Investigation Related to Wear Behaviour of HVOF Sprayed Carbide based Coatings

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***Abstract*- Structure components such as boilers fail in high-temperature situationsbecause of contact of the atmosphere with the material, resulting in erosion, wear and successiveenhanced degradation, or to unintentional overheating due to reduced process control. To overcome this problem, three carbide based coatings namely WC-Co, CrC-NiCr and WC-Co-Cr coating were effectively deposited on ASTM-SA213-T11 boiler tube steel by HVOF thermal spray method. In the present work, wear testing was done to examine the performance of the coating. Wear testing was approved on pin on disc wear test set up by means of two different loads 2kg and 3kg and two disc speeds 500rpm and 800rpm. Wear resistance was determined from the weight loss outcomes.The outcomes of the coated steels have also been equated with the uncoated substrate steel. The samples were categorized by SEM analysis.Coating of CrC-NiCr showed maximum resistance through wear testing.**

Keywords: Wear; HVOF Spray; WC-Co, CrC-NiCr, WC-Co-Cr; Boiler Steel

I. INTRODUCTION

Workable engineering elements have todepend on their majority material properties along with the design and features of their surface. This has been seen in wear resistance elements because their surface must accomplish lot of engineering functions in a range of difficult environments. The study of the material is then greatly reliant onthe surface of the material, surface contact area and the atmosphere under which the material must work[1].The metallic material surface is comprised up of a matrix of individual grains, which fluctuate in size and bond strength reliant on the resources by which the material was produced and on the elements used to make those grains [1]. Structure components as boilers fail in high-temperature situations can be because of contact of the atmosphere with the material, causing in erosion, weardue to reduced process control. Wear is linked to communications between surfaces and more precisely the elimination and deformation of material on a surface as a effect of mechanical action of the reverse surface [2]. Erosion is well-defined as the wear produced by hard particles striking a surface, passed by a gas stream, or entrained in a flowing liquid medium [3]. Solid particle erosion (SPE) for the electric power industry is a main issue, costing an about US$150 million a year in productivity loss, repair costs [4]. At high temperatures, erosion is a main issue in lot of engineering systems, taking steams and jet turbines, boilers [5].Wear because of abrasion mostly rely on the surface of the material visible to the fluid and on the properties of the particles passed with the fluid [6].T11and SA516 substrate steels are commonly used in hydroelectric power plants becauseof their superior erosion properties and tolerable resistance to solid particle erosion.Thermal spraying method is one of the commonlyadaptable hard-facing techniques offered for the use of coating materials to guard components from abrasive wear, adhesive wear,erosive wear[7].The coating material shall be in the form of a powder, wire, ceramic-rod, or molten materials [8]. Thermal sprayed coatings are applied to enhance the wear characteristics of surfaces as they combine different attractive features i.e. resistance to abrasion, high temperature, erosion and corrosive atmospheres [9]. This issue of wear and erosion at high temperatures in boilers can be resolved out by various thermal spray coatings. In the present work HVOF spraying technique has been appliedto deposit coatings on T11 substrate. High-velocity oxy-fuel (HVOF) spraying is a rapidly emerging thermal spray technology for deposition of surface coatings. This is because of the attainment of higher kinetic energy of the particulates and lower melting degrees which empower particle flattening in the plastic state [10]. Components coated by the HVOF method include pump impellers and casings, valve bodies and pipe systems [11].Other benefits of these coatings include the ease of application[12].The process has been most effective for deposition of cermets materials (WC–Co, etc.) and corrosion-resistant alloys (stainless steels, nickel-based alloys, aluminium etc. [13]. Powder particles of the preferred coating material are fed axially into a hot gas stream, thereafter into a spray gun, where they are liquefied and propelled to the work piece surface to be coated [14].T11 substrate steel is mostly used in boiler power plants because of their brilliant resistance to solid particle erosion and wear resistance properties. In this work testing will be carried out on the coated and uncoated T11 steel. Various powders used for

deposition of carbide based coatings are WC-CO-Cr, CrC-NiCr and WC-CO. Wear testing is carried out at different loads and disc speeds. The SEM analysis will also be carried out for various specimens.

