Journal of Green Engineering (JGE)

Volume-10, Issue-3, March 2020

Environmental Protection of SS 304 from Corrosion Using Ceria Zirconium

[1]P.Praveen Raj and [2]M.Kanthashoba

[1,2]Assistant Professor,Department of Mechanical Engineering,ThanthaiPeriyar Government Institute of Technology, Bagayam, Vellore, Tamilnadu, India.
E-mail:[1]ppraj.tn@gmail.com,[2]kanthashoba79@gmail.com

Abstract

Degradation of materials in marine, industrial, aircraft as well as land base gas turbines is because of high-temperature oxidation. In India, serious problems based on coal-based power generation plants are known as hot corrosion as well as erosion. Hot corrosion, as well as erosion in boilers along with relevant elements, is liable for massive losses, each direct and indirect, in power generation. Information on these issues along with, therefore to build up appropriate protective methods is necessary for the maximum use of such mechanism. These issues could be avoided through either altering the environment or changing the material or through separating the element surface from the environment. In surface engineering, Corrosion prevention through utilization of coatings for sorting out objects from the environment is achieving significance. The plasma spray coatings of yttrium stabilized a zirconium coating which offers high-quality resistance to the high speed steels, stainless steels, as well as other materials to with stand best corrosion with wear properties. Additional, the ceria is added to the zirconium outcomes among superior corrosion resistance. The corrosion resistance property of samples consists of 20% 25% 30% of ceria has been determined using a salt spray test and found that percentage increase in ceria resulted in the increased corrosive resistance.

Keywords: Ceria, Plasma spray coating, Zirconium, corrosion resistance,Enviromental Protection

Journal of Green Engineering, Vol. 10_3, 897–911.

Alpha Publishers

1 Introduction

Plasma sprayed ceramic coatings are widely utilized for thermal barrier, corrosion resistance, wear, and chemical barrier applications. The choice of the specific ceramic material is determined through its chemical stability, thermal stability in the operating environment.

Portinha et al [1] studied the Thermal Barrier Coatings (TBC) which is a new theory that includes a standard NiCoCrALY bond coat as well as an atmospheric plasma spray ZrO-8 wt%Y0, topcoat. The micro-hardness was calculated with a Vickers indenter along with 0.981 N loads. They studied the description of thermal barrier coatings through incline in porosity. Image analysis was used to measure the absolute porosity. The image analysis method was moreover utilized to estimate the porosity variant alongside the cross-section. Moskal et al [2] studied Atmospheric Plasma Spray (APS) method to achieve the porosity evaluation of thermal barrier coatings. A process of porosity assessment, utilize automatic image analysis, as well as quantitative metallographic ethics, have been preferred, collectively with kinds of quantitative parameters as well as approaches of their application. It was established that the application of the quantitative metallographic strategies collective among automatic image evaluation could make an effective instrument of both quantitative as well as qualitative assessment with such parameters of structural ceramic layers as porosity.

VikasChawla [3] studied the hot corrosion and erosion issues in coal-based power plants in India along with potential solutions. Hot corrosion, as well as erosion, is known as serious issues in coal-based power generation plants in India. In power generation, hot corrosion, as well as erosion in boilers along with its related components, is liable for vast losses, both direct as well as indirect. These problems could be prohibited by either altering the environment or varying the material. In surface engineering, significance are being gained by corrosion prevention with the utilization of coatings for sorting out materials from the environment.

Scrivani et al [4] studied the Porous Thermal Barrier Coatings Systems as well as Thermal Fatigue Behavior of Thick. Furnace cycle test was performed by utilizing test tools together with an isothermal fixed air furnace (kind: three- zone split tube. Tmax: 1300°C), an illustration tray in Hastelloy X located on a vertical elevator , with a round tube for enforced cooling of samples while the elevator is decreased.

