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Degradation Studies of Wire arc Sprayed FeCrBSiMn alloy Coating in Molten Salt Environment

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Abstract

The aim of the current investigation is fabricate the FeCrBSiMn alloy coating onto 310S stainless steel substrate by wire arc spraying process and to study degradation behavior of the coating exposed to molten salt environment (Na_2SO_4-82%$Fe_2(SO_4)_3$) at 900°C under cyclic conditions after 50 cycles. X-ray diffraction (XRD) and scanning electron microscopy/energy-dispersive analysis (SEM/EDS) were used to characterize morphology of coated and uncoated samples for substantiating the degradation mechanisms. The dense and globular morphology of the coatings is observed from the SEM analysis. The maximum microhardness of coating was found to be (430-1060 HV). The coating showed superior hot corrosion resistance as compared to boiler steel due to the formation of protective scale, Cr_2O_3. The protective scale formed at high temperature prevents hot corrosion of coated boiler steel as evident from the morphological studies made by using FE-SEM/EDS. The FeCrBSiMn alloy coating showed good adherence to the 310S substrate with negligible microspalling of the scales.

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Keywords: Wire arc spray; Coating; Microhardness; Hot corrosion.

1. Introduction

Corrosion is a serious problem in superheater of coal fired boilers. Degradation of components occurs due to high temperature oxidation and hot corrosion of boiler tubes in steam generating system of power generation industry [1-8]. Huge amounts of material wastage in super heaters due to the combustion of fuels are reported [9-15]. Literature reveals the wide contribution of thermal sprayed coatings for the protection of turbine engine and boiler tubes against high temperature corrosion attack [16-21]. Recently, there has been an increasing interest in producing Fe-base alloy coatings due to their high strength and hardness, superior wear and corrosion resistance [22]. HVAS process is preferred for the deposition of FeCr base coatings on bare substrate compared to other thermal spray techniques due to its cost effectiveness (operating

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lower cost), high deposit efficiency and less applications difficulties.[23-24] The degradation mechanisms of high velocity arc sprayed FeCr based alloy coatings exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions is scarce in the literature. Therefore, the present work has been focused to study microstructural changes and hot corrosion behavior of FeCr-based coatings after exposure of 50 hours in molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C by using FE-SEM/EDS, XRD and X-ray line mapping, respectively.

2. Experimental

The austenitic stainless steel (310S) was used as substrate in the present study. The chemical composition (wt.%) of the substrate material is given in Table 1.

Table 1 Chemical composition of substrate material

Chemical composition (wt.%) of 310S									
C	**Cr**	**Ni**	**Mn**	**Si**	**Cu**	**Mo**	**P**	**S**	**Fe**
0.0409	25.18	19.14	1.32	0.486	0.189	0.177	0.0202	0.004	Balance

Spectrometric analysis was used to determine the chemical composition of the substrate (310S stainless steel).Specimens with dimensions of approximately 20×15×5 mm^3 was cut from the sheets. The specimens were polished and grit blasted with alumina powders prior to coatings. The size of the alumina powder used for grit blasting the substrate specimens was ~350 µm . FeCrBMnSi alloy coating was deposited on the 310S steel substrates by using the HVAS process, at M/s Industrial Processors and Metallizers (IPM), Pvt. Ltd, New Delhi, India using the standard spray parameters. Fe-base cored wires (TAFA 95 MXC) used as feedstock. Chemical composition (wt %) is listed in Table 2

Table 2 Chemical composition (wt.%) of feedstock wire material.

elements	Cr	B	Mn	Si	Fe
95MXC	< 29	< 3.75	< 1.65	< 1.6	Bal.

The surface of the specimens was cleaned by polishing with alumina powder followed by cleaning by acetone. To remove the moisture, polished samples were pre-heated for 1 hour at 250°C. A coating of uniform thickness with 4-5 mg/cm^2 of Na_2SO_4-82% $Fe_2(SO_4)_3$ was applied with a camel hair brush on the preheated sample (250 ^{0}C). Bare and coated specimens were exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 cycles. One hour heating in a SiC tube furnace, followed by 20 minutes cooling at room temperature (25°C) is adopted in each cycle. The corrosion products and cross sectional analysis of the scale were characterized by X-ray diffraction (XRD), and field emission scanning electron microscope (FESEM, FEI, Quanta 200 FEG-SEM) with EDAX Genesis software attachment; XRD analysis was carried out using a Bruker AXS D-8 Advance powder diffractometer (Germany).

3. Results and discussion

3.1 Coating Characterization

The dense and globular morphology of the coatings is observed from the SEM analysis. The microstructures revealed that coating consist of irregular shaped splats which are interconnected (Fig 1a). The coated samples were cut in cross-section, mounted in transoptic powder and subjected to mirror polishing. Optical microscopy image of cross-section of coated specimen is shown in Fig. 1b. Micro hardness of the coating was determined across the cross-sectioned samples. The micro hardness of the as sprayed coatings was measured by using Micro hardness Tester (VHM-002 Walter UHL, Germany) using 300 grams (2.941N) load applied for a dwell time of 15 sec. The maximum microhardness of as sprayed coating was found to be 1060 Hv.