II. EXPERIMENTAL PROCEDURE

A. Substrate and Feedstock Powder

Substrate material choosen for the current study is T11 steel designated as ASTM-SA213-T11 steel with chemical composition (weight %) C 0.15, Mn 0.3-0.6, S 0.03 max, P 0.03 max, Si 0.5-1, Cr 1-1.5, Mo 0.44-0.65 and rest is Fe. It was procured from Cheema Boilers Limited, Ban Majra, Kurali (India). For wear testing specimens were cut in cylindrical form each measuring 20mm x 5mm x 5mm approximately. The specimens were polished and grit blasted by Al_2O_3 (Grit 60) before the deposition of the coatings. Three types of carbide based coating powder compositions were deposited on the given steel by the HVOF spraying, which include WC-CO, CrC-NiCr and WC-CO-Cr powder.

B. Deposition Technique and Equipment

HVOF spraying was applied for deposition of coatings. HVOF spray coatings were deposited at Metalizing Equipment Private. Ltd, Jodhpur. The various parameters used during HVOF spraying have been given in Table 1.

Table 1-Process parameters for the HVOF spray process

Process gas	Oxygen
Air pressure	6 Kg/cm^2
Process gas pressure	10 Kg/cm^2
Powder feed rate	40g/min
Carrier gas flow	18 kg/hr
Spray distance	6 inches
Coating thickness	225-250µm

C. Wear Experiments

Wear tests were executed on the pin specimens that had flat surfaces in the contact regions. The pin was held static against the counter face of a rotating disc made of En-32 steel at 100 mm track diameter. En-32 steel is a plain carbon steel; case hardened 62 to 65 HRC as provided with the pin-on-disc machine.

After that SEM analysis on Sophisticated Analytical Instruments Laboratories, Punjabi University, Patiala (Punjab) was done on all samples.

III. RESULTS AND DISCUSSIONS

A. Hardness Analysis

Hardness analysis was prepared for all the coated and uncoated specimens of T11 steel. Hardness values for substrate T11 steel is shown in Table 2. From all the specimens, T11 steel having CrC-NiCr coating indicated maximum hardness and T11 steel having WC-CO coating indicated minimum hardness. Sequence based upon overall hardness values for the coated and uncoated T11 steel was as follows:

CrC-NiCr>WC-Co-Cr>WC-Co>Uncoated T11 steel.

Table 2-Hardness values for substrate T11 steel

S.No.	Coating	Hardness values (HRA)
1.	Uncoated T11	216
2.	WC-CO coating on T11	228
3.	WC-CO-Cr coating on T11	235
4.	CrC-NiCr coating on T11	236

The results presented that maximum hardness was obtained by CrC-NiCr coating. Further addition of Cr to WC-Co increases its hardness value and has higher contiguity [15].

B. Wear Testing

T11 steel was examined for wear testing on the pin on disc wear test set up. The wear rate of the uncoated and coated steels was carried out at two loads i.e. 2kg and 3kg and at two disc speeds i.e. 500rpm and 800rpm.The test was conducted using disc track diameter 80mm. For each sample six reading were taken and the time interval for each reading was 2mins.

