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CHARACTERIZATION OF AS-SPRAYED STELLITE-6 COATING DEPOSITED BY D-GUN SPRAY PROCESS FOR PERSPECTIVE WEAR APPLICATION

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Abstract-Studies have shown that Stellite-6 coatings are suitable for protection against wear. This paper reports perspective applications of as-sprayed Stellite-6 coating deposited through Detonation gun spray on SS-310 steel by recording exhaustive analysis. For characterization, surface of coating layers were analyzed by Scanning electron microscope (SEM), Energy Dispersive Spectroscopy (EDS) and X-Ray diffraction (XRD) and X-mapping analysis. SEM images of specimen surface showed that coating was uniformly deposited on SS-310 through Detonation gun spray technique. X-Ray diffraction (XRD) patterns revealed Co and Cr phases along with their secondary oxide phases. Surface roughness, micro-hardness followed by scratch test was also recorded. Enhancement of Micro-hardness was followed by protective formation of oxide layers observed may benefit against wear applications.
Keywords: Detonation gun spray (D-Gun), SS-310, X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), Stellite-6 (ST-6)

1. INTRODUCTION

Wear occurs when the surfaces make contact with each other. It imparts loss of wear from the contact surface and result in less strength and corrosion resistance. To recover the hardness of material withstands the load, deposition of suitable alloys with high hardness. Different modes of wear are principal when two sliding parts are in contact with each other. The resistance of wear will be enhanced by thermal spray coating with various special alloys which would recover wear [1-4]. Stellite-6 has excellent resistance towards abrasion, corrosion, galling and cavitations form of wear without affecting the base metal and properties. It is a Cobalt and chromium base alloy material with other alloying elements such as, tungsten, carbon, iron and nickel. It consists of complex carbides mixed in a Co-Cr solid solution strengthened alloyed surrounding substance with the dendritic structure. The wear resistance of Stellite-6 alloy is due to its high wear resistant properties formed by hard carbides dispersed in a cobalt alloy atmosphere [5-8]. When the Stellite-6 is coated over steels by D-Gun coating process directly, there is admixture of Stellite-6 alloy and base metal, resulting in higher iron content in the overlay. It alters the microstructure of coated Stellite-6 and base metal and affects its mechanical properties. [6].

2. EXPREMENTAL PROCEDURE

2.1. Substrate Steels

The composition and grade of the substrate was tested at Patiala Metallurgical Lab, Industrial Focal Point, Patiala, (Punjab). The results are as reported in table 1 the substrate has high percentages of Cr and Ni. Stellite-6 coating with composition is shown in table no. 2. Stellite-6 Powder was layered on SS-310 by Detonation Gun Spray technique, which has a wide range of applications in wear, especially when the service conditions are stringent from the point of wear.

Table 1: Chemical composition (wt %) of SS-310

Element Analysed	Result % (obtained)
Cr	24.82
Ni	19.80
Mn	1.52
Si	0.69
C	0.10
P	0.025
S	0.022
Mo	Traces
V	Traces

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Table 2: Chemical composition (wt %) of Stellite-6

Element Analysed	Result % (obtained)
Co	59.67
Cr	28.65
W	3.96
Si	0.56
C	7.17

Specimens of cylindrical shape with dimensions of approximately 30mm length and 6mm dia. in were cut from the SS-310 rod. The surface of Specimens on end faces was finished by using emery papers and grinding was followed by polishing with 1/0, 2/0, 3/0 and 4/0 grades polishing papers.

2.2. Development of Coatings

Specimens were grit blasted with alumina powder before coating. Commercially Stellite-6 alloy in the powder form were used as the coating material in the study. The coating powders were made available by SVX POWDER M SURFACE ENGINEERING Pvt. Ltd., Greater Noida (India).

