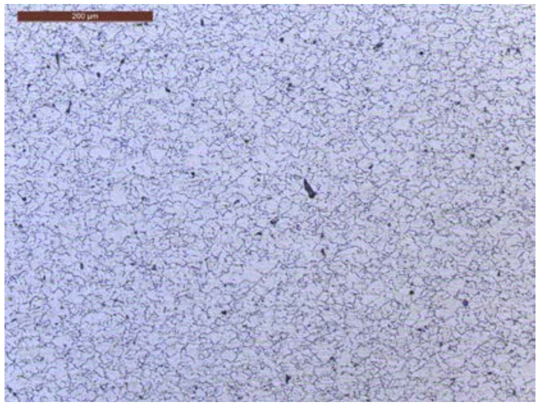

Fig 4: Micro graph of uncoated AISI 316 mag: 200x

VI. RESULTS

6.1 Salt spray test

Salt spray test parameters are given as fallows Chamber temperature is in between 34.5-35.5^{o} C And the pH value is 6.65-6.85 and the volume of the Nacl solution collected is about 1.0-1.5 ml/hr and its Concentration is 4.80-5.30% of Nacl.Air pressure maintained is 14-18 psi Components should be loaded in chamber position: 30 degree angle

6.1.1 Observation

For uncoated steel specimen:

Red rust formation noticed at 12 hours

For coated steel specimen:

No red rust formation noticed up to 12 hours

6.2 Rockwell hardness test

In this test the indenter used is 120 0 diamond cone indenter Observed values in HRC for un coated specimen: 25.8, 25.7, 25.4 and the average of these three is 25.633 Observed values in HRC for coated specimen: 27.4, 27.3, 28.8 the average of this test is 27.833

VII. CONCLUSION

In this project the alumina coating is done on AISI austenitic steel and their corrosion resitance and hardness is measured and is found that the uncoated specimen properties are lower than the coated specimen in quality and its microstructure is studied.

REFERENCES

[1] Evaluation of arc sprayed coatings for erosion protection of tubes in atmospheric fluidised bed combustion (AFBC) boiler was presented by Krishnarao Venugopal, Manish Agrawal.

[2] Hot Corrosion & Erosion Problems in Coal Based Power Plants in India and Possible Solutions-A Review were presented by Vikas Chawlaa, Amita Chawlab, D. Puric, S. Prakashc, Prema G. Gurbuxanid and Buta Singh Sidhue

[3] Particle characterization for angularity and the effects of particle size and angularity on erosion in a fluidized bed environment was presented by S.L. Palasamudram a, S. Bahadur b

[4] Erosion-Corrosion behavior of Ni-based super alloy Superni-75 in the real service environment of the boiler was presented by T S Sidhu1, S Prakash2, R D Agrawal2 and Ramesh Bhagat.

[5] High Temperature Degradation by Erosion-Corrosion in Bubbling Fluidized Bed Combustors was published by Peggy Houa, Stuart Macadam, Yan Niuc, John Stringerd.

[6] Corrosion fatigue cracking of tube coils in an actifier column catalytic cracker was published by Xuan Shia, Yaowu Shib.

[7] Numerical modeling of brown coal combustion in a tangentially-fired furnace. Zhao feng tian, peter j. Witt, m. Phillip schwarz and William yang.

[1] MANETs. *Bonfring International Journal of Industrial Engineering and Management Science, 7*(1), 29-31.

[8] Morad, M.J.A., Talebiyan, S.R., & Pakniyat, E. (2015). Design of New Full Swing Low-Power and High-Performance Full Adder for Low-Voltage Designs. *International Academic Journal of Science and Engineering, 2*(4), 29-38.

[9] Fouladgar, N., & Lotfi, S. (2015). A Brief Review of Solving Dynamic Optimization Problems. *International Academic Journal of Science and Engineering, 2*(6), 26-33.

[10] Grace, M.C., Shanmathi, S., & Prema, S. (2016). Design ofRFID based Mobile Robotand its Implementationin Pharmacy Dispensing System. *International Journal of System Design and Information Processing, 3*(1), 6-12.

[2] Karuppasamy, S., Dr.Singaravel, G., & Kaveen, P. (2018). Scrum Investigation Analysis for Android Application. *Bonfring International Journal of Networking Technologies and Applications, 5*(1), 12-16.

[11] Cowl, D., and Sim, S. (2017). A Complete Introduction to the Swarm Robots and its Applications. *Bonfring International Journal of Power Systems and Integrated Circuits, 7*(2), 6-12.

[12] Dr.Prabakaran, S. (2018). Farmers Resource Make Use of Technical Efficiency - Organic and Modern Agriculture. *Journal of Computational Information Systems, 14*(5), 85 - 91.

[13] Dr.Murugamani, C., & Dr.Berin Jones, C. (2018). A Novel Approach to Secure and Encrypt Data Deduplication in Big Data. *Journal of Computational Information Systems, 14*(5), 92 - 99.

[14] RavindraBabu, B. (2018). Resource Provision for Software as a Service (SaaS) inCloud Computing Platform.. *Journal of Computational Information Systems, 14*(5), 100 - 111.

[15] Sowmyadevi, D. (2018). Secured and Freshness Ensured Provenance Sharing Scheme for the Heterogeneous Wireless Sensor Network. *Journal of Computational Information Systems, 14*(6), 1 - 17.