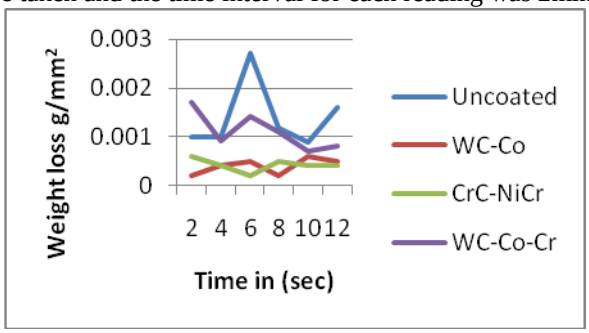

Figure 1- Wear rate for coated and uncoated T11 steels at 2kg load and 500rpm

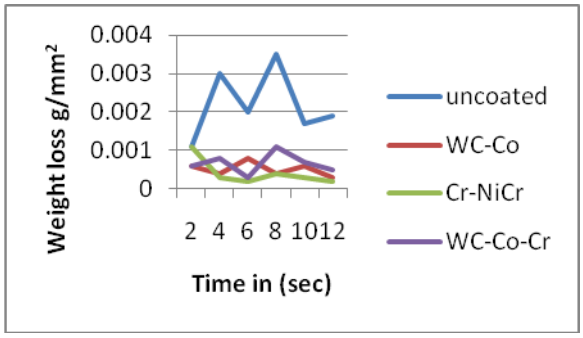

Figure 2- Wear rate for coated and uncoated T11 steels at 2kg load and 800rpm

Weight loss after each cycle (g/mm^2) at both loads 2kg and 3kg and at both speeds 500rpm and 800rpm during wear testing has been reported in Table 3 and 4. It can be inferred from the plots that the necessary

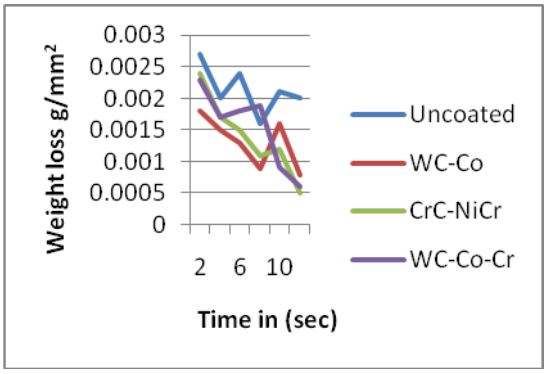

Figure 3- Wear rate for coated and uncoated T11 steels at 3kg load and 500rpm

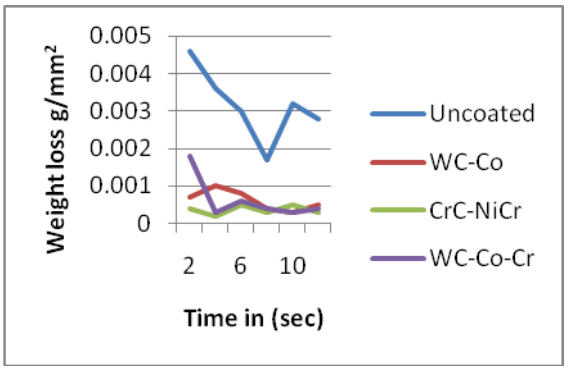

Figure 4- Wear rate for coated and uncoated T11 steels at 3kg load and 800rpm

protection against wear has been provided by all the coatings as the weight loss values for the coated steels are smaller than those for the uncoated steel.

It can be clearly seen from the figure 1-4that uncoated T11 steel conceived higher weight loss than all the coated T11 steels. It can be observed that T11 steel having coating WC-Co was least resistant and coating CrC-NiCr was most resistant to wear rate in comparison to other coatings. Sequence of the wear resistance based upon overall weight loss for the coated and uncoated T11 steel at 2kg and 3kg load for speed 500 rpm and 800 rpm was as follows:

CrC-NiCr>WC-Co-Cr>WC-Co> Uncoated T11 steel

The results presented that maximum resistance to wear was obtained by CrC-NiCr coating. It is known that addition of Cr to WC–Co increases binding of the metallic matrix with the WC grains and provides better wear resistant coating. Thus, WC–Co–Cr is considered to be a potential wear resistant coating material as compared to WC–Co coating [16].

