Development of Thermal Coatings on Turbine Blades to Resist the Corrosion

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Abtract- The present investigation is on the High Velocity Oxy-Fuel coating of Ti-31 alloy and SuperCo-605 superalloy materials where used in gas turbine blades using fused, blended powders, WC/Co + NiCrBSi. Hot corrosion experiments were done on the coated and uncoated materials under a salt environment of 40%Na_2SO_4 and 60%V_2O_5 at 700°C. Thermogravimetric cycles of 1 hour heating and 20 minute cooling was followed for hot corrosion study. After each cycle weight measurement was carried out. It was observed that the coated sample is more resistant to hot corrosion than uncoated samples. Gravimetric analysis indicated that the sample weight gain was following a parabolic relationship with time. A damage mechanism is discussed for the hot corrosion damage of the samples. Presence of high level of chromium in HVOF sprayed coating imparts improved hot corrosion resistance at 700°C, in a molten salt environment of Na_2SO_4 + 60%V_2O_5. Based on the thermogravimetric data, the relative hot corrosion resistance is more of the WC/Co+NiCrBSi coated and compare to uncoated materials. Also both coated materials are shown more corrosion resistance comparing to uncoated materials.

Keywords Ti-31, Superco-605, Hot corrosion, HVOF coating , WC/Co+NiCrBSi

1 INTRODUCTION

Turbines are used in many different areas, and each type of turbine has a slightly different construction to perform its job properly [1]. Turbines are used in wind power, hydropower, in heat engines and for propulsion. Turbines are extremely important because the fact that nearly all electricity is generated [2]. Today gas turbines are used extensively to produce power for satisfying the demands of electricity, chemical, pharmaceuticals, fertilizer sectors, etc. An important developing area in the gas turbines is use of modern materials to improve efficiencies and to reduce emissions [3]. There are additional demands from the customer on to power sector. Some of them are requirements to operate the power on part load, run with frequent starts and flexibility to run on different fuels .Though various alter natives exist for the fuel material, coal is still a predominant fuel material for the power suppliers and be so in the future as well [4]. This means that turbine components will be exposed to an environment consisting of abrasive, erosion, corrosion and oxidation phenomenon under hostile chemical conditions. Surface engineering of these components helps in protecting the components against said environments [5]. Thermal spray coatings are especially interesting for their cost/performance ratio. Unique alloys and microstructures can be obtained with thermal spraying which are not possible with a wrought material [6]. This includes continuously graded composites and corrosion resistant amorphous phases on the component surface. Thermal spray coatings additionally offer the possibility of on-site applications and repair of components, if sufficient accessibility for the sprayer and his equipment is available. Thermal spray coatings are being increasingly and successfully used for broad variety of high temperature corrosion applications [7].

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2 EXPERIMENTAL SETUP

The proposed research work is aimed at understanding the high temperature corrosion behaviour of gas turbine super alloys coated with cermets using HVOF process.

1. Selection of materials for the study: Titanium alloy (Ti-31), which is candidate materials for turbine blades were procured from Mishra Dhatu Nigam Limited, Hyderabad, India. The stated composition of the substrate material is given in the Table 2.1. Materials were brought in sheet form and coupons of size 25 mm X 25 mm X 5 mm were cut and used for deposition.

Table 2.1 Substrate material composition

Sl No	Name of the Material	ASTM Grade	Composition	Applications
1	Titanium alloys (Ti-31)	ASTM B338 Grade 5	Ti-6Al-4V	Pressure vessel, gas turbine blades, gas and chemical pumps, marine components
2	Cobalt base super alloy (Superco-605)	(ASTM F90-09)	Co-3Fe-10Ni-20Cr-1.5Mn-0.3Si-0.08C-15W	Gas turbines, furnace muffles in oxidizing atmosphere

2. Powders were chosen based on their resistance against hot corrosion. Two types of powders were chosen for deposition and the nominal compositions of the powder are given in the Table 2.2

Table 2.2 Compositions of the powders used for coating

Sl.No.	Coating powder	Chemical composition	Shape	Particle size
1	Tungsten Carbide alloy powder	WC/Co + NiCrBSi (Fused powder) Powder Alloy Corporation, Cincinnati, Ohio.	Spherical	-45 to +15µm