Menghani J et al [5] studied and Wear Behavior of ZIN Thin Films. ZrN coatings of varying thickness were deposited on 316 stainless substrates through cathode are Evaporation, in a reactive nitrogen surroundings. The wear behavior was tested by a pin on disc method. The result indicated that the wear features of the films were relay on the thicknesses of lamellae in the

film structure. Wear resistance was not just dependent on thickness but additionally at the deposition parameters such as high porosity within coating as well as internal stresses.

Almond [6] utilizes pin-on-disc equipment for experimenting ceramics as well as cemented carbides on alumina discs utilizing the pin because of the exploration material. In a two-body abrasion experiment, a coated pin was pressed towards a rotating abrasive document creating a spiral direction to avert overlapping. This experiment procedure is very normal for lean coatings.

Ramesh et al [7] studied the corrosionbehavior of A16061-frit particulate metal template complex in sodium chloride solution Corrosion tests had been conducted by utilizing potentiostatic model SEP238C wherein 3.5% NaCl formula was utilized as corrodent. Ascorrosion happens, in the corroding solution electrons are released through metal (oxidation) as well as gained through elements (reduction). Since here is a flow of electrons (current) inside the corrosion response, it could be calculated as well as controlled electronically. The tests have been performed in 3.5% solution of sodium chloride (NaCl). The specimens were rigid to the working electrode as well as corrosion experiments were conducted.

Saremi Mohsen et al [8] studied the bond coat oxidation as well as hot corrosion actions of plasma-sprayed of YSZ coating on superalloy . The two major detrimental aspects of Thermal Barrier Coatings are Oxidation and hot corrosion . Spallation became observed on the bond coat/YSZ interface after 100 h oxidation . XRD, as well as SEM studies after hot corrosion, shows the development of monoclinic ZrO_2, crystals as hot corrosion products that origin the degradation of YSZ coating. Dinesh Gond [9] Yttria-Stabilized Zirconia (YSZ) coatings have been deposited on a T-22 boiler steel . NiCrAIY was utilized as a bond coat along with YSZ as topcoat. Hot corrosion research has been performed on uncoated and plasma spray-coated sample in air and salt (75 wt. % Na_2SO_4 + 25 wt. % NaCl) at 900°C underneath cyclic conditions. This YSZ overlay coatings improve resistance to corrosion considerably that could be accredited to the creation of zirconium oxides (ZrO_2) and yttrium oxide ($Y2O_3$).

Kristina Brinkiene et al [10] studied the hardness properties of plasma sprayed coatings. The homogeneous microstructure was relevant to higher microhardness and better tribological properties of sprayed ceramics. The microhardness measurements data resulted that coatings formed from zirconia based ceramics were characterized by higher microhardness values.

Kennedy [11] studied the techniques of wear trying out for superior surface coatings as well as bulk materials. Test equipment for erosion, sliding wear, effect as well as dynamic wear tests was mentioned, the procedure for

calculating wear rates have been highlighted along with an easy process for manner wear test to replicate industrial wear issues was specified. The wear conditions, as well as the wear test selected, came across in real applications must match for experts to create an adequate judgment on the life of a specific issue in service.

Zhang [12] studied the ceria as well as yttria-stabilized zirconia (CYSZ) coating customized through Al deposition along with selective laser remelting to improve hot corrosion resistance. It was found that the minimum surface roughness, as well as solid dotted units, enhanced the hot corrosion resistance of the scattered coating. The thick α-Al_2O_3 cover becomes chemical inertness efficiently reserved the penetration of dissolved salts that caused the best DA coating of the hot corrosion resistance . Lashmi [13] studied, bilayered 8 wt% yttria-stabilized gadolinium zirconate (GZO)/zirconia (YSZ) TBC structure created by atmospheric plasma spraying (APS) procedure from powders ready through a single step co-precipitation method. It was found that YSZ/GZO bilayer TBC exposed a superior thermal cyclic life (300 cycles) than the solitary layer 8YSZ (175 cycles) coatings at 1100 °C . Mohamad [14] evaluated hot corrosion actions of sprayed as well as laser glazed $Al2O_3$+YSZ blend coatings within the existence of 55% V2O5 + 45% Na_2SO_4 dissolve salt become control. In the laser glazing process, Coating of Laser glazed YSZ + Al_2O_3 demonstrates dual enhancement of hot corrosion resistance. Decrease of the reaction among dissolve salt as well as zirconia stabilizer resulted in surface roughness reduce as well as a particular reactive surface received through laser glazing procedure.