Detonation gun spray consists of a discharge pipe, which is connected to a combustion chamber at one side. A mixture of acetylene, oxygen and spray powder is fed into the chamber and detonated using a spark. The shock wave is produced in the pipe accelerates by the spray particles. These are then heated at the front of the flame and propelled at high speed in a focused jet onto the prepared work-piece surface. After each detonation, the combustion chamber and the pipe are purged with nitrogen (Figure 1). The very high quality standard of these spray coatings generally justify the higher cost involved in this process.

Figure 1. Detonation gun spray system set up

Table 3: Process parameters employed during Detonation Gun Spray Process

Parameters	ST-6
Pressure of Fuel gas (Oxygen)	2 bar
Pressure of Fuel gas (Acetylene)	1.5 bar
Pressure Carrier gas (Nitrogen)	3 bar
Flow rate of Fuel gas (Oxygen)	3120 (SLPH)
Flow rate of Fuel gas (Acetylene)	2400 (SLPH)
Flow rate of Carrier gas	800 (SLPH)
Stand-off distance (mm)	150 mm
Shot frequency (shots/s)	3 (held constant)
Substrate temperature (°C)	110
Coating thickness (microns)	200-250

Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 3890°C and the velocity of the shock wave can reach 3500m/s. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage and also accelerate the particles to a velocity of 1200m/s. These particles then come out of the barrel and impact the component held by the manipulator to form a coating. The coating thickness developed on the work piece per shot depends on the ratio of combustion gases, powder particle size, carrier gas flow rate, frequency and distance between the barrel end and the substrate. Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second. [9] All the process parameters, including the spray shown in Table-3.

2.3. Characterizations of as Sprayed Coatings

2.3.1. SEM/EDS Analysis

The Stellite-6 coated samples were characterized by SEM/EDS analysis, to study the surface micro-structural features, and composition of the coatings. SEM (JEOL, JSM – IT 100) along with EDS was used to observe the surface at National Institute of Technical Teacher Training and Research, Chandigarh (NITTTR). The coated samples were then fixed on stub and top surface was connected with the stub/carbon tape using silver conductive adhesive paste.

2.3.2. X-Ray Diffraction Analysis

The X-ray diffraction of top surface of coating was analyzed by using a Panalaytical X'Pert, Pro multipurpose diffraction (MPD) at Indian Institute of Technology, Ropar (Roop Nagar), India with Cu (Anode Material) Kα radiation and nickel filter at Generator Settings 40 mA. under a voltage of 45 KV. These specimens diffracted with 2º/min speed in 2ɵ range from 10º to 110º and radius was 240 mm.

2.3.3. Surface Roghness and Microhardness

Mitutoyo SJ-310 portable surface roughness tester was used to measure the surface roughness of the as sprayed coating specimen and base material SS-310 at Nation Institute of Technical Teacher Training and Research, Chandigarh (NITTTR).

The micro-hardness of the Stellite-6 coating specimen and base material SS-310 was measured using Vicker Micro-hardness Machine FIE make at Chandigarh Industrial & Tourism Development Corpn. Ltd., Chandigarh in CITCO-IDFC Testing Laboratory. 1 kgf load was applied for 15 second to the indenter for penetration of as sprayed coatings. Five tests were carried out at each point on the specimen and the average value was taken at each point. Hardness value was calculated from the relation $HV = 1854.46 * F/d^2$ where F is the load in g and d is the diameter of the indenter in micrometer.

2.3.4 Scratch Test

The mechanical properties and especially adhesion of coating to substrate material were evaluated by the scratch testing using DUC.M (Scratch Tester TR – 102) at Nation Institute of Technical Teacher Training and Research, Chandigarh (NITTTR) in material testing Laboratory.

The surface of coated sample was cleaned from contaminants such as oil, grease and moisture prior testing. The diamond stylus, Rockwell C, had geometry with angle of 120° and spherical tip radius 200 µm. The traction force and acoustic emission (db) signals were recorded, along with normal load in total length of stroke.

3. RESULTS

3.1 SEM/EDS Analysis

SEM of as sprayed Stellite-6 coating deposited by D-Gun on SS-310 is shown in Fig. no. 2. The result shows cloudy morphology with irregular shaped splats. Some voids are also present in SEM analysis.

