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Oxidation resistance by HVOF coating of MDN-121 on turbine material

Surface corrosion, such as oxidation, occurs in gas turbines at high-temperature locations such as turbine edges. Because of the absconds, the turbines became less compelling and loud. The focus of the exhibit is on a high speed oxy-fuel coating of MDN-121 unusual steel using a blended mix of cermets powder consisting of 25% Cr_3C_2-NiCr+75% NiCrAlY. In a hot environment at 750°C, oxidation tests were performed on coated and uncoated MDN-121. Cycles of 1 hour warming and 20 minutes cooling were used in thermogravimetric testing. Weight estimation was done after each cycle. The tests were characterized using XRD and SEM/EDS after 50 cycles were completed. It was observed that the coated test is more oxidation safer than the uncoated test. Surface morphology from SEM/EDS shows that the surface is wealthy in oxides. Gravimetric examination demonstrated that the weight picks up of the test takes after a illustrative relationship with time. The rate steady for the coated test was much for the coated sample was much lesser compared to the uncoated sample.

Keywords: Fracture toughness, stellite-6, Ti-31, high velocity oxyfud (HVOF), characterization etc.

1.0 Introduction

Except for gold, there are no pure metals or alloys that are stable in air at normal temperature. Alloy oxidation is more complicated than pure metal oxidation, and there is no universal theoretical treatment for ternary alloy oxidation mechanisms at high temperatures (Reidar Haugsrud 2001). Metals are prone to forming oxides, the pace of reaction is often quite sluggish at low temperatures.

Reaction rates, and at very excessive temperatures most reactions are executed within a few minutes (Ivan Anzel 2000). Oxidation can be regarded as a chemical reaction between a metallic and oxygen gasoline to structure the steel oxide. When a clean steel M reacts with oxygen gas, the oxide M_xO_y forms. Alloys are used commercially and incorporate many alloying factors to acquire suited mechanical properties. Such alloy factors have different affinities for oxygen and diffusion rates differ in the oxide/alloy. Consequently, the scale and alloy compositions change in a complicated way with time. The second factor can also enter the scale, affecting its structure, or may accumulate as steel or oxide under the principal scale. If oxygen diffuses into the alloy, precipitation of the oxide of the much less noble steel may additionally take place as inside oxide. Thermal spray coatings are a type of coating that has a strong cost-to-performance ratio. Its utility is derived from its capacity to deposit coatings with thicknesses ranging from a few micrometres to tenths of millimetres to improve resistance to surface deterioration. It is also adaptable to a wide range of forms and sizes, with the added benefit of keeping the substrate temperature low. These coatings function by forming a shielding oxide film on the metal surface to prevent metal loss due to oxidation.

These protective oxides (e.g. Al_2O_3, Cr_2O_3, etc.) reduce the penetration of gaseous or liquid substances, corrosive liquid combination towards the substrate alloy/metal, preventing substrate components from diffusing to the exterior surface, where they could react with the coated elements, causing damage. Furthermore, there should be minimal inter-diffusion between the coating and the substrates to prevent surface deterioration. (1989, Mevrel).

The production of combustion is then discharged through a cooled nozzle at high velocity. Powders to be deposited are fed into the combustion location by a provider gas, where they are heated and carried via the gases. Molten or partially molten powder particles arrive at the substrate, or have an effect on flatten and solidify rapidly. Coating thickness is generally vary from 100 to 325 μm. Depending upon the injection pressures of the fuel gases, jet velocities exiting the nozzle can be in the order of 700 m/s (Mohanty et al. 2006).

2.0 Experimental set up

The substrate material used in the present investigation was MDN-121. The substrate material was supplied by Midhani, Hyderabad, India. The specimen of approximately 25mm × 25mm × 5mm were cut, ground and subsequently grit blasted with alumina powders. They were used as substrates for HVOF coating. Commercially available fused, blended cermet powder was used for deposition. The details of the substrate used is given in Table 1. The details of the coating powder used is given in Table 2.

