CORROSION BEHAVIOR OF PARTIALLY STABILIZED ZIRCONIA COATED STEELS

Anderson A^1 , Ramachandran S^2

¹Research scholar, Sathyabama University ²Department of Mechanical Engineering, Sathyabama University, anderson_chrisson@hotmail.com

Abstract

Ceramic coatings are applied on various engineering hardware components to provide protection against wear, corrosion and high heat fluxes. Metal hardware operating in harsh environments could fail prematurely due to wear, corrosion and high temperature exposure. A protective layer of coating is typically applied to provide a barrier which prolongs component durability and the desired properties of the hardware components. A salt spray corrosion technique has been used to study the corrosion of coated mild steel plates by sea salt particles. It has been shown that sea salt particles can cause severe corrosive damage to these materials and that the predominant mode of material loss is by removal of oxide scale. This behavior can account for the reported increase in corrosion of yttria stabilized zirconia coated mild steel.

I. INTRODUCTION

Corrosion is costly and even dangerous when it affects working and structural parts therefore corrosion protection is an essential factor in production sectors and our industrial economy. Ceramics is one of the materials most widely used in anticorrosion coatings for the shield of iron and steel products against rust worsening.

II. PLASMA SPRAY COATINGS

Among the different coating systems, the thermal barrier coatings (TBCs) are commonly used to protect hardware operating in high temperature environments, such as combustor liners and gas turbine blades, from excessively high heat fluxes and temperatures. Among the different ceramic coating systems, yttria stabilized zirconia is widely used as thermal barrier coatings. They are conventionally applied by introducing a powder of the coating material into a plasma jet in which powder particles are melted and accelerated towards the surface to be coated.

Plasma spraying is relatively straight forward in concept but rather complex in function. The gun operates on direct current, which sustains a stable non-transferred electric arc between a thoriated tungsten cathode and a annular water-cooled copper anode. A plasma gas generally, argon, complemented by a few percent of an enthalpy enhancing gas, such as hydrogen is introduced at the back of the gun interior, the gas swirling in a vortex and out of the front exit of the anode nozzle. The electric arc from the cathode to the anode completes the circuit, generally

on the outer face of the latter, forming an exiting plasma flame which axially rotates due to the vortex momentum of the plasma gas. The temperature of the plasma just outside of the nozzle exit is effectively in excess of 15,000 K for a typical dc torch operating at 40 kW. The plasma temperature drops off rapidly from the exit of the anode, and therefore the powder to be processed is introduced at this hottest part of the flame. The powder particles, approximately 50 micrometers in diameter, are accelerated and melted in the flame on their high speed 100-300 M/sec path to the substrate, where they impact and undergo rapid solidification (106 K/sec). Plasma spray is used to form deposits of 250 μ m of yitria stabilized zirconia (8% Y₂O₃ + 92%) Zr_2O_3) and ceria stabilized Zirconia (8% Y_2O_3 + 67%) $Zr_2O_3 + 25\%$ CeO₂). The coating parameters in this project are explained as follows. The technical specification of plasma spray gun is 3MB gun for a typical dc torch operating at 40 kW with Metco MN





Anderson et al: Corrosion Behavior of Partially ...

plasma spray system and GH Nozzle with arc current of 500 Amps and Arc voltage 70 Volts. The primary gas is argon with flow rate 80 - 90 lpm and the secondary gas is hydrogen with 15 - 18 lpm keeping the spray distance as 80 mm.

The substrate used is AISI 1020 steel having dimension of 150 mm \times 30 mm \times 8mm thick.

III. EXPERIMENTAL PROCEDURE

Two coated specimens of size 150 mm \times 30 mm \times 8 mm thick is kept in salt spray chamber as per ASTM B117. This practice does not prescribe the type of test specimen or exposure periods to be used for a specific product, nor the interpretation to be given to the results. Prediction of performance in natural environments has seldom been correlated with salt spray results when used as stand-alone data. It should be noted there is usually not a direct relation between salt spray resistance to corrosion in other method. The reproducibility of results in the salt spray exposure is highly dependent on the type of specimens tested. Unless otherwise specified the specimen shall be supported or suspended between 15° and 30° from the vertical.

In summary, the procedure is

Wooden racks are contained in the salt fog chamber (3' high, 3' deep, 5' wide). Place samples on a the wooden rack at a small tilt angle. 5% NaCl in tap water pumped from a reservoir to spray nozzles. Solution mixed with humidified compressed air at nozzles. Compressed air atomizes NaCl solution into a fog at the nozzles. Test duration is till the sample starts to form red dust. Within the chamber, the samples are rotated frequently so that all samples are exposed as uniformly as possible to the salt spray mist.



Fig. 2 Salt Spray Chamber

IV. RESULTS

4.1 Localised corrosion behavior

In the neutral salt spray fog the type of corrosion attack was predominantly pitting. The red dust shows the starting of corrosion. The coated specimen was kept for 216 hours. After coating, the specimens were examined visually for appearance and tested in neutral salt spray for corrosion resistance The table 1 determines the weight loss of the specimen coated by yitria stabilized zirconia (8% $Y_2O_3 + 92\% Zr_2O_3$) exposed to the salt spray tests is shown for various exposure time periods. The onset of red rust on a sample started at 85 hours. Initially the weight of the specimen was 295.81 gms. It is clearly identified that the weight loss is very less.