Reza [15] investigated the nanostructured Scandia-Ceria stable Zirconia (SCSZ) manufactured by a sol-gel route as well as the belongings of various contents of Scandia stabilizer (3.6–8 mol. %) on fraction balance and thermal shock resistance . The consequences of thermal shock resistance demonstrate a capable cyclic lifetime. Thakare [16] experimented with the hot corrosion opposition of air plasma-sprayed 8YSZ-Al_2O_3-multiwall carbon nanotubes (MWCNTs), analyzed as well as estimate them with of 8YSZ coating. The Weibull evaluation of the Young's modulus of the bond coat proves that the kind IV coating displayed the maximum heterogeneousness in Young's modulus . Lastly, the adding of MWCNT changed into observed to be harmful in the cyclic hot corrosion experiment because it directs the coatings into the cracking.

A Ni-based super- alloy is used as the turbine blade materials. Most of the investigators have studied the testing of Aluminum oxide coatings. There is very limited published literature on the low percentage addition of cerium oxide mixed zirconia powder coatings. The Zirconia Ceria powder coatings were used in high-temperature applications. For high-temperature applications, super alloy has been developed, however, superalloys are

unable to fulfill the necessities of corrosion resistance, high-temperature strength as well as high-temperature erosion concurrently. Gas turbine Coatings serve a variety of purposes, whether in jet engines, land-based power or marine engines generation turbines. Improved strength is an initial necessity to work turbines at extreme temperatures. Regrettably, these circumstances also indicate severe oxidation/corrosion problems. Plasma spray coating is widely used since thick coatings could be applied at high deposition rates and due to its excellent surface finish and high adhesion to the substrate. Among the various coating powders, Yttria Stabilized Zirconia was used widely but only a few studies on Zirconia Ceria powder were reported.

2 Materials and Methods

The purpose of this investigation is to estimate plasma sprayed coatings by various tribological tests. The experimental work has been planned in the following sequence:

(i) Selection of base metal which can withstand high temperature and resists corrosion.
(ii) Preparation of base metal samples for coating conforming to ASTM standards
(iii) Coating the base metal samples by the plasma spray process
(iv) Conducting corrosion test