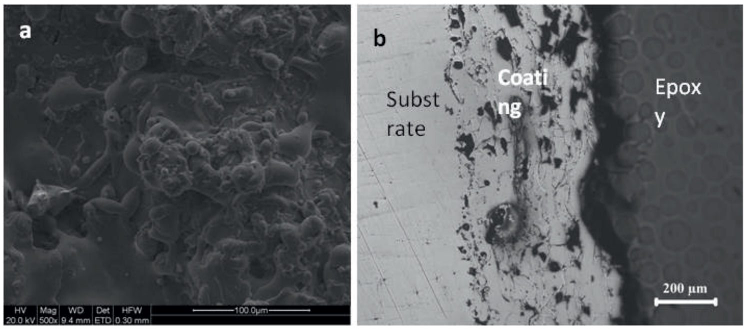

Fig 1: (a) FE-SEM micrograph showing the morphology of as-sprayed coating, (b) Optical microscopy image of the cross-sectional view of the as-sprayed coating.

3.2 Surface morphology

FE-SEM micrographs with EDS analysis for the bare and coated specimens exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 hours are shown in Fig. 2 and Fig. 3, respectively. The scale formed on alloy substrate was porous and less adherent.

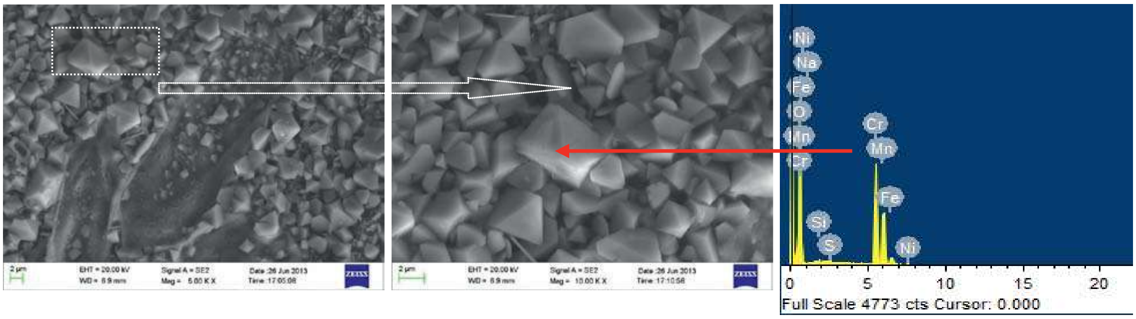

Fig 2: FE-SEM/EDS surface analysis of bare substrate exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 hours.

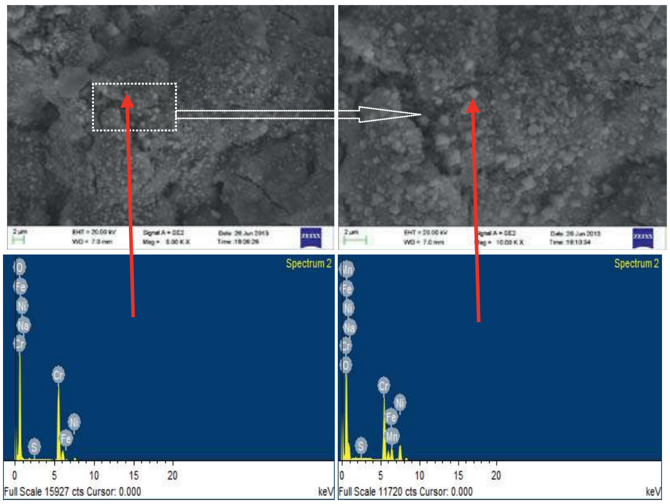

Fig 3: FE-SEM/EDS surface analysis of coated substrate exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 hours.

The scale consists mainly of Cr, Ni, Fe and O. Spalling and cracking were observed in case of alloy substrate as shown in Fig 3. Wang also observed severe spalling of the oxide scale during cyclic study of 2.25Cr-1Mo steel at 740^0 C in coal-fired boiler [25]. The FeCrBMnSi alloy coating deposited on 310S by the high-velocity arc spraying process behaved very well in molten salt environment. The oxide scale of the coated specimen appears as consisting of spongy nodules. EDS analysis of surface indicates Cr, O, Fe, B . Minor amount of Mn, Na, S and Si are detected in the oxide scale. The scale was adherent and minor spalling observed at the edges of the coated specimen.

