HVOF COATING FOR THE PROTECTION OF BOILER TUBE MATERIAL FROM CORROSIVE ENVIRONMENT

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Abstract

Boiler tube materials are exposed to high temperature environment under corrosion and oxidation is major problem for downtime of thermal power plants. This problem is overcome by thermal coatings, HVOF coating is better than other coatings because of less porosity also offer a low cost-effective and to improve durability of the substrate material. In the present work, developed HVOF coating NiCrAlY and CNT with different ratio like 3, 5,7% on boiler tube material SA213 T12. Hot corrosion studies were carried out by thermogravimetric method by 1hr heating (700℃), and 20 mins cooling at room temperature environment and followed by weight gain checked. The corroded samples were evaluated by advanced microscopic XRD and SEM/EDX to identify the oxide layer.

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

Introduction

Today, thermal plant industries are used extensively to produce power for satisfying the demands of electrical power in double. Though various alternatives exist for the fuel material, coal is still a predominant fuel material for the power plants [1]. This means that boiler components will be exposed to an environment consisting of abrasive, corrosion, and oxidation phenomenon under hostile chemical conditions. Surface engineering of these components helps in protecting the components against said environments [2-5]. 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 wrought material. This includes continuously graded composites and corrosion resistant amorphous phases on the component surface [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 Na_2SO_4-50%V_2O_5. The tests were conducted for 50 cycles, of which each cycle consisted of 1 hour heating at 700 ºC 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 Na_2SO_4-50% V_2O_5 was applied using camel hairbrush on the preheated samples (250 ºC). The melting temperature of the salt mixture is 700 ºC. The coated samples were dried by heating in an oven at 250 ºC 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/cm^2) 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 (mg^2/cm^4) data is plotted as a function of time in Fig.2.2. The plot shown an observable deviation from the parabolic rate law

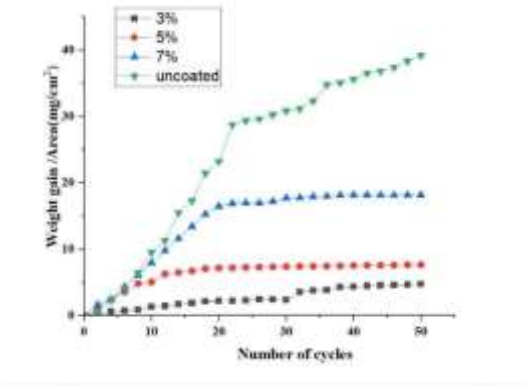


Fig. 2.1: Weight gain/Area vs.No.of cycles graph for uncoated,3%,5%,7% samples subjected to hot corrosion

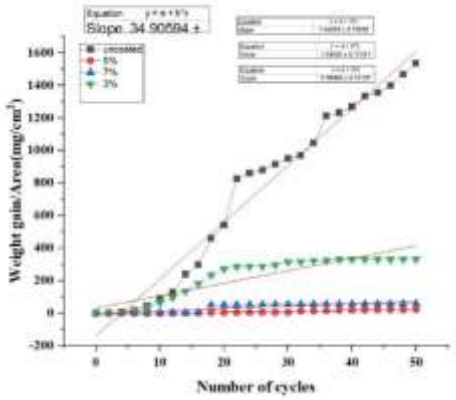
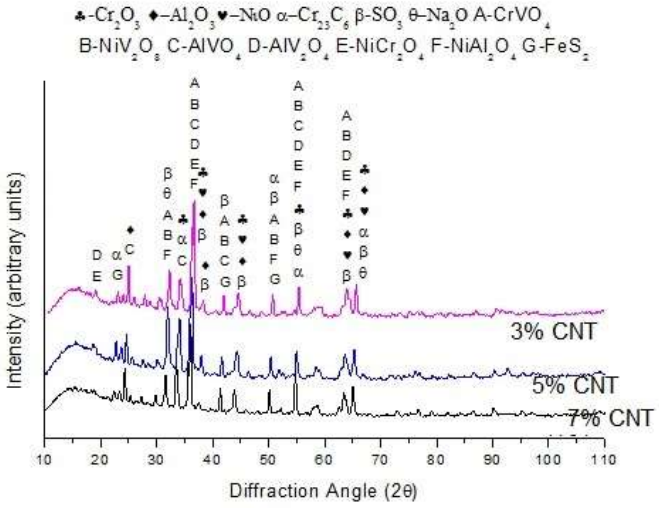


Fig.2.2: (Weight gain/Area)^2 vs.No.of cycles graph for uncoated,3%,5%,7% samples subjected to hot corrosion

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 $9.696*10^{-10}$,$2.124*10^{-9}$,$1.4313*10^{-10}$, $4.149*10^{-10}$ g^2cm^{-4} s^{-1} respectively.