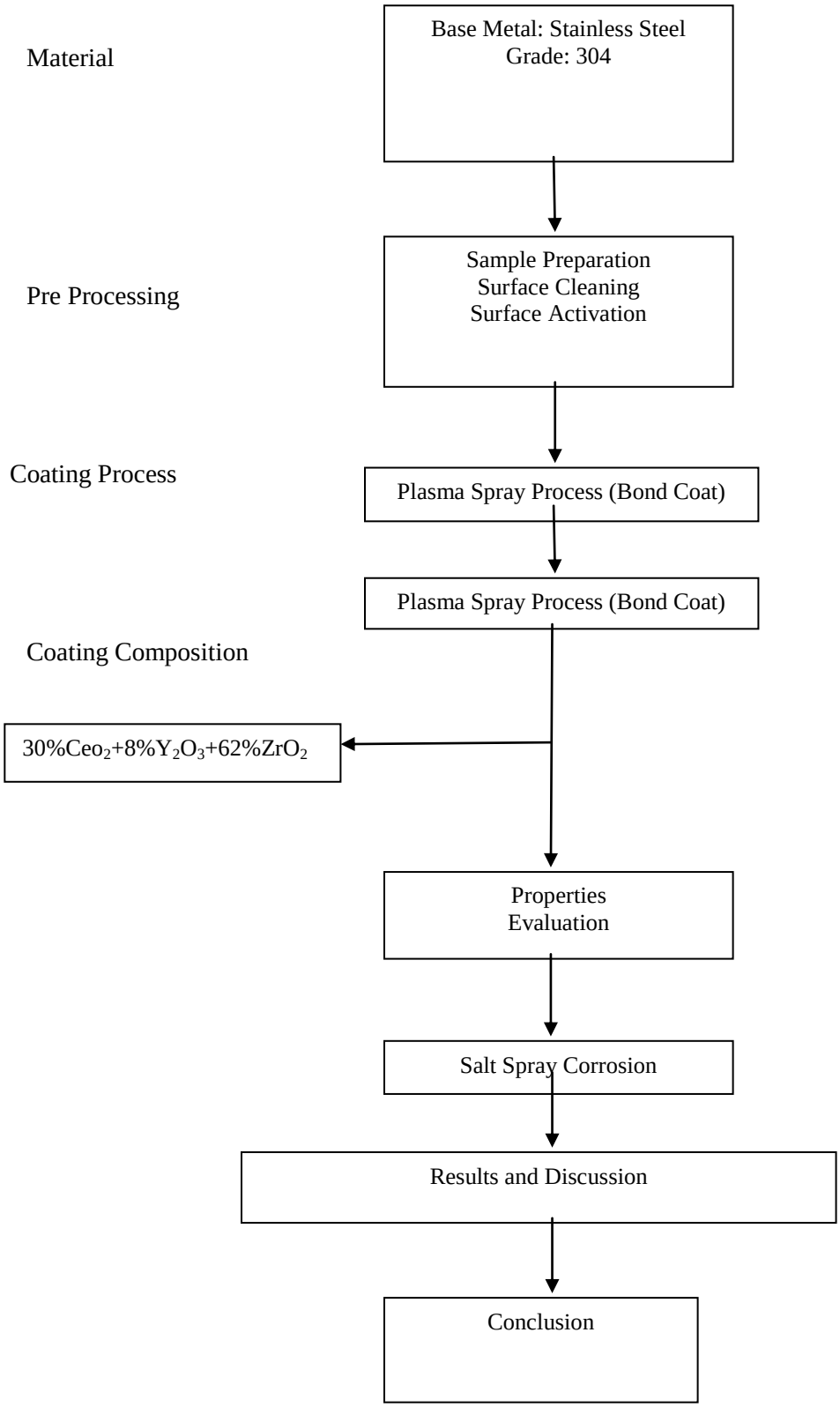


Figure 1 Flowchart of Methodology

The scheme of research followed in the present investigation are illustrated in the flowchart as shown in Figure 1.

2.1 Selection of Base Metal

At high temperatures, Superalloys are metallic substances for service mainly in zones (turbine blades) of gas turbines. Such materials permit the turbine to function more proficiently through withstanding higher temperatures. These high-pressure turbine blades are made up of Nickel and Chromium. Since Stainless steel contains Nickel and Chromium and also it is commercially available, the base metal is taken as stainless steel. Stainless Steel 304 grade is taken as base metal, because it withstands high temperature and resists corrosion. Stainless steel 304 grades are economical. Table 1 shows the composition of base metal used.

Table 1 Chemical Composition (Weight percentage %) Of the Base Metal

Cr	Ni	Mn	C	S	Si	P
20	10.50	2.00	0.08	0.030	1.00	0.045

2.2 Specimen Preparation and Powder Preparation

Stainless steel is utilized as a sample material. Dissimilar specimens of changeable dimension wear taken for evaluation. The specimen among size is demonstrated in Figure 2. By coating, the metal substrate must be handled. The substrate becomes typically enclosed with grease which guards the surface from corrosion. In the cleaning process, the grease is removed. Cleaned items are shaped to get preferred sizes to evade sharp angles which are hard to be coated. The residual area excluding the coated area has been covered with mask throughout spraying. The final, instantly proceeding to the authentication procedure, the surface needs to be activated. Lacking activation, the coating could not stay to the substrate covering. Activation through abrasive grit blasting, is roughening, that is the most often functional procedure these days. Blasting, that is roughening is the most regularly applied method these days.