Energy dispersive spectroscopy (EDS) of as sprayed Stellite-6 coating deposited by D-Gun is shown in Fig. no. 3. The results disclose higher percentages of Co and Cr. Moreover, W, C, and Si present in small amounts.

3.2 X-Ray Diffraction (XRD) Analysis

XRD of as sprayed Stellite-6 coating deposited by D-Gun on SS-310 is shown in Fig. no. 4. It has been observed in the results that Co and Cr phases are present as higher phase and Cro phase are present as lower phase.

3.3. X-ray mapping Analysis

X-ray mapping of as sprayed Stellite-6 coating deposited by D-Gun on SS-310 is shown in Fig. no. 5. The area mapping suggested that these splats consist of Co, Cr and W chemical compounds distributed uniformly throughout the coating.

3.4. Scratch Test Analysis

Scratch test of as sprayed Stellite-6 coating deposited by D-Gun on SS-310 was performed at progressive load the measurement condition. As it can be seen from the experiment was performed on Stellite-6 coated sample at different loading rates. The test was run with linearly increased from 20 to 100 N.

It has been measured the adhesion of coating to substrate by determine the critical load L_c based on the acoustic emission. Also determine the maximum force and the length of diamond indicator displacement until the coating delaminated.

Scratch Velocity 0.20 mm/sec the first critical load (Lc_1) is 30.49 N and corresponds to the point at which first damage is observed at 0.62 mm distance with Traction Force 12.05 (N) and Acoustic emission 43.95 (db) is shown Fig. no. 6. The second critical load (Lc_2) is 48.62 N at 1.53 mm distance with Traction Force 16.83 (N) and Acoustic emission 41.21 (db) and it is the point at where damage becomes continuous. The delamitation of coating begin at a critical value of 68.98 N (Lc_3) at 2.53 mm distance with Traction Force 26.54 (N) and Acoustic emission 53.73 (db). The complete delamitation of coating takes place at value of 97.83 N (Lc_4) corresponding to a diamond indenter displacement of 3.99 mm with Traction Force 26.45 N and 38.17 (db) Acoustic emission.