3. HVOF spray process will be used for deposition of above said powders on turbine blade materials.

4. Coated as well as uncoated alloys will be subjected to cyclic hot corrosion studies in aggressive salt environment of 40%Na_2SO_4-60%V_2O_5 at a temperature of 700^{0}C for 50 cycles in the Silicon carbide tube furnace. Each cycle consist of 1 hour heating followed by 20 minutes cooling. Thermo gravimetric techniques will be used to study the corrosion rate and kinetics. Hot corrosion studies will be conducted in a tube furnace with a temperature tolerance of +/-2°C

5. Identification and structural investigation of the reaction products of the corroded and eroded samples will be made by means of Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Analysis (EDX) techniques.

3 RESULTS AND DISCUSSION

3.1 Hot corrosion studies

The uncoated and coated samples Ti-31 and SuperCo-605 which were subjected to hot corrosion in 40%Na_2SO_4+60%V_2O_5 molten salt for 50 cycles at 700 °C .It is to be noted that after 20th cycle crack formation was taking place in the uncoated sample whereas the there was no change in coated sample. At the end of 50th cycle eroded layers were observed in the uncoated samples, whereas no changes were observed in the coated sample

3.2 Thermogravimetric Studies on Coating-1

The plots of cumulative weight gain as a function of time expressed in number of cycles are shown in Fig.1.The weight gain for coated (WC/Co+NiCrBSi) Ti-31 and SuperCo-605 at the end 50 cycles.

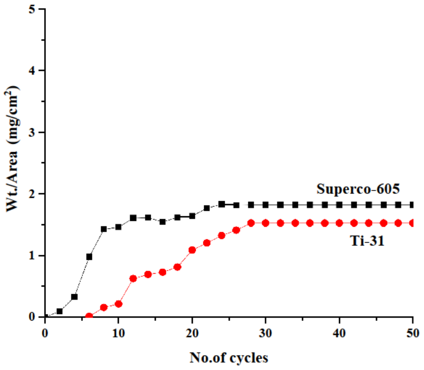

Fig.1 Plot of weight gain/area versus number of cycles for coated (WC/Co+NiCrBSi) samples of Ti-31 and SuperCo-605 subjected at 700°C

The plots of cumulative weight gain^2 as a function of time expressed in number of cycles are shown in Fig.2.The weight gain for coated (WC/Co+NiCrBSi) Ti-31and SuperCo-605 at the end 50 cycles

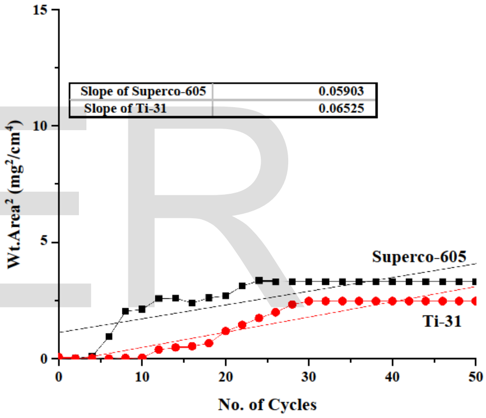

Fig.2 Plot of weight gain^2/area versus number of cycles for coated (WC/Co+NiCrBSi) samples of Ti-31 and SuperCo-605 subjected at 700°C

The WC/Co+NiCrBSi coated Ti-31 and Superco-605 materials showed lower weight gain in comparison with the uncoated materials when exposed to 40%Na_2SO_4+60%V_2O_5 salt environment. The weight gain after 50 cycles of exposure of the WC/Co+NiCrBSi coated Ti-31 and Superco-605 materials are found to be 2.2 and 1.51 mg/cm^2, respectively. Further, to explore the possibility of parabolic relationship between weight gain and time of exposure, square of weight gain (mg^2/cm^4) data is plotted as a function of cycles. From this plot, the value of parabolic rate constants are estimated and they are (K_P in 10^{-11} g^2 cm^{-4} s^{-1}) 1.8125 and 1.63972 g^2 cm^{-4} s^{-1} for the WC/Co+NiCrBSi coated Ti-31; Superco-605 materials, respectively.

