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Sea water corrosion behavior of plasma sprayed abradable coatings

M Parida*[1], S.P.Nanda[2] and S.C.Mishra[3]

[1]Dept. Of Chemistry, SCITM, Similiguda.
[2]Dept. Of Chemistry, CUTM, Paralakhemundi.
[3]Metallurgical & Materials Engineering Department, NIT, Rourkela.

E-mail: rinaa26@yahoo.com

Abstract. Aluminum based abradable coating is used for sealing purpose in compressor casing of aero engines to withstand up to a service temperature of 450^0C. Al-BNSiO_2 composite coating is deposited using thermal plasma spray technique. Coating thickness measured and porosity of the coating is evaluated.Coating morphology is observed and EDSanalysis is done with SEM (Jeol make). The effect of time on the sea water corrosion behavior of the coating is evaluated. It is observed that, there is a sharp increase in weight gain of the coating up to six weeks of immersion. This behavior is attributed to the adsorption /deposition of other elements/reactions taking place during interaction with sea water.

1. Introduction

Abradable aluminum base composite coating is used for clearance control and sealing in compressor of aero engines, thereby improving engine efficiency [1]. This abradable aluminum coating is used as top coat with a bond coat being nickel-aluminide etc. [2].Abradable aluminum coating is used in the area of cold end components like compressor casings, rings of gas generator, and internal rings etc. To deposit such coatings, flame or plasma spraying is considered as the most effective method. Since 1960, atmospheric plasma spraying (APS) is widely used in many fields of engineering applications. One of the main advantages of plasma spraying process is that, the substrateis heated very little during the coatingdeposition. During plasma spray process the plasma thermal energy melts the coating/feed material (usually in the form of powder/wire). Molten material is propelled by the carrier gas on a cleaned and prepared specimen surface, where it bonds to the surfacepredominantly by mechanical bonding. Coating characteristics are very much dependent on substratesurface and critical plasma spraying parameter (CPSP) [3-6].

Parameters those are important in choosing the abrasive for surface roughening are type, size, shape, purity and hardness of blasting powder. Specific CPSP is used for this aluminum based abradable coating for clearance control [7]. These parameters also affect the corrosion behavior of plasma spray ceramic coatings [8].This coating is intended for operation, when the operating temperature is below 450ºC in the rotor sealing of gas turbine engine at general climatic condition. But however study has not been reported for this abradable aluminum coating related to corrosion testing in saline climatic condition. The main aim of the work is to study the sea water corrosion behavior of this abradable aluminum-based composite coating.

2. Experimental Procedure

Before carrying out Nickel plating of Aluminum powder, it was prepared by sheaving the powder with mesh size between 1-60. Granularity structure of the powder was maintained. Nickel chloride (30kg) was added to 50litersof solution made with (Boric acid + NaCl +Oxalic acid + HF).

All the chemicals were dissolved in distilled water at 70- 80 ^{0}C. Then sprinkling of already prepared aluminium powder was doneat a temperature of 22 – 25 ^{0}C within 5to 10minutes at a rate of 96gm /ltr. Then excess solution was taken out and flushedwith drinking water for 6 – 8 times. Finally

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the powder was taken in a stainless steel tray and heated at 180- 200 ^{0}C. The powder should have granular size between 16-56 mesh.

Aluminium powder is sieved through mesh size 016. Aluminium powder 74- 76 % and BoronNitride 24-26% were mixed with 40-60 rpm in a ball mill for 10-12 hrs. The dry mixture is mixed with liquid glass 140 -160 cc for 1 kg of dry mixturefor 30-40 minutes. The blend is dried at 140-160 ^{0}C for 8- 10 hrs and sieved through vibro-sieve no 315.

2.1 Substrate Preparation

Nickel based Nimonic(70% Ni,23%Cr) plate was selected as substrate for coating. The surface of the substrate prepared for coating was made free from moisture, oil, and other contaminates. The time gap between surface preparation and spraying process was lessthan 2 hours,to avoid disintegrationof coating. Substrate surface was roughened using Al_2O_3 powderof grit size 60.