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Table 1: Substrate composition

Name of the material	ASTM grade	Composition	Application
MDN121 (iron based alloy)	ASTM A565 Gr616	Fe-0.8Ni-12Cr-IMo-0.6Me 0.25Si-0.2C-0.3V	Turbine blades

Table 2: Coating powder composition

Coating powder	Chemical composition	Shape	Particle
Carbide alloy powder	25% (Cr, Cr-25 (Ni2OCr) 75% (Bal Ni-21Cr-8A1.0.5Y) (Mechanical blend) Sulzer Mecto (Japan) Ltd. Japan	Speherica 1	–45 to

Coating thickness: 5μm

The coatings were sprayed at Spraymet India Ltd., Bangalore, using a Metco DJ 2600 (India) gun. The spray parameters were oxygen flow rate: 250 litres per minute (LPM), fuel (LPG) flow rate: 60-70 LPM, air flow rate: 700 LPM, spray distance: 20-25 cm, powder feed rate: 30-50 g/min, fuel pressure: 7 kg/cm^2, air pressure: 5.5 kg/cm^2, oxygen pressure: 10 kg/cm^2, nitrogen gas (powder carrying gas) pressure: 5 kg/cm^2. Uncoated and HVOF coated specimens were subjected to oxidation test at 750°C (±5°C). The samples were properly cleaned with acetone and dried before investigation. The physical dimensions of the samples were recorded before oxidation experiment. During oxidation, the specimen was kept in aceramic boat and weight of the boat and the specimen was measured. The oxidation study was conducted under cyclic conditions. The tests were conducted for 50 cycles of which each cycle consisted of 1-hour heating at 750°C followed by 20 minutes cooling in air environment. The weight change values were measured at the end of each cycle to check weight difference. Visual observations were made at the end of each cycle. The oxidation products of the uncoated and HVOF coated materials were analysed by using X-Ray Diffractometry (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) to reveal their morphological and microstructural features.

From the visual observations, during the conduction of cycles, formation of oxide layer was observed in the first few cycles itself for both coated and uncoated MDN-121. On the uncoated MDN-121, brown patch formation started appearing in around the 10th cycle and sputtering occurred from the 14th cycle, after which the light patches turned dark and appeared to increase with successive thermal cycles. On the coated MDN-121 substrate, there was a colour change in the 3rd cycle from light grey to light black and there was complete colour change to black in the 9th cycle. Sputtering was observed after the 16th cycle for few successive cycles. The surface of the sample turned ash grey from the 30th cycle onwards. Samples after 50 thermal cycles are shown in Fig. 1.

The result of thermogravimetric analysis is displayed in the form of a plot of cumulative weight gain (mg/cm^2) as a function of time expressed in number of cycles shown in the Fig.2.

Fig.1: MDN-121 uncoated (left) and coated (right) after oxidation

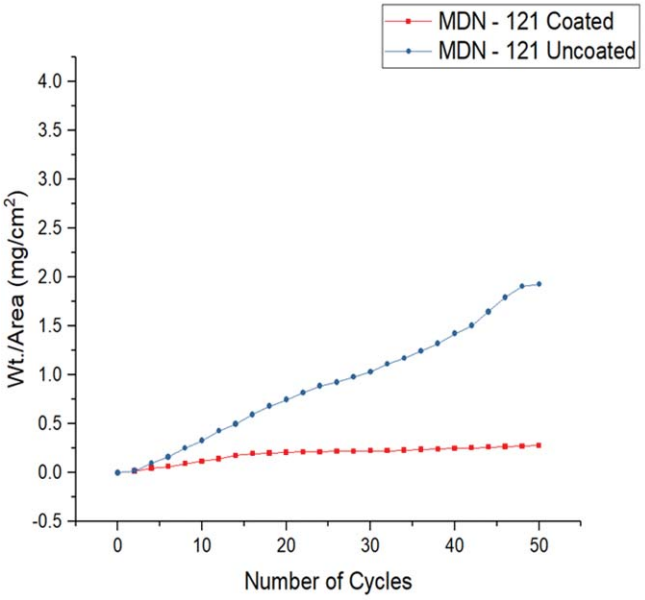

Fig.2: Thermogravimetric data of coated and uncoated MDN-121 subjected to hot oxidation, weight gain per unit area versus number of cycles