C. SEM analysis of wear tested samples

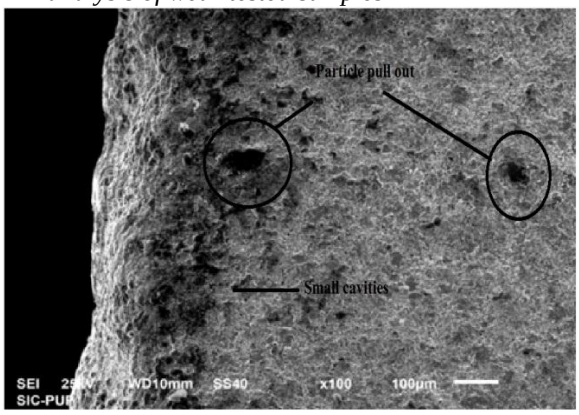

Figure 5- SEM micrograph of WC-Co coated T11 steel after wear testing

From the SEM micrograph (figure 5) it can be seen that WC-Co coated T11 steel after wear testing shows the presence of particle pull out and small cavities are showing material removal. The blackish area at the sides of specimen represents deformation ofmaterial in the form of cavities. From the SEM micrograph (figure 6) of WC-Co-Cr coated T11 steel after wear testing, presence of grooves and cavities shows the deformation of material during wear testing. Some areas also show delamination. From the SEM micrograph (figure 7)of CrC-NiCr coated T11steel after wear testing it can be clearly observed that this coating possess uniform and least wear loss than all other coatings with very small cavities and grooves.

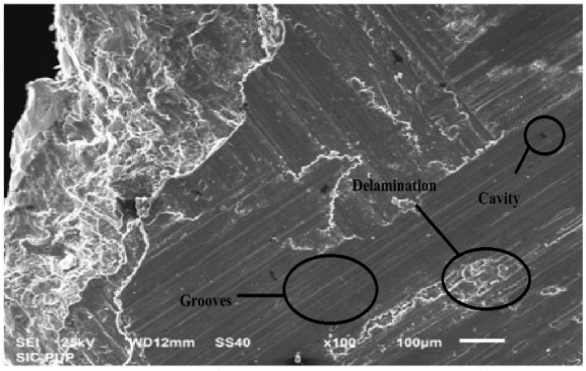

Figure 6- SEM micrograph of WC-Co-Cr coated T11 steel after wear testing

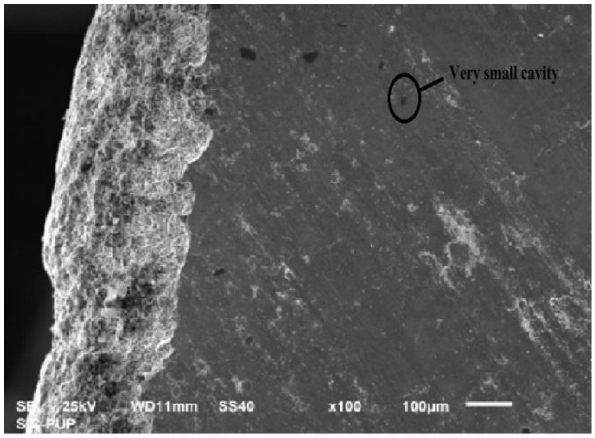

Figure 7- SEM micrograph of CrC-NiCr coated T11 steel after wear TESTING

IV. CONCLUSIONS

Conclusions from the present study have been summarized as given below.

- Uncoated substrate T11 possessed higher weight loss in comparison to coated T11 substrates at both loads i.e. 2kg and 3kg and at both speeds i.e.500rpm and 800rpm during wear testing.
- During wear testing, at both 500rpm and 800rpm at same load 2kg, CrC-NiCr coating possessed least weight loss in comparison to the WC-Co-Cr and WC-Co coatings, which showed that, CrC-NiCr possess the least wear rate.
- During wear testing, at both 500rpm and 800rpm at same load 3kg, WC-Co coating possessed highest weight loss in comparison to the CrC-NiCr and WC-Co-Cr coatings, which showed that, WC-Co possesses the highest wear rate.
- At both speeds 500rpm and 800rpm and at both loads 2kg and 3kg,during wear testing CrC-NiCr coating possessed least weight loss in comparison to the WC-Co and WC-Co-Cr coatings, which showed that, CrC-NiCr possess the lowest wear rate.

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