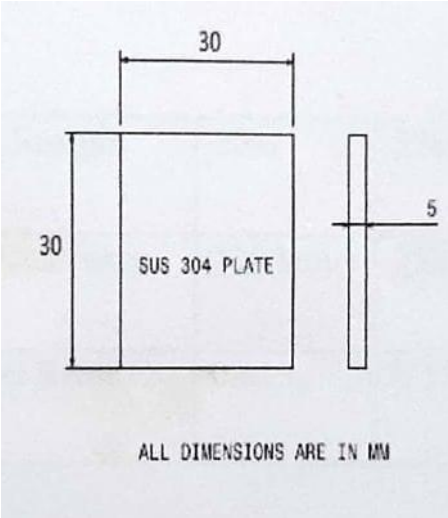


Figure 2 Sample size dimension fabricated for salt spray test

2.3 Surface Cleaning

Degreasing of recent metal substrates was completed through the utilization of natural solvent acetone. The procedure was carried through in a room which is clean along with the leftover liquid was cautiously reused. Each care becomes taken to guard the worker from dangerous exposure.

2.4 Substrate Shaping

The substrates must to be formed to satisfy the dimensional condition. Small amounts of material have to be detached within the locations wherein the covering is usually to be deposited. Shaping is additionally essential to keep away from sharp ends or sharp angles in which it is complex to spray a coating or, on alternatively, wherein adherence to the substrate is reduced. The adherence turns into lesser as of the higher awareness of thermal stresses in the coatings sprayed in these kinds of places. Wire cutting method utilized for Substrate shaping.

2.5 Surface Activation

Surface roughness is the constraint that is strongly connected to grit blasting and, however, strongly impacts the adhesion of the coating to the substrate. Roughness is increased in outcomes in an enhancement in the adhesion.

In this research, Abrasive grit blasting was utilized to stimulate metal substrates. The procedure constraints for abrasive grit blasting are

specified in Table 2. In this procedure, s.grit is sucked in the nozzle. Elevated in a compressed air stream as well as sprayed upon the substrate covering Alumina with940 -1905 microns size of grit become utilized as common powder. Sand grit among size 63- 203 microns become utilized as a fine powder. The blasting period for roughening the sample surface was 45 minutes.

Table 2 Process parameters for abrasive grit blasting

Parameters	Values
Grit size (Alumina)	940-1905 microns
Grit size(sand)	63-203 microns
Operating pressure	8 bar
Blasting time	45 min
Nozzle diameter	2.38mm

2.6 Powder Preparation

Over coal is supplied above the bond coat through an appropriate mixture of powdered substances. The powder substances which have been chosen are yttria-stabilized zirconium, cerium oxide. Blending of powder with a few mixtures chosen as per the assets we required to progress within the coating. Consequently, from the examining of preceding mechanism researchers got to understand 25% of ceriumin the covering offers progressed corrosive property . I desire to manufacture the covering by 30% of cerium in the grouping. Consequently, integration must be completed according to the necessity of grouping of mixture. Through utilizing the chemical stability exposed of 100g, we had to insert the materials 62% zirconium oxide, 8%yttrium oxide, as well as30% cerium oxide to create a contribution all collectively to make 100g.

2.7 Pre-Treatment Process

In thermal-barrier coatings, a bond coating of NiCoCrALY was utilized. The bond coating becomes a sprayed through the plasma spray procedure. An enhancement in oxide coating adhesion could be accomplished through the request of bond coatings. The bond coat is known as the initial layer of the coating. It allows the covering to bond more the substrate as well as, thus plays a crucial part in developing a thermal barrier.

