HOT CORROSION BEHAVIOR OF HVOF COATED T11 STEEL IN HIGH TEMPERATURE ENVIRONMENT

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Abstract: High temperature corrosion is an acute form of corrosion occurring at elevated temperature in the presence of aggressive environment. To protect materials from this type of corrosion, a wide variety of materials can be deposited on the materials by several spraying processes. The present study was focused on the hot corrosion behavior of HVOF sprayed Cr3C2-NiCr coatings with different proportions on T11 steel. The hot corrosion behavior of coated as well as bare boiler steels was evaluated in the simulated environment of Na2SO4–60% V2O5 under cyclic conditions at 700oC. The kinetics of the corrosion was approximated by the weight change measurements made after each cycle for a total period of 50 cycles. Each cycle consisted of 1 h heating in a tube furnace followed by 20 min cooling in ambient air. X-ray analysis (SEM/EDAX) techniques were used to analyze the corrosion products. The Cr3C2-NiCr coated steels showed lesser weight gains and the oxide scales remained intact till the end of the experiment. The phases revealed in the oxide scales of the coated specimens were mainly oxides of chromium and nickel which are reported to be protective against the hot corrosion. The conclusion was Cr3C2-NiCr coating on the boiler steel was successful to decrease the hot corrosion.

***IndexTerms:* –corrosion, analysis techniques, Coating**

I. INTRODUCTION

Hot corrosion was first identified as a big problem in the 1940s in link with the degradation of fireside boiler tubes in the coal-fired steam generating plants. A project was begun in israel air force intended towards increasing the awareness of maintenance team to developing technical instructions to avoid it (eliaz et al., 2000). Hot corrosion is a high-temperature analog of aqueous atmospheric corrosion in which molten salts form a film on the metal surface that fluxes, destroys or disrupts the normal protective oxide layer. A thin film of fused salt deposits on an alloy surface, causes accelerated corrosion kinetics. In coal gasification pilot plants, in which some metallic components are brought to corrosive environment at high temperature. The corrosive environment contains sulphur, oxygen carbon etc. Which lead to degradation of the material, failure of components by long term contact. In boiler the common deposits found are na2o, v2o4.5v2o5 which melts at a low temperature (550oc) and above the melting point it corrodes the boiler tube i.e. Super heater tubes etc. When the temperature rises above the melting point lead to developing the corrosive environment in which molten salt diffuse the protective oxide layer (sidhu et al., 2006). It is essential to point out that under hot corrosion conditions, the protective oxide scale should not react with the corrosive environment and at the same time, the corrosive species should not diffuse into the coating. Therefore, development classification of an appropriate coating is of great attention for such applications (gurrapppa, 2000). In boilers, high temperature attack may possibly be due to fire side corrosion, sulfidation or hot corrosion. Fire side corrosion is seen at about 550oc or above in industrial and marine boilers using high sulfur fuel. Vanadium as a contamination in fuel leads to serious corrosion problems because of the formation of v2 o5 which has a melting point of 670oc. It is classified into two categories:

(1) under deposit corrosion of furnace wall evaporator tubes,

(2) under deposit corrosion of superheater and reheater tubes and the upper end of the furnace chamber and in the convection pass (andijani et al., 2004).

II. EXPERIMENTAL METHODOLOGY

Boiler steel "ASTM-SA213-T11" have been selected as the substrate material for the present study after reading many research papers. Some of the power plants used this type of boiler steel in Northern India. The material for the study was made available from the Guru Nanak Dev Thermal Plant, Bathinda (Punjab), India. Chemical composition of ASTM A213 T11 is shown in table 1 and mechanical properties are shown in table 2-:

2.1 PREPARATION OF SUBSTRATE MATERIAL

The sample of the boiler steel ASTM-SA213-T11 in hollow tube shape. This tube was cut with dimensions of approximately 20 mm x 15 mm x 5 mm in rectangular shape. The specimens were refined by using SiC emery paper of 180, 220, 400, 600, 800, 1000 grit sizes.