The weight loss is negligible in the neutral salt spray test.

Table 1. The weight of the specimen coated by yitria stabilized zirconia in salt spray chamber.

Initial	100	150	200	216
weight	hours	hours	hours	hours
(Gms)	(Gms)	(Gms)	(Gms)	(Gms)
295.81	295.75	295.55	294.91	294.74

The table 2 determines the weight loss of the specimen coated by ceria stabilized Zirconia (8% Y_2O_3 + 67% Zr_2O_3 + 25% CeO_2) exposed to the salt spray tests is shown for various exposure time periods. The onset of red rust on a sample started at 96 hours. Initially the weight of the specimen was 288.82 gms. It is clearly identified that the weight loss is vey less. The weight loss is negligible in the neutral salt spray test.

Table 2. The weight of the specimen coated by ceria stabilized Zirconia in salt spray chamber.

Initial	100	150	200	216
weight	hours	hours	hours	hours
(Gms)	(Gms)	(Gms)	(Gms)	(Gms)
288.82	288.75	288.55	288.15	287.90



Fig. 3. Weight loss of coated samples

The surface views of the various specimens are given below



Fig. 4. yitria stabilized zirconia 8% Y_2O_3 + 92% $$Zr_2O_3$$



Fig. 5. yitria stabilized zirconia 8% Y_2O_3 + 92% $$Zr_2O_3$$

Fig. 6. aprile stabilized Zirappia (00/ McOs + 670/

Fig. 6. ceria stabilized Zirconia (8% Y_2O_3 + 67% Zr₂O₃ + 25% CeO₂)



Fig. 7. ceria stabilized Zirconia (8% Y_2O_3 + 67% Zr₂O₃ + 25% CeO₂)

Figure 4, 5 represents the yitria stabilized zirconia 8% Y_2O_3 + 92% Zr_2O_3 coated sample before and after the test. Figure 6, 7 represents the ceria stabilized

Zirconia (8% Y_2O_3 + 67% Zr_2O_3 + 25% CeO_2) coated sample before and after the test.

CONCLUSION

Salt spray tests were conducted for ceria stabilized Zirconia coated sample and yitria stabilized zirconia 8% $Y_2O_3 + 92\%$ Zr_2O_3 coated sample. The experimental results revealed that the ceria stabilized Zirconia (8% $Y_2O_3 + 67\%$ $Zr_2O_3 + 25\%$ CeO₂) coated sample has much corrosion resistance than yitria stabilized zirconia 8% $Y_2O_3 + 92\%$ Zr_2O_3 coated sample.

REFERENCES

- [1] Lifka B.W., Sprowls D.O.; Corrosion 22 (1966) 1-7.
- [2] ASTM American Society for Testing of Materials. ASTM B 117-07a Standard Practice for Operating Salt Spray (Fog) Apparatus, 2007.
- [3] Deutsches Institut für Normung e.V. DIN 50021 Sprühnebelprüfungen mit verschiedenen Natriumchloridlösungen. Beuth Verlag GmbH, 1988. This standard has been superseded by ISO 9227 and it is only mentioned for bibliographic purposes.
- [4] ISO International Organization for Standardization. ISO 9227 Corrosion tests in artificial atmospheres — Salt spray tests, 2006.
- [5] ISO International Organization for Standardization. ISO 4628-3 Paints and varnishes. Evaluation of degradation of coatings. Designation of quantity and size of defects, and of intensity of uniform changes in appearance. Part 3 Assessment of degree of rusting.
- [6] Peters M., Bachmann V., Welpmann K., Bellingradt H., Braun R.: DFVLR FB 86-40, Koln, 1986.
- [7] Lane P.L., Gray J.A., Smith C.J.E.; Proceedings of the 3rd. Int. Conference on Al-Li Alloys, Oxford, The Institute of Metals, London, 1986, p.273.
- [8] Peters M., Eschweiler J., Welpmann K.; Scripta Metallurgica 20 (1986) 259.
- [9] Niskanen P., Sanders T.H., Marek M., Rinker J.G.; in Aluminium-Lithium Alloys; T.H. Sanders, Jr. and E.A. Starke, Jr.; TMS-AIME, Warrendale, 1981, p.347.
- [10] Speidel M.O.; Metallurgical Transactions A. 6A (1975) 631.
- [11] Sotoudeh K., Nguyen T.H., Foley R.T., Brown B.F.; Corrosion 37 (1981) 358.
- [12] Holroyd N.J.H., Gray A., Scamans G.M., Hermann R.; Proceedings of the 3rd. Int. Conference on Al-Li Alloys, Oxford, The Institute of Metals, London, 1986, p.310.
- [13] Foley R.T., Trzaskoma P.P.; Corrosion 33 (1977) 435.