XRD and SEM Analysis of uncoated material



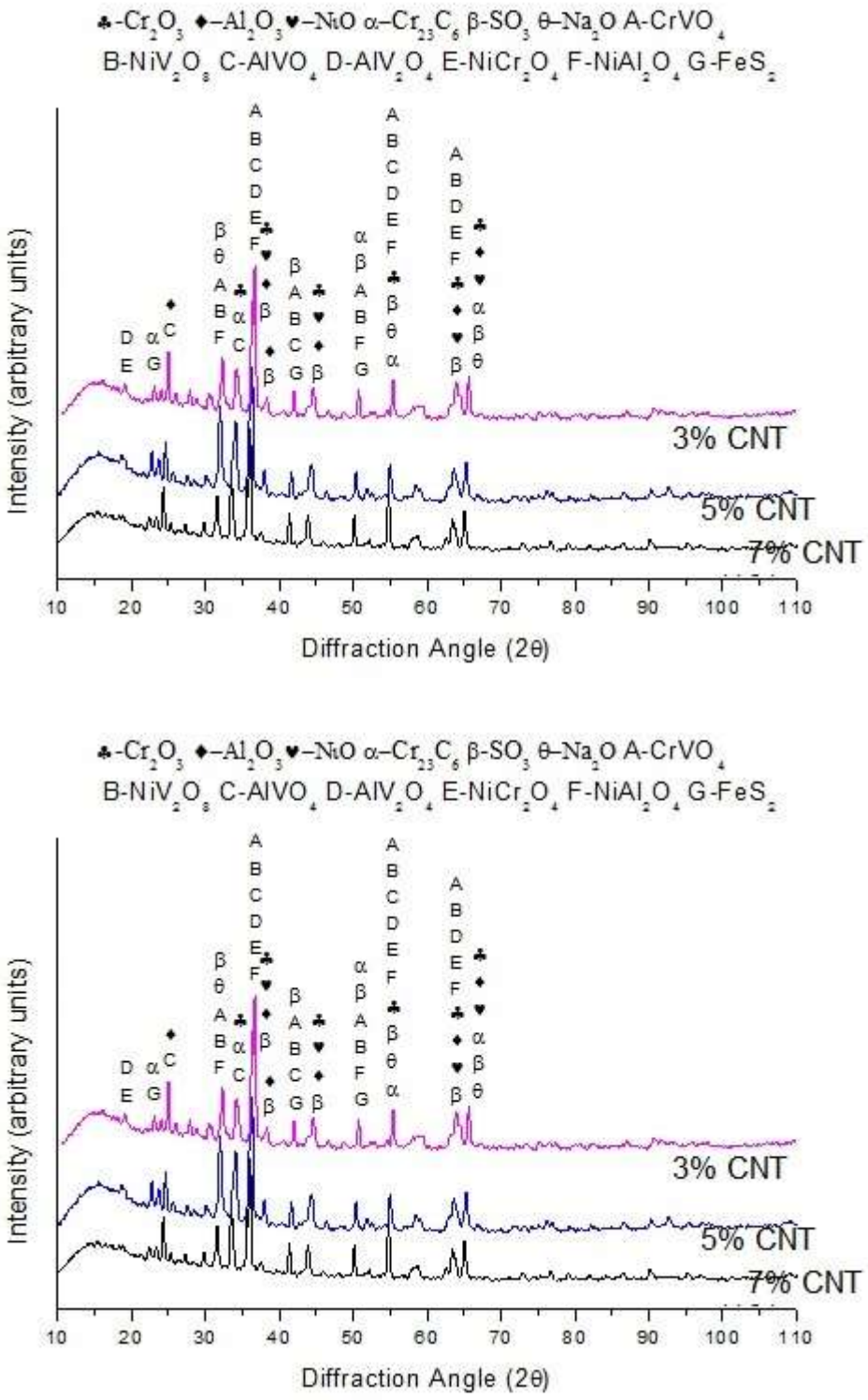


Fig.3: X-ray diffraction patterns for uncoated substrate materials subjected to hot corrosion in Na_2SO_4-50%V_2O_5 for 50 cycles at 700 ºC.

X-ray diffraction patterns of the scale formed on the uncoated is shown in Fig.3. The scale on the uncoated contains Fe_20_3,Na_2SO_4 and V_2O_5 . The X-ray diffraction patterns of the top scale, after its exposure to salt environment at 700ºC for 50 cycles are shown in Fig. 3. The scale on all the coated substrate under study consisted of Cr_2O_3, NiO, Al_2O_3 and Fe2O3 as major phases on the surface. The samples also showed the presence of $NiCr_2O_4$, $Cr_{23}C_6$, $AlVO_4$, AlV_2O_4, $NiCr_2O_4$, $CrVO_4$ and FeS_2 as minor phases of oxide scale.