Both, weight gain after 50 cycles of hot corrosion and the parabolic rate constant (K_p) decreases for coated Ti-31 and

Superco-605 materials in comparison with the uncoated materials and therefore, it can be inferred that the necessary protection has been provided by the HVOF sprayed WC/Co+NiCrBSi coatings to the Ti-31, Superco-605 substrate materials.

The weight gain in WC/Co+NiCrBSi coated Ti-31 material is higher than that of the Superco-605 materials and this may be attributed to the development of cracks after 9^{th} cycle of hot corrosion studies in molten salt environment for 50 cycles. The thermal shocks generated due to the differences in thermal expansion coefficients of coatings, substrate, and oxides may be responsible for the development of cracks (Mishra et al. 2006).

4 CONCLUSIONS

Following are the salient conclusions from the present investigation.

1.HVOF sprayed WC/Co+NiCrBSi coating are successfully deposited on Ti-31 and Superco-605 substrate materials. Under the given spray parameters, coatings are laminar structured, dense with porosity less than 2%. The thickness is in the range of 260-325 µm.

2. The WC/Co+NiCrBSi coating shows cobalt rich phase as principal phase. None of the coating materials undergo significant phase transformation during HVOF spraying.

HOT CORROSION STUDIES IN 40%Na_2SO_4-60%V_2O_5 SALT MIXTURE

3.The cumulative weight gain for all three HVOF coated Ti-31 and Superco-605 samples are significantly lower than that of uncoated samples subjected to hot corrosion in 40%Na_2SO_4-60%V_2O_5 molten salt environment for 50 cycles at 700ºC. Uncoated Ti-31 suffered a higher corrosion rate and intense spalling of oxide scale (TiO_2: rutile) is observed. Uncoated Superco-605 exhibited weight loss during the complete cycles of hot corrosion studies as a result of intense sputtering of the oxide scale formed during hot corrosion.

4. Based on the thermogravimetric data, the relative hot corrosion resistance of the various coating under study can be arranged in the following sequence:

[WC/Co+NiCrBSi] > Uncoated

5. All the coated samples exhibit characteristic thick protective oxide scale, Composed of oxides and spinal oxides of the active elements of the coating andimparted resistance to the hot corrosion. The superior hot corrosion resistance of Al_2O_3+NiCrBSi is attributed to the oxide scale containing a continuous film of Cr_2O_3 which has minimal solubility in highly acidic 40%Na_2SO_4-60%V_2O_5 melt.

6. The analysis of corrosion kinetics (and parabolic behavior) observed during the thermo gravimetric studies shows that the reaction rate is diffusion limited.

7. The hot corrosion resistance of WC/Co+NiCrBSi coated substrate is comparatively lower than the other coatings and it is attributed to higher value of porosity.

4 References

[1] Annual Energy Outlook 2003, Energy Information Administration, U.S Department of Energy, 5-6.

[2] Bolles, C. (1995). "HVOF thermal spraying an alternative to hard chrome plating." Welding Journal, 74(10), 31-35.

[3] Gosipathala Sreedhar, Masroor Alam, M.D. and Raja, V.S. (2009). "Hot corrosion behavior of plasma sprayed YSZ/Al2O3 dispersed NiCrAlY coatings on Inconel-718 superalloy." Surface and Coatings Technology, 204, 291-299.

[4] Mishra, S.B., Prakash.S., Chandra, K. (2006). "Studies on erosion behavior of plasma sprayed coatings on a Ni-based superalloy." Wear, 260, 422-432.

[5] Ramesh, M.R., Satya Prakash, Nath, S.K., PawanKumar Sapra, Venkataraman, B. (2010). "Solid particle erosion of HVOF sprayed WC-Co/NiCrFeSiB coatings." Wear, 269, 197-205.

[6] Subhash Kamal, Jayaganthan, R., Satya Prakash, Sanjay Kumar. (2008). "Hot corrosion behavior of detonation gun sprayed Cr_3C_2-NiCr coatings on Ni and Fe-based superalloys in Na_2SO_4-60%V_2O_5 environment at 900°C." Journal of Alloys and Compounds, 463, 358-372.

[7] Toma, D., Brandl, W., Koster, U. (2000). "The characteristics of alumina scales formed on HVOF-sprayed MCrAlY coatings." Oxidation of Metals, 53 (1/2), 125.