3.3 Cross-sectional analysis

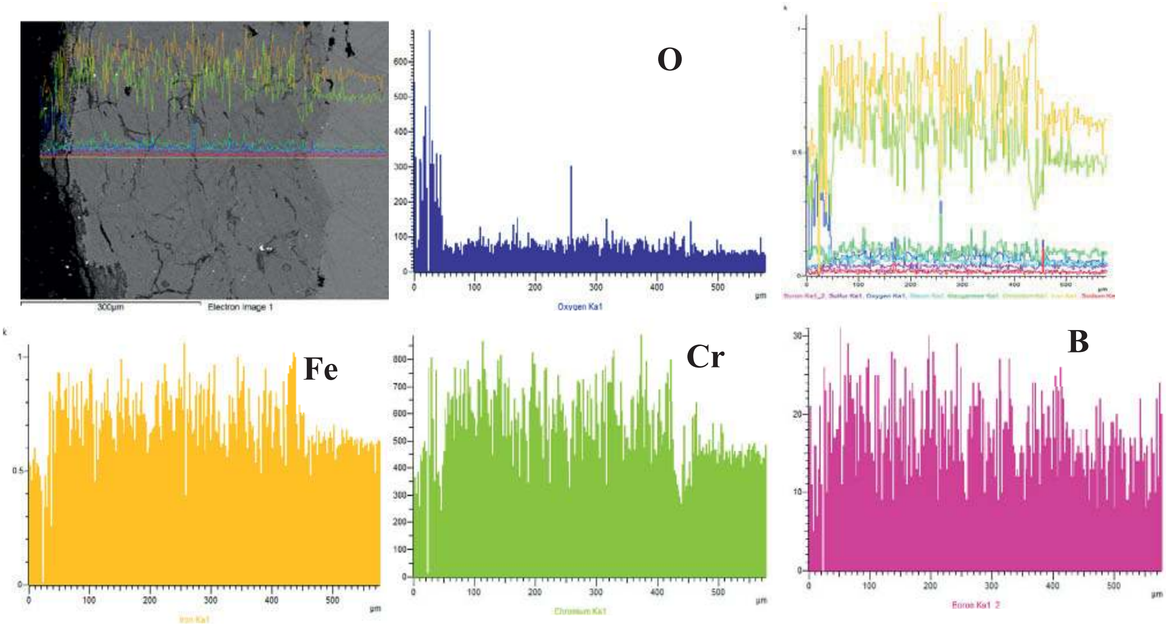

Fig 4: X-ray line mapping of the cross section of coated substrate exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 hours.

The cross-sectional analyses and X-ray line mapping of different elements of the coated specimens exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions after 50 cycles are shown in Fig. 4. The Scale mainly consists of Fe, Cr and O along with significant amounts of B, Si, Ni, Na and S. The coating is intact with the substrate and there is no sign of crack at the interface.

3.4 X-ray diffraction (XRD) analysis

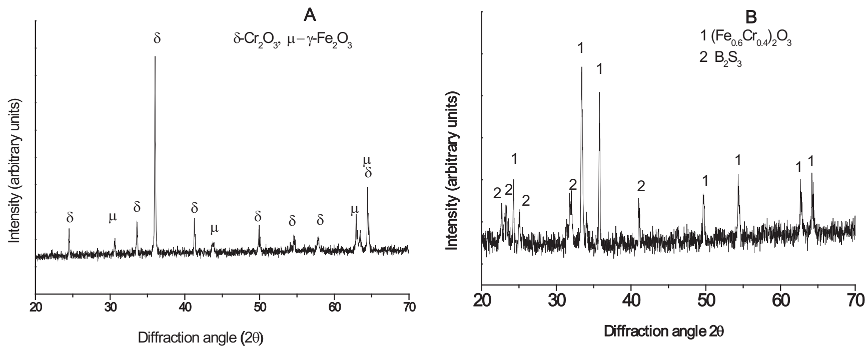

Fig 5: (a) The XRD patterns of the scale formed on (a) bare substrate, and (b) coated substrarte, exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions for 50 hours.

The XRD patterns of the scale formed on bare and coated specimens exposed to molten salt (Na_2SO_4-82% $Fe_2(SO_4)_3$) environment at 900^0C under cyclic conditions after 50 cycles are shown in Fig. 5a and Fig. 5b. XRD analysis of the surface of the bare specimen after 50 cycles at 900^oC revealed the presence of Cr_2O_3 and γ-Fe_2O_3, whereas the XRD diffractograms for the coated specimen revealed the presence of $(Fe_{0.6}Cr_{0.4})_2O_3$ and B_2S_3.

4. Conclusion

FeCrBMnSi alloy coatings were deposited successfully on 310S by the high-velocity arc spraying process. Coating consisted of very dense structure. The maximum microhardness of as sprayed coating was found to be 1060 Hv. FeCrBMnSi alloy coatings exhibited excellent oxidation and wear/spallation resistance. The oxide scale of coated specimen showed the presence of mainly oxides of Cr and Fe which might be responsible for better corrosion resistance. There is perceptible diffusion of some elements from the substrate to the coating.

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