Weight gain of uncoated MDN–121 after 50 cycles was found to be 1.92 mg/cm^2, whereas weight gain of coated MDN–121 after 50 cycles was found to be 0.28 mg/cm^2. Further to investigate the possibility of parabolic relationship, weight gain square (mg^2/cm^4) is plotted as a function of number of cycles as shown in Fig.3. The rate constant from the parabolic curve for uncoated MDN-121 was found to be 19.667 g^{2}cm^{-4}s^{-1}, whereas the rate constant from the parabolic curve for coated MDN-121 was found to be 0.444 g^{2}cm^{-4}s^{-1}.

X-Ray Diffraction pattern of uncoated MDN–121 after oxidation is shown in Fig.4. The scale on the uncoated MDN –121 contains iron oxide (Fe_2O_3), chromium carbide (Cr_3C_2), manganese oxide (MnO) and silicon carbide (SiC) as major phases. Traces of iron chromium (FeCr) and silicon oxide (SiO_2) were found and are the minor phases in the uncoated MDN–121.

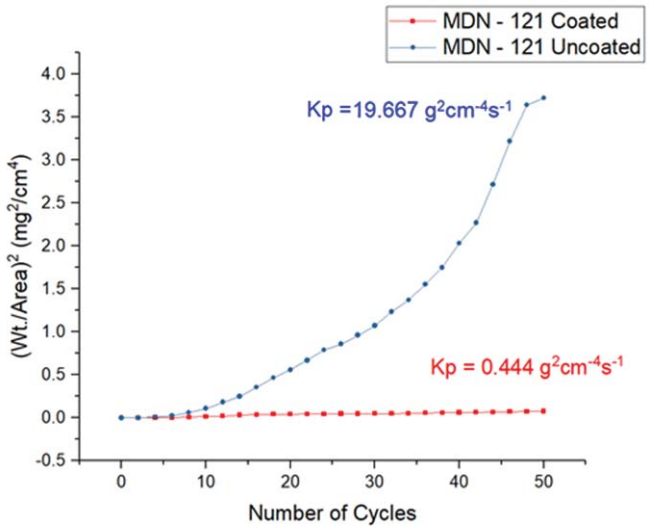

Fig.3: Thermogravimetric data of coated and uncoated MDN-121 subjected to hot oxidation, square of weight gain per unit area versus number of cycles