2.8 Plasma Spray Coating

Between the distant coating methods, the plasma spray method is usually utilized to defend the hardware working in excessive temperature environments, like gas turbine blades as well as combustor liners from extreme high heat fluxes and temperatures. Metal in powder form is utilized in Plasma spraying. The coating resources within the kind of a powder is passed in the plasma jet in that powder particles are melted as well as speed up to the surface to be coated. The powder contaminants, about 50 micrometers in distance, are increased as well as melted within the flame on their excessive speed 200 m/sec trail to the substrate, where they effect as well as experience quick solidification. Table 3 shows the plasma spray's technical specification.

Table 3 Plasma spray operating parameters

Operating Parameters	
Plasma Gun	3MB Gun, 40 Kw
Inert gases	Argon, Hydrogen
Flow rate	Argon, -80-90 LPM
	Hydrogen: - 15 to 18 LPM

The plasma spray's scientific requirement is a gun with 3MB gun for an ordinary dc torch working at 40 kW through Metco MN plasma spray structure as well as GH Nozzle through arc current of 500 Amps along with 70 Volts of Arc voltage. Argon was utilized as the main gas at a flow speed of 80 - 90 LPM , as well as hydrogen, is utilized as the minor gas at a flow speed of 15 - 18 LPM. The space among the substrate as well as the nozzle became reserved as 80 mm. Figure 3 demonstrates the plasma spray process.

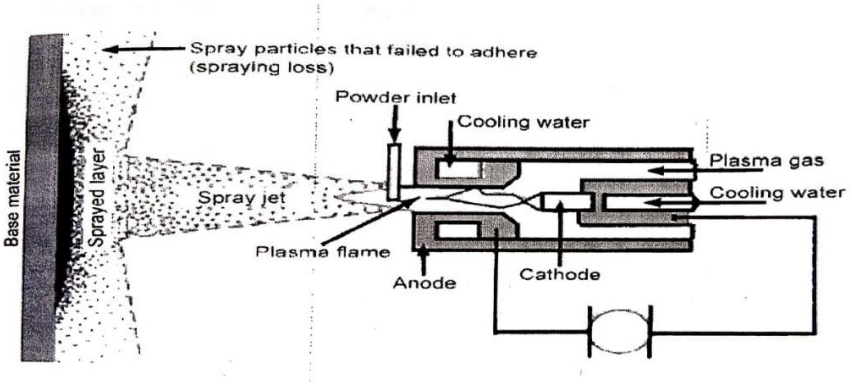


Figure 3 Plasma Spray Coating Process

3 Results and Discussions

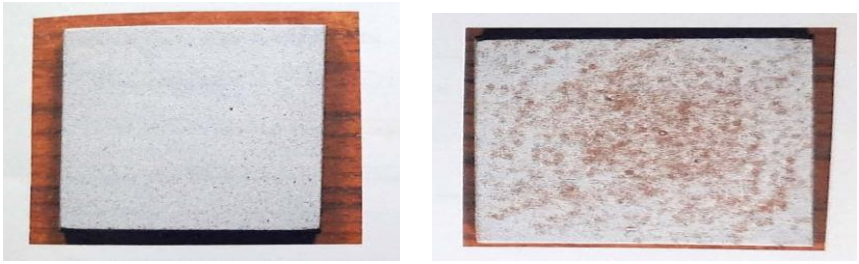
3.1 Plasma Spray Composition

Plasma spray is utilized to develop deposits of 250 m of Zirconia Ceria powder through structure of Ceria is 62% zirconium oxide, 8%yttrium oxide, as well as 30% cerium oxide.

250 um is the best possible thickness for turbine blades as per the literature review.

3.2 Testing of Coatings

The specimen of coating composition is taken for the test. Once the coatings over the samples are completed, they have been subjected to experiment like the Salt spray corrosion test. The specimen after and before the salt spray experiment is demonstrated in Figure 4.



(a) (b)

Figure 4 Rectangular Specimen a) Before Salt Spray Test b) After Salt Spray Test

ASTM B117 is the most extensively utilized salt spray cabinet test. The Salt Spray (Fog) experiment is frequently utilized to calculate the virtual corrosion resistance of coated and uncoated substances showing to some salt spray or fog at an eminent temperature. Table 4 shows the results of the salt spray test.