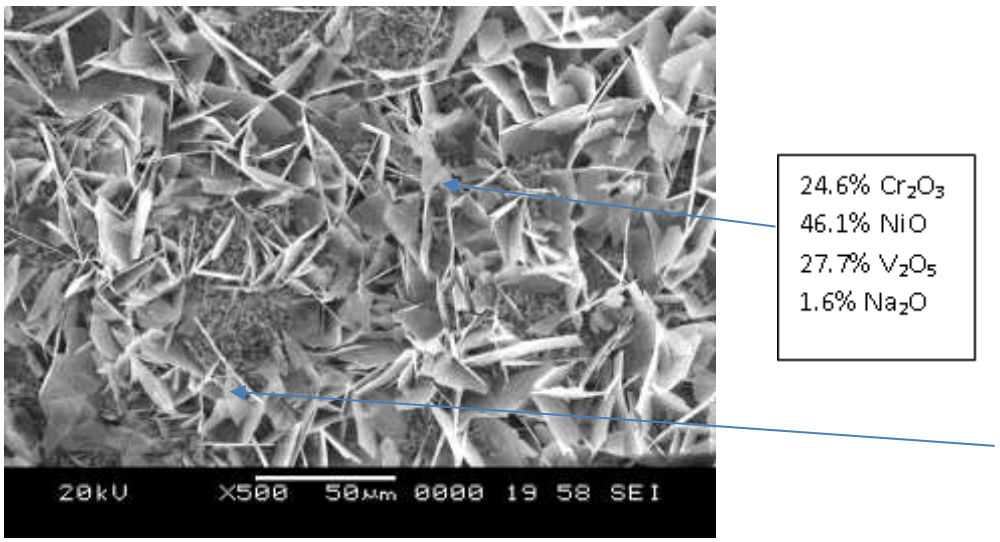
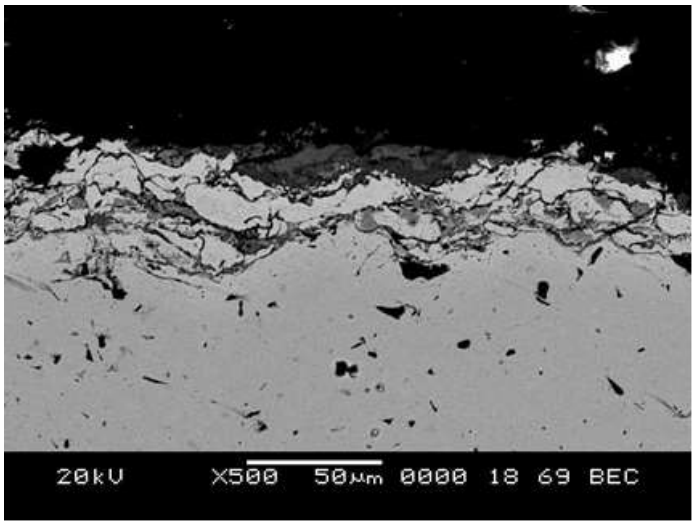


Fig.4: SEM/EDX analysis for NiCrAlY+CNT coated materials subjected to hot corrosion for 50 cycles in Na_2SO_4+V_2O_5 at 700º C.

The morphologies of the corroded, CNT+ NiCrAlY coated materials along with EDX analysis are shown in Fig. 4. Cr_2O_3 and NiO has been observed for all three coated surfaces as major phases.



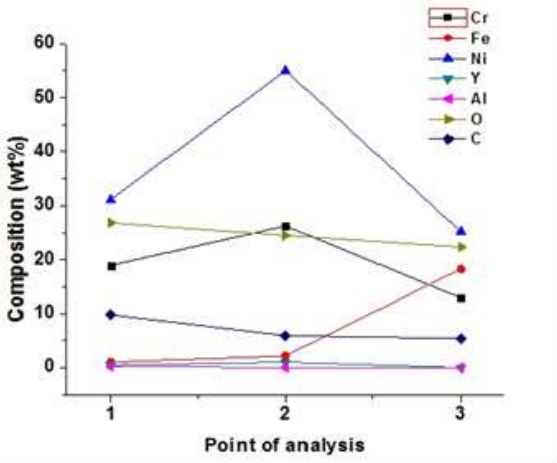


Fig. 5 Back scattered image and EDX analysis (wt%) across the cross-section of the NiCrAlY coated T12 material subjected to hot corrosion for 50 cycles in Na_2SO_4+50%V_2O_5 at 700º C

4. Conclusions

The uncoated and HVOF coated 3%,5%,7% material was coated using High Velocity Oxy-Fuel process using a fused blend powder of NiCrALY+CNT. The uncoated and coated 3%,5%,7% substrates were subjected to hot corrosion experiments under the environment of 50 wt% Na_2SO_4+50 wt% V_2O_5 at 700°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 5% CNT coated were performed good resistance comparing to 3% and 7%. XRD and SEM analysis shows various phases are identified on the corroded samples. Fe_20_3 phase is identified on the uncoated samples and Cr_7C_3, NiO phases are on coated samples.

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