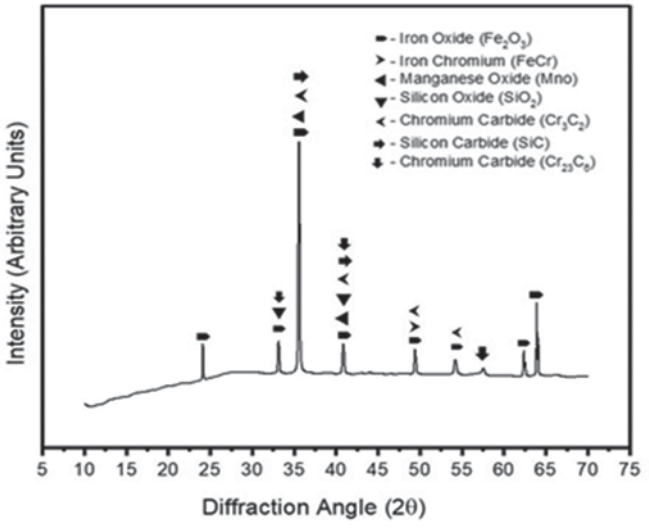

Fig.4: XRD graph of uncoated MDN-121 after oxidation

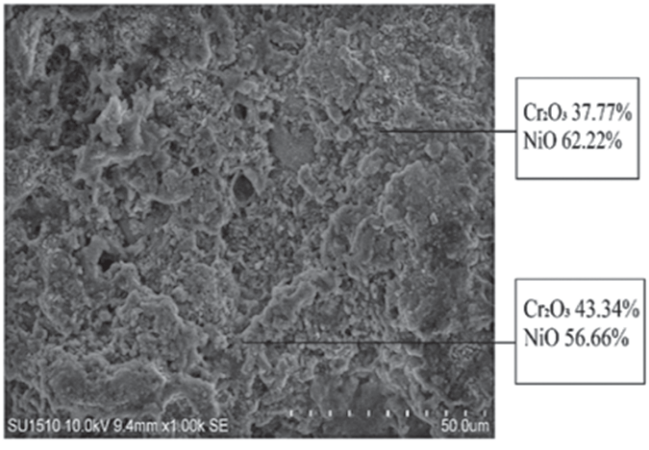

Fig.5: Morphological investigation of MDN-121 uncoated after oxidation

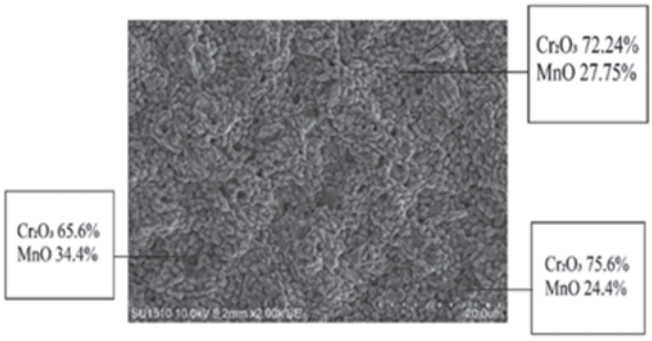

Fig.6: Morphological investigation of MDN-121 coated with Cr_3C_2–NiCr+NiCrAlY powder after oxidation

Fig.5 shows SEM micrograph of scales formed during hot oxidation of uncoated MDN–121 substrates. The figure shows scales formed on the uncoated MDN–121. The morphology clearly indicates that the scale is blistering and non-compact type, which promotes continuous oxidation. This is also indicated in the weight gain data. EDS on the scales clearly indicates that oxides of chromium (Cr_2O_3) (~70%) and oxides of manganese (MnO) (~28%) were found to be the major oxide layers formed along with minor amounts of oxides of carbon (C), molybdenum (Mo) and magnesium (Mg) (~1%). Fig.6 shows SEM micrograph of MDN–121 coated with Cr_3C_2–NiCr+NiCrAlY powder after oxidation and thermogravimetric analysis. The morphology clearly indicates that the scale is of continuous type. The EDS of the powder clearly indicates that the powder is rich in oxides of nickel (NiO) (~60%) and oxides of chromium (Cr_2O_3) (~38%). It was reported that oxides of nickel and chromium form continuous oxides and protect the substrate from surface degradation.

4.0 Conclusions

The MDN-121 material was coated using high velocity oxy-fuel (HVOF) process using a fused blend cermet powder of Cr_3C_2–NiCr+NiCrAlY. The coated and uncoated MDN-121 substrates were subjected to hot oxidation experiments under air environment at 750°C for 50 cycles of 1-hour heating followed by 20 minutes cooling. The weight gain during each cycle is estimated and observed that the weight gain follows a parabolic relationship with time. The rate constant for coated sample was much lesser compared to uncoated sample. XRD and SEM analysis indicates that the surface of the substrates, after hot oxidation were rich with oxides of Cr and Mn whereas the surface HVOF coated surface is rich in oxides of Cr and Ni. The oxides of chromium and nickel provide improved hot oxidation resistance property for the HVOF sprayed coatings and itreduces oxidation rate by more than 40times compared to uncoated MDN-121.

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