Table 4 Salt Spray Test Results

Percentage of Ceria in the sample	20%	25%	30%
Time for minute red rust occurrence	324 hours	367 hours	392 hours
Weight of the coating material removed	0.603g	0.511g	0.39g

Through the above structure is subjected to salt spray corrosion check the substance stainless steel (grade 304) coated. The experiment has to be completed up to the red rust start to show on the surface of the covering section because every experiment is completed on the coating substance through 25% cerium coated sample as well as 20% cerium coated samples are examined up to the time while it appears the red rust. The period for red rust happening in the 20% along with 25% is 320 hours as well as 358 hours correspondingly. The coating test includes 30% of cerium is positioned in the experimenting tools that must be covered from every side by the wrap tape. The sample is positioned in the experimenting tool that includes circumstances like attentiveness of sodium chloride, air pressure, Ph solution, chamber temperature as per ASTM principles, solution discharge per hour. Following the starting of the experiment, the samples have to be mentioned in the gap of time intervals. The red rust starts to come into view in the test subsequent to 396 hours (17 days).

The outcomes attained have been studying extremely evidently as of the outcomes of the preceding experiments it has been accomplished to the percentage enhancement in the cerium oxide is the reason for the better resistance to corrosion , thus with the increment of 5% in the cerium oxide content increase the life of the covering towards the corrosive destruction . Relatively 30% cerium oxide test through stand more than the 25% cerium oxide tests.

4 Conclusion

In this research, Zirconia Ceria powdered coatings have been deposit through Atmospheric Plasma Spray procedure on 304-grade stainless steel. The thickness of the coating was considered as 250 um because it is the best thickness of the coating for turbine blades. NiCoCrAIY was utilized as a bond coat Plasma spray procedure was utilized to shape deposits of the Zirconia Ceria powde of composition 62% zirconium oxide, 8%yttrium oxide, as well as 30% cerium oxide. Salt spray tests have been completed on the components to discover the corrosive resistive assets of the covering substance enriched by cerium content. Thus, 30% cerium alloy coating tested with stand up over 25% cerium alloyed coating test ,thus protecting from environmental effect.

References

[1] A.Portinha, V.Teixeira, J.Carneiro, J.Martins, M.Costa, R.Vassen, D.Stoever,"Characterization of Thermal Barrier Coatings with a Gradient in Porosity", Surface and Coatings Technology, Vol. 195, pp.245– 251, 2005.

[2] L.Swadzba, G.Moskal ,M.Boguslaw , T.Gancarczyk, "Characterisation of air plasma sprayed TBC coating during isothermal oxidation at 1100oC", Journal of Achievements in Materials and Manufacturing Engineering, Vol.21, 2007.

[3] VikasChawla.Sindhu, "Hot corrosion and erosion problems in coal-based power plants in India and possible solutions", Characterization and Engineering, Vol.10, No 4. pp.367-385 , 2011.

[4] A.Scrivani, G.Rizzi, U.Bardi,"Thermal Fatigue Behavior of Thick and Porous Thermal Barrier Coatings Systems", Journal of Thermal Spray Technology, Vol.16**,** pp.816–821, 2007.

[5] N.S.Patel, J.Menghani, K.B.Pai ,M.K.Totlani,"Study of corrosion behavior of zirconium based multi constituent thin films" ,International Journal of Applied Chemistry, Vol. 6, No. 3, pp.321-326, 2010.

[6] E.A.Almond,L.A.Lay, M.G.Gee,"Comparison of sliding and abrasive wear mechanisms in ceramics and cemented carbides", Institutional Physics, pp. 919–948, 2002.

[7] D.Ramesh, S.Ragera, T.K.Chandrashekar,."Corrosion Behaviour of Al6061-Frit Particulate Metal Matrix Composites in Sodium Chloride Solution", Journal of Minerals and Materials Characterization and Engineering ,Vol.01, pp.15-19, 2013.