2.2 Spray Deposition

Coating was made on the surface with a sub layer of nickel-aluminide, of 50 micron thickness by plasmaspray techniqueusing a specific critical plasma spraying parameters (CPSP). The plasmaspray parametersused for spraying are listedin table – 1. After coatingthe sampleswere heat treatedat 450^{0}C for 30 minutes.

Table 1.CPSP for deposition of coatings

Sl. No.	Parameter	Value
1	Nozzle Dia	6 mm
2	Primary plasma Gas	Argon (45 lpm)
3	Secondary Plasma-gen gas	Argon (7 lpm)
4	Current	570 Amp
5	Powder carrier gas	Argon (3 lpm)
6	Powder feed rate	90 % on machine scale
7	Spray distance	120 mm

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2.3 *Specimen preparation for corrosion test*

Ten specimensof thickness 3 -4 mm and weight (ranging between 5-9 grams)were cutfrom preparedcoatings by wirecut EDM.The abradablealuminumcomposite coatings were subjected to corrosion test, deeping in sea water for different time periods. Sea water was collected from Bay of Bengal; the composition of sea water is shown in table 2.

Table 2. Composition of sea water.

Type of ion	Element	Concentration (Mg/ltr)	% by wt.
Cation	Na^{+1}	10500	30.42
	Mg^{+2}	1350	3.91
	Ca^{+2}	400	1.16
	K^{+1}	380	1.10
	Sr^{+2}	8	0.02
Anion	Cl^{-1}	19000	55.04
	So_4^{-2}	2655	7.04
	$C0_3^{-2}$	140	0.41
	Br^{-1}	65	0.19
	Bo_3^{-3}	20	0.06
	Sio_3^{-2}	8	0.02
	F^{-1}	1	0.003

3. Results and discussion

3.1 Hardness test

The heat-treated coatedsample surfaceswere polishedusing emery paperfor hardness measurement. The coatingswere checked for any defect using 7X magnifying glass. Blow holes, cracks, separation and unfused particles were not found. Hardness was measured (with Brinell hardness tester) on five areas of the sample after making the surface smooth. Ball indenter of diameter 5mm was used at a force of 62.5 kg/cm2., having indentation dia of 3.15 to 2.4mm. Ten readings were taken and the Hardness of the specimens was in the range of 7 – 13 HB.

3.2 Corrosion Test

Specimens were weighed in a balance of least count 0.01 gm. Prior to corrosion test the samples were washed with distilled water and dried at 110 – 120 ^{0}C for 1 hr. The specimenswere put in the sea water at different interval of time and kept under observation. After 10 weeks of observation samples were taken out and again dried at110 – 120 ^{0}C for 1 hr. Again weight of specimens were taken and listed at table – 3 and shown in Figure 1.

Table 3. Change in weight percent of the samples with treatment time.

Sl. No.	Time in days	Initial weight	Final weight	Change in weight	Percent weight gain
1	86	6.28	6.86	0.58	9.24
2	79	5.02	5.38	0.36	7.17
3	65	8.1	8.88	0.78	9.63
4	58	8.26	8.99	0.73	8.84
5	44	6.97	7.62	0.65	9.33
6	36	6.47	6.7	0.23	3.55
7	28	6.7	6.98	0.28	4.18
8	19	6.34	6.61	0.27	4.26

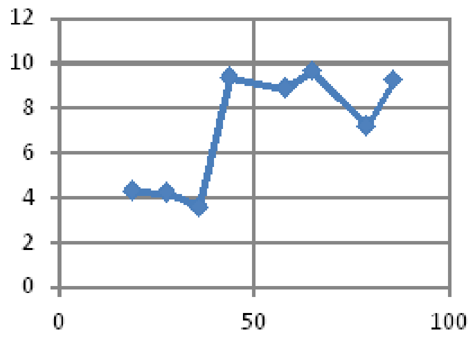

Figure 1. Time dependence of wt. change in sea water corrosion.

From the figure, it is evident that, the rate of increase in wt. is very rapid up to six weeks and then takes a linear trend.