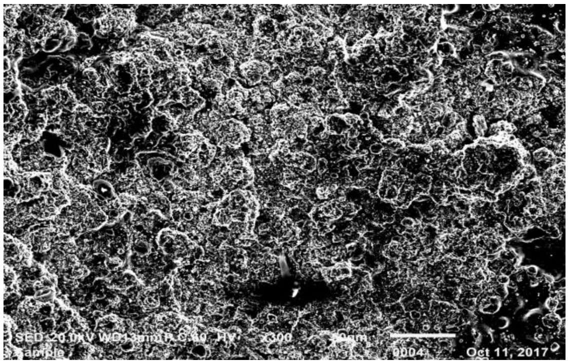

Figure 2. SEM Analysis

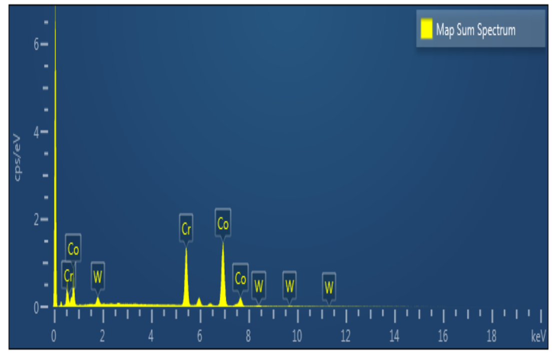

Figure 3. EDS Analysis

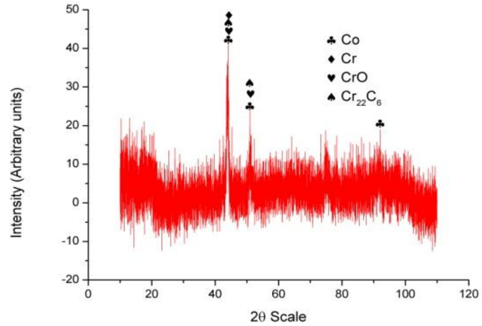

Figure 4. X-Ray Diffraction (XRD) Analysis

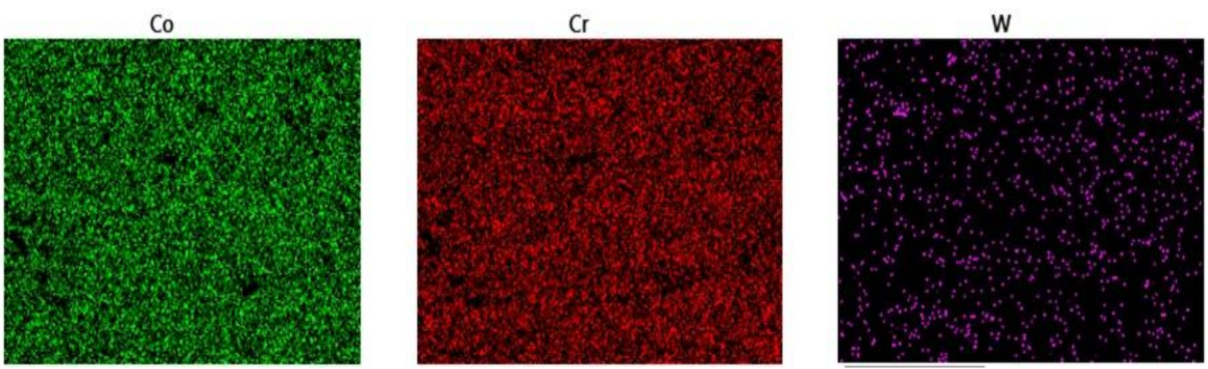

Figure 5. X-Ray mapping of As-sprayed Stellite-6 coating

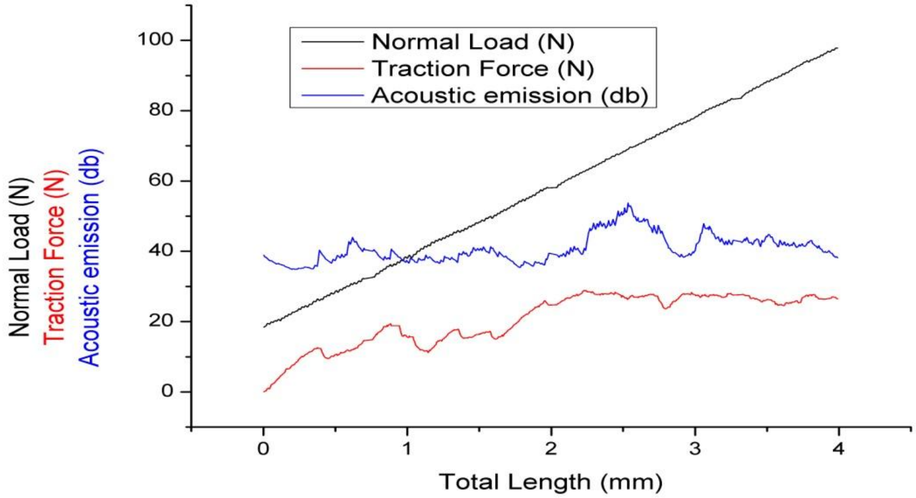

Figure 6. Scratch Test Analysis

3.5. Micro-hardness and Surface roughness analysis

Micro-harness test performed on coating substance and base material. The results of hardness shown in table 4 the average value of base material is 221 HV and Stellite-6 coated sample 558 HV. Surface roughness (Ra) of D-gun sprayed coating was found to be 4.44µm.

4. DISCUSSION

Stellite-6 coating has been successfully deposited by d-gun spray process on ss-310 above said conditions in the present work.

SEM/EDS analysis is showed that the produced by D-Gun spray process have very dense structure with low porosity due to high impact of powder particles. The surface morphology of as sprayed coating has cloudy morphology with uneven splats with oxides. Similar finding of such morphