

BOILER TUBE MATERIAL CORROSION PROTECTION FROM CORROSIVE ENVIRONMENT WITH HVOF COATING

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Abstract

Thermal power facilities frequently experience downtime due to corrosion and oxidation of boiler tube materials exposed to high temperature environments. Thermal coatings can solve this issue. HVOF coating is superior to other coatings because it has less porosity, is more cost-effective, and increases the substrate material's longevity. The SA213 T12 boiler tube material was coated with an HVOF coating of NiCrAlY and CNT in a variety of ratios, including 3, 5, and 7. In order to conduct hot corrosion tests using the thermo gravimetric method, temperatures were heated to 700°C for one hour, cooled to room temperature for 20 minutes, and the weight increase was then measured. Advanced microscopic XRD and SEM/EDX evaluations were performed on the corroded samples to determine the oxide layer.

Keywords: SA213 T12, HVOF, SEM/EDX, Porosity etc.

Introduction

Thermal plant industries are widely employed nowadays to generate the energy needed to meet the doubled demand for electrical power. Although there are a number of fuel substitutes, coal remains the most common fuel for power plants [1]. This means that under harsh chemical circumstances, boiler components will be exposed to an atmosphere with abrasive, corrosion, and oxidation phenomena. These components' surface engineering helps to shield them from the aforementioned conditions [2–5]. The cost-performance ratio of thermal spray coatings makes them particularly intriguing. Thermal spraying makes it feasible to create uncommon alloys and microstructures that are not attainable with wrought material. This comprises corrosion-resistant amorphous phases on the component surface and continuously graded composites [6&7].

The proposed work is carried out to understand the high temperature corrosion on boiler tube material (SA213 T12) behaviour of uncoated and HVOF coated with CNT and NiCrAlY. Thermogravimetric techniques will be used to study the corrosion rate. The identification and structural investigation of the reaction products of the corroded samples will be made by the means of XRD and SEM analysis.

Experimental work

HVOF Process

HVOF spraying was carried out using METCO DJ2600 equipment, which utilizes a supersonic jet generated by the combustion of liquid petroleum gas and oxygen mixture. The spraying parameters employed during HVOF deposition is listed in Table 1. Before HVOF spraying, substrate materials were grit-blasted with alumina, to develop better adhesion between the substrate and the coating. The HVOF coating process was carried out in Spraymet Coating Industries, Bangalore, India .

Table No.1: HVOF Process Parameters

Oxygen flow rate	250 LPM
Fuel (LPG) flow rate	60-70 LPM
Air flow rate	700 LPM
Spray distance	0.20-0.25 m
Powder feed rate	0.3-0.50 g/min
Fuel pressure	68 X10 ⁴ N/m ²
Oxygen pressure	98 X 10 ⁴ N/m ²
Air pressure	54 X 10 ⁴ N/m ²
Nitrogen gas (powder carrying gas) pressure	49 X 10 ⁴ N/m ²

Substrate material composition

Table No.2: Substrate of T12 Alloy Steel Chemical Composition

Grade	C≤	Mn	P≤	S≤	Si≤	Mo
T12	0.15 max	0.30~0.60	0.025	0.025	0.50~1.0	0.44~0.65

Coated powder compositions

Powders were chosen based on their resistance against hot corrosion and oxidation. Two types of powders were chosen for deposition and the nominal compositions of the powder are given in the Table 3.

Table No. 3: Coated powder compositions

Sl.no	Coating powder	Chemical composition (Wt %)
1	NiCrALY	Ni(67%)AL(10%)Cr(22%)Y(1%)
2	CNT	CNT

Results and Discussions

Thermogravimetric Analysis

Hot corrosion studies were conducted at 700°C in a laboratory silicon carbide tube furnace with an accuracy of ±5 °C. The uncoated specimens were polished with 600-1000 grade emery paper and coated samples were not polished to retain original coated surface before being subjected to hot corrosion run. The physical dimension of the specimen was then recorded carefully with a vernier caliper, to evaluate their surface area.

Subsequently specimen were washed properly with acetone and dried in hot air by heating both boat and specimen in an oven at 150 °C for about 30 minutes to remove the moisture. During experimentation the prepared specimen was kept in an alumina boat and the weight of boat and the specimen was measured.

The hot corrosion studies, under cyclic conditions, were conducted in a molten salt environment of Na₂SO₄-50%V₂O₅. The tests were conducted for 50 cycles, of which each cycle consisted of 1 hour heating at 700 °C in silicon carbide tube furnace followed by 20 minutes cooling in air. Salt coating of uniform thickness with coverage of 3-5 mg/cm² of Na₂SO₄-50% V₂O₅ was applied using camel hairbrush on the preheated samples (250 °C). The melting temperature of the salt mixture is 700 °C. The coated samples were dried by heating in an oven at 250 °C for 1 hour.

The boat containing the specimen was inserted into hot zone of tubular furnace set at a temperature of 700 °C. Holding time in the furnace was one hour (in molten salt) after which the boat with specimen was taken out and cooled to room temperature for 20 minutes. Following this, weight of the boat along with the specimen was measured

and this constituted one cycle of the hot corrosion study. Any spilled scale in the boat was also taken into consideration for the weight change measurements. Electronic balance (model AY120, make Shimadzu Analytical (India) Pvt. Ltd, India) with a sensitivity of 10⁻⁴ g was used to conduct the thermogravimetric studies. Weight change values were measured at the end of each cycle with the aim to understand the kinetics of hot corrosion. Visual observation was made after the end of each cycle with respect to colour, luster or any other physical aspect of the oxide scales being formed. During this investigation, the hot corrosion studies were cyclic and were carried out for 50 cycles. The corrosion products of the uncoated and HVOF coated materials are analyzed by using XRD, SEM and EDX to reveal their microstructural and compositional features for elucidating the corrosion mechanisms.

The plots of cumulative weight gain (mg/cm²) as a function of time expressed in number of cycles are shown in Fig.2.1. The weight gain for uncoated, 3%, 5%, 7% at end of 50 cycles are found to be 38.67304, 4.394619, 6.534091, 16.560976 respectively. Evidently the uncoated showed a maximum weight gain during the hot corrosion studies in molten salt environment as compared to the 3%, 5%, 7% HVOF coated samples. Further the weight gain square (mg²/cm⁴) data is plotted as a function of time in Fig.2.2. The plot shown an observable deviation from the parabolic rate law

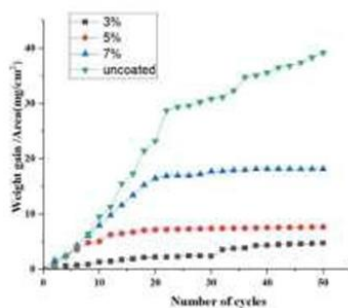


Fig. 2.1: Weight gain/Area vs.No.of cycles graph for uncoated,3%,5%,7% samples subjected to hot corrosion

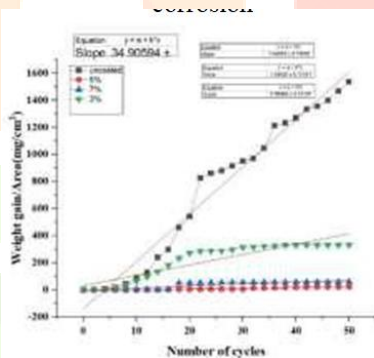
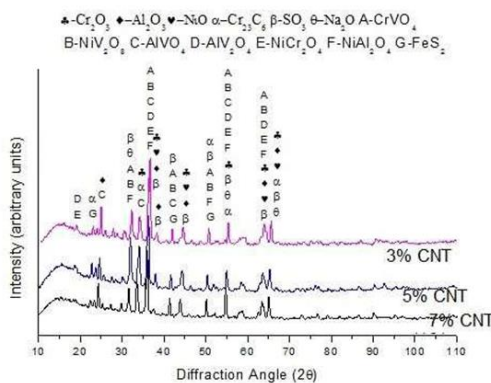


Fig.2.2: (Weight gain/Area)² vs.No.of cycles graph for uncoated,3%,5%,7% samples subjected to hot Corrosion for the uncoated which indicates that the oxide scale is not very protective in molten salt environment .It is evident from the plot that the 3%,5%,7% follow parabolic behaviour. The parabolic rate constants, k_p for the uncoated, 3%, 5%, 6% are 9.696×10^{-10} , 2.124×10^{-9} , 1.4313×10^{-10} , 4.149×10^{-10} g²cm⁻⁴ s⁻¹ respectively.

XRD and SEM Analysis of uncoated material



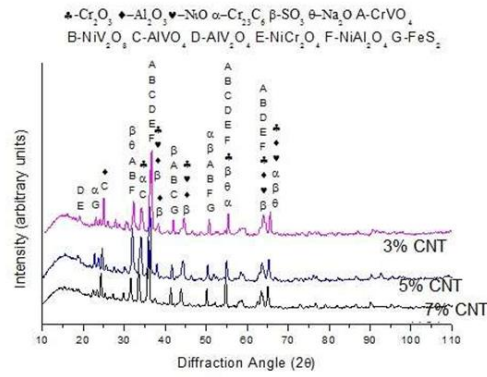


Fig.3: X-ray diffraction patterns for uncoated substrate materials subjected to hot corrosion in Na₂SO₄-50% V₂O₅ for 50 cycles at 700 °C.

X-ray diffraction patterns of the scale formed on the uncoated is shown in Fig.3. The scale on the uncoated contains Fe₂O₃, Na₂SO₄ and V₂O₅. The X-ray diffraction patterns of the top scale, after its exposure to salt environment at 700°C for 50 cycles are shown in Fig. 3. The scale on all the coated substrate under study consisted of Cr₂O₃, NiO, Al₂O₃ and Fe₂O₃ as major phases on the surface. The samples also showed the presence of NiCr₂O₄, Cr₂₃C₆, AlVO₄, AlV₂O₄, NiCr₂O₄, CrVO₄ and FeS₂ as minor phases of oxide scale.

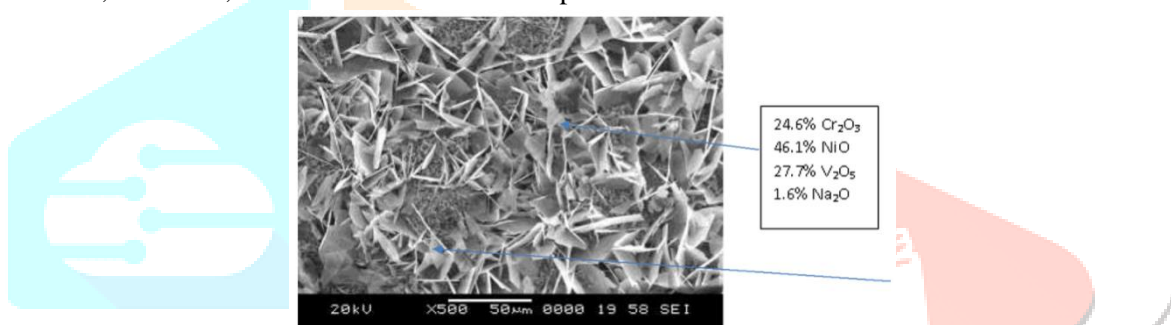


Fig.4: SEM/EDX analysis for NiCrAlY+CNT coated materials

SEM/EDX analysis for NiCrAlY+CNT coated materials subjected to hot corrosion for 50 cycles in Na₂SO₄+V₂O₅ at 700° C. The morphologies of the corroded, CNT+ NiCrAlY coated materials along with DX analysis are shown in Fig. 4. Cr₂O₃ and NiO has been observed for all three coated surfaces as major phases.

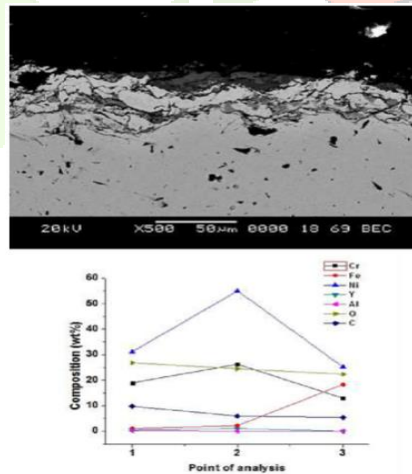


Fig. 5 Back scattered image and EDX analysis (wt%) across the cross-section of the NiCrAlY coated T12 material subjected to hot corrosion for 50 cycles in Na₂SO₄+50% V₂O₅ at 700° C

Conclusions

High Velocity Oxy-Fuel coating was applied to the uncoated and HVOF coated 3%, 5%, and 7% materials using a fused mix powder of NiCrALY and CNT. The 3%, 5%, and 7% substrates, both uncoated and coated, were put through hot corrosion tests in an atmosphere of 50 weight percent Na₂SO₄ and 50 weight percent V₂O₅ at 700°C for 50 cycles of one hour heating and 20 minutes chilling. Each cycle's weight growth is calculated, and it is shown that the increase has a parabolic connection. 5% CNT coated were better at resisting wear and tear than 3% and 7%. On the corroded samples, several phases may be seen according to XRD and SEM examination. Uncoated samples have Fe₂O₃ phase, whereas coated samples have Cr₇C₃, NiO phases.

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