3.3 Microstructural observations

SEM and EDS analysis is done with the raw and corroded samples, shown in figure 2 and figure 3 for these samples, respectively.

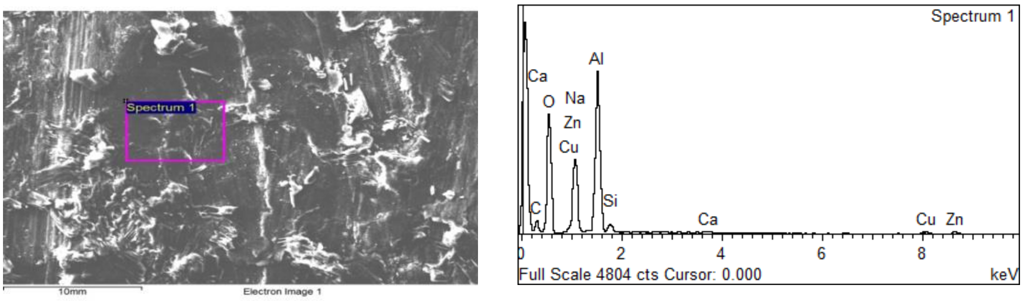

Figure 2. SEM and EDS spectrum of the surface of the coating.

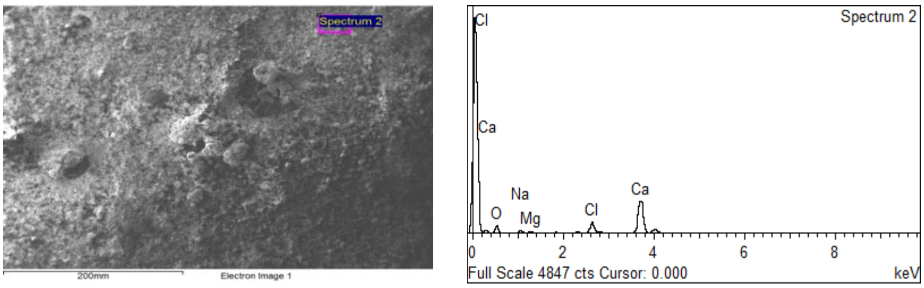

Figure 3. SEM and EDS spectrum of the surface of the untreated specimen.

From the above figures, it can be seen that, very good quality coatings could be made with using the above said plasma operating parameters. It is well known that, plasma spraying parameters plays an important role on deposition and the microstructure and the surface morphology is more important for optimization of plasma spray parameters for developing the best quality coatings [9-11]. Hence the selection of plasma spray parameters (in our case) is suitable to develop dense coatings. In case of the corroded specimen, fig.2, deposition of small particles and dimples are developed on the coating/surface. From the EDS composition analysis, table – 4 and 5, it can be seen that there is major increase in amount of Ca, Cl and a little increase in Mg also. This implies that, some kind/type of ionic change/reactions is taking place on the samples and investigations in this regard are on the way.

Table 4. EDS elemental analysis of the coating surface prior to treatment.

Element	Weight%	Atomic%
C K	11.40	17.71
O K	49.04	57.20
Na K	12.35	10.03
Al K	17.30	11.97
Si K	1.16	0.77
Ca K	0.27	0.13
Cu K	1.61	0.47
Zn K	2.19	0.63
Br L	4.67	1.09
Totals	100.00	

Table 5.EDS elemental analysis of the coating surface after dipped in sea water for 10 weeks.

Element	Weight%	Atomic%
O K	51.43	70.76
Na K	3.92	3.75
Mg K	1.06	0.96
Cl K	8.06	5.00
Ca K	35.54	19.52
Totals	100.00	

4. Conclusions

Aluminum based composite coating is deposited through plasma spraying bears the hardness of 7-13HB. With sea water treatment, weight gain of the samples is observed. The rate of increase in wt. is very rapid up to six weeks and then takes a linear trend. There a change in surface morphology of the coating after corroded in sea water. Deposition of Ca and Cl is observed on the surface of the sea water treatment.

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