2.2 DEVELOPMENT OF COATING

2.2.1 Selection of coating material

The samples were coated with Cr3C2-NiCr powder using HVOF thermal spray process. The coatings were deposited at Metallizing Equipment Co. Pvt. Ltd., Jodhpur, Rajasthan (India). The different proportions of coating are shown in table 4.3-

Table 1 Chemical Composition (%) for ASTM A213 T11 boiler Steel

Elements	C	Mn	Si	S	P	Mo	Cr	Fe
Nominal	.15	0.3-0.6	0.5-1	.03	.03	0.44-0.65	1-1.05	Bal
Actual	.161	.441	.282	.005	.013	.512	.914	Bal

Table 2 Mechanical properties for ASTM A213 T11 Low Alloy Steel

Tensile strength(min)	415Mpa
Yield strength(min)	220Mpa
Elongation	30%
Delivery condition	annealed

Table 3 Different Proportions of Coating Material

Substrate no.	**Coating Material**	**Weight percentage**
1	Cr_3C_2	100%
2	$90Cr_3C_2$-10NiCr	90-10%
3	$80Cr_3C_2$-20NiCr	80-20%
4	$65Cr_3C_2$-35NiCr	65-35%

Table 4:- The parameters employed for HVOF spraying

Variant	HVOF spray
Oxygen flow rate	200 SLPM
Fuel (LPG) flow rate	50 SLPM
Air-flow rate	900 SLPM
Spray distance	20 cm
Powder feed rate	25–30 g/min
Fuel pressure	6.00 kg/cm2
Oxygen pressure	8.00 kg/cm2
Air pressure	6.00g/cm2

2.3 Characterization of substrate

The Cr_3C_2-NiCr coating was characterized for its interface development with substrate, microstructure and elemental distribution. The surface analysis was done with SEM/EDAX

III. SEM/EDAX ANALYSIS

The surface morphology and EDAX analysis of Cr_3C_2-NiCr coated samples of ASTM- SA213-T11 are shown in Fig 1

3.1 Experimentation of Substrate

The experiment was done in a Silicon tube furnace in which an simulated environment was created with a temperature of 700oC. The carbide boats were used to place the substrates. These carbide boats were preheated at 250oC for maintaining their performance at high temperature. The substrate were coated with molten salt and then preheated at 300oC then it was weighted with electronic weight gauge. Weight measuring technique was used after each cycle and the cycles were repeated upto 50 cycles.

IV. Coating Characterization

The HVOF coated and non coated samples were characterized for its elemental distribution, microstructure, interface development with substrate and coating thickness. The surface was analyzed by SEM/EDAX and XRD analysis.

4.1 Visual Observation

Visual observation was done after each cycle of the substrate. Any changes in substrate i.e. color change, spalling of substrate, growth of crack etc. were examined by visual observation. Their micrographs were taken after completion of cycles followed by 1 hour heating and 20 minute cooling.

4.2 SEM/EDAX Analysis

The Surface morphology of Cr3C2-NiCr alloy coating on substrate "ASTM-SA213-T11" steel was studied using Scanning Electron Microscope with EDAX software attachment at Thapar University, Patiala. The elemental composition (weight %) present at point was indicated by EDAX genesis software.