[8] A.Keyvani, S.Mohsen ,H.S.Mahmoud, ”Oxidation resistance of the nanostructured YSZ coating on the IN-738 superalloy”, Journal of ultrafine grained and nanostructured materials (JUFGNSM).,Vol.47, pp. 89-96, 2014.

[9] D.Gond, R.Lalbondre, D.Puri, S.Prakash, "High Temperature Oxidation and Hot Corrosion Behaviour of Yttria- Stabilised Zirconia as Plasma Sprayed Coating in Air and Salt at 900°C under Cyclic Condition", Journal of Minerals and Materials Characterization and Engineering,Vol.11, No.3, pp.285-302, 2012.

[10]Brinkiene Kristina, Kėželis, Romualdas, Čėsnienė, Jūratė, MėčiusVladas, ŽundaAudrius,” Characteization of Wear Properties of Plasma Sprayed Ceramic Coatings”, Materials Science (MEDŽIAGOTYRA), Vol. 14, No. 4, 2008.

[11]D.M.Kennedy, M.S.J.Hashmi, "Methods of wear testing for advanced surface coatings and bulk materials",Journal of materials processing Technology, Vol.77, pp.246-253, 1998.

[12]P.Zhang, X.Zhang, F.Li, Z.Zhang, Z.Li, H.Wang, Y.Ren, L.Liu,” Effects of Selective Laser Modification and Al Deposition on the Hot Corrosion Resistance of Ceria and Yttria-Stabilized Zirconia Thermal Barrier Coatings”, Coatings, Vol.*9*, pp. 353-662 , 2019.

[13]P.G.Lashmi, S.Majithia, V.Shwetha, N.Balaji, S.T.Aruna, “Improved hot corrosion resistance of plasma sprayed YSZ/Gd2Zr2O7 thermal barrier coating over single layer YSZ”, Materials Characterization, Vol.47, pp.199-206, 2019.

[14]M.S.Ahmadi, S.R.Rezai, Z.Valefi, H.Jamali “Evaluation of hot corrosion behavior of plasma sprayed and laser glazed YSZ–Al2O3 thermal barrier composite”, Optics & Laser Technology, Vol.111,pp. 687-695 , 2019.

[15]M.T.Reza, R.Rahmanifard, Y.Seyed, “The study of phase stability and thermal shock resistance of a Scandia–Ceria stabilized zirconia as a new TBC material”, Surface and Coatings Technology, Vol. 374, pp. 752-762, 2019.

[16]J.G.Thakare, R.S.Mulik, M.M.Mahapatra, “Evaluation of Cyclic Hot Corrosion Resistance of Plasma-Sprayed Composite Coating in Na_2SO_4-60%V_2O_5 Molten Salt Environment”, Journal of Thermal Spray Technology, Vol.29**,** pp.811–824, 2020.

Biographies

P.Praveen Raj was born in the year 1979 in India. He completed his B.E.in Mechanical Engineering from Vellore Institute of Technology formerly Vellore Engineering College in the year 2000 and completed his M.E.in Manufacturing Engineering and Ph.D from Anna University, Chennai .He is currently working as Assistant Professor in the Department of mechanical Engineering, ThanthaiPeriyar Government Institute of Technology,Vellore,India.He has nearly nineteen year of teaching experience .His has published more than forty five research papers in refereed International journals and conferences in the area of composite machining, Natural Fibers ,optimisation ,nano composites, coatings etc.

KanthaShoba M graduated in B.E. Mechanical Engineering from Thiagarajar College of Engineering, Madurai in 2000. She has worked in the department of Mechanical Engineering of AlagappaChettiar College of Engineering, Karaikudi – initially as a lecturer, and since 2006 as Assistant Professor. Currently, she is teaching courses in Machine Design that addresses machine design, transmission systems, finite element analysis, all with special focus on design and optimization. Her main research interest includes study on design ,theory and methodologies on gears and environmental friendly coatings.