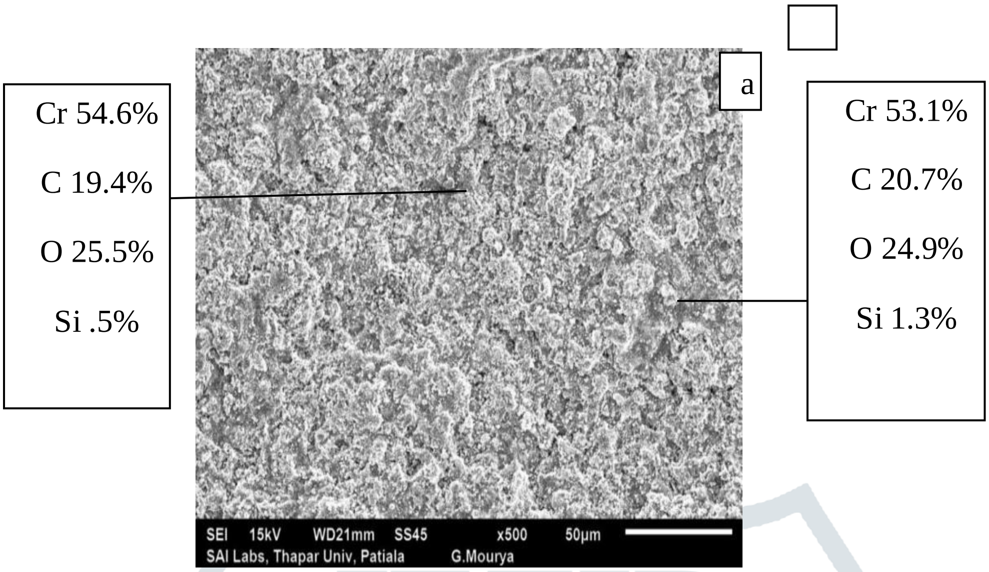
V. RESULTS AND DISCUSSION

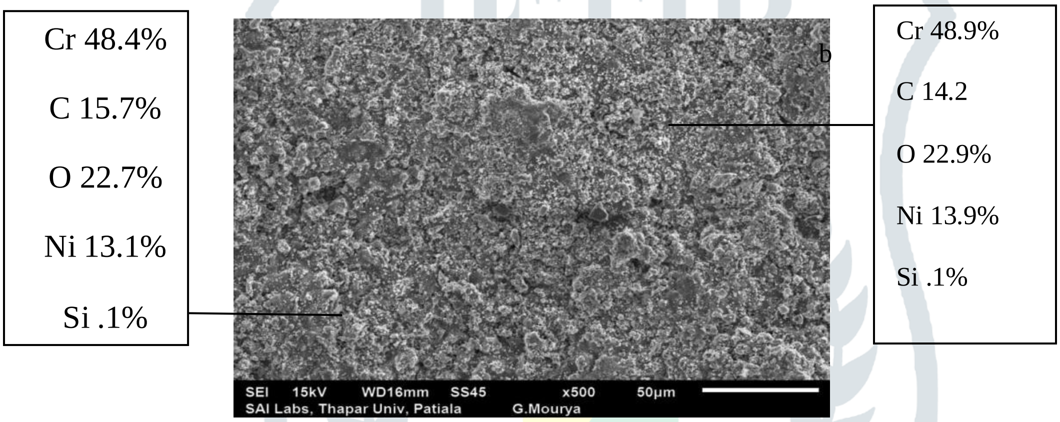
The performance of boiler steel ASTM-SA213-T11 with or without coating with Cr3C2-NiCr using HVOF thermal spray was discussed. All the experiments were done in simulated environment at 700oC under cyclic condition. Visual observation and weight change measurement was analyzed in this chapter. The SEM/EDAX, XRD results was discussed in the following sections.

(1)The substrate 1 of ASTM-213-T11 coated with Cr3C2 heated at 700oC in molten salt environment under cyclic condition. After three cycles the material of the surface was peeled off. After 11th cycle the weight of substrate was suddenly decreased up to 19th cycle after its weight was gradually increased but only a bit. (2) The substrate 2 was coated with 90Cr3C2- 10NiCr. The shining spots on the surface were found. (3)The substrate 3 was coated with 80Cr3C2-20NiCr. After 1st cycle the weight was decreased but after third cycle the weight was gradually increasing in little value. (4)The substrate of number 4 coated with 65Cr3C2- 35NiCr after 2^{nd} cycle irregular pattern appeared. After 18^{th} cycle yellow color spots were observed. (5) The uncoated substrate, the material from surface of substrate was peeled off. After some cycles the color was changed i.e. red brown. Weight was increased in large amount.

VI. CONCLUSION

a. The Cr2C3-NiCr coating was successfully deposited on the samples of ASTM-SA213- T11 boiler steel by high velocity oxy fuel process.
b. High velocity oxy fuel process was successful in forming adherent and dense coating on the substrate of ASTM SA 213 T11 boiler steel.
c. HVOF coating of Cr3C2-NiCr alloy powder was found to be useful in developing hot corrosion resistance in ASTM SA 213 T11 steel in simulated environment at 700^{o}C.
d. The uncoated substrate showed high corrosion rate as compared to coated substrates during exposure to the simulated environment at 700^{o}C.


a
Cr 54.6%
C 19.4%
O 25.5%
Si .5%
Cr 53.1%
C 20.7%
O 24.9%
Si 1.3%
SEI 15kV WD21mm SS45 x500 50µm
SAI Labs, Thapar Univ, Patiala G.Mourya


b
Cr 48.4%
C 15.7%
O 22.7%
Ni 13.1%
Si .1%
Cr 48.9%
C 14.2
O 22.9%
Ni 13.9%
Si .1%
SEI 15kV WD16mm SS45 x500 50µm
SAI Labs, Thapar Univ, Patiala G.Mourya

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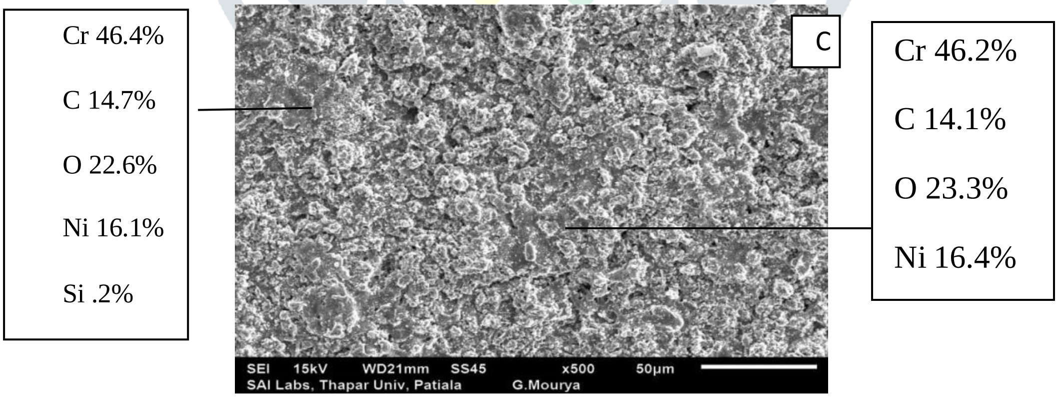
c
Cr 46.4%
C 14.7%
O 22.6%
Ni 16.1%
Si .2%
Cr 46.2%
C 14.1%
O 23.3%
Ni 16.4%
SEI 15kV WD21mm SS45 x500 50µm
SAI Labs, Thapar Univ, Patiala G.Mourya

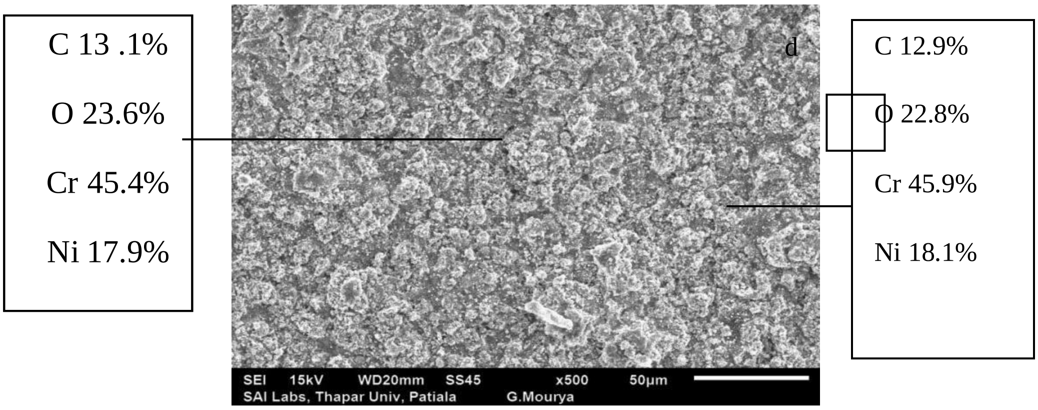

Fig 1 SEM/EDAX analysis of characterization of coated substrates of the boiler steel was:

(a) Cr_3C_2 (b) $90Cr_3C_2$-10NiCr (c) $80Cr_3C_2$-20NiCr (d) $65Cr_3C_2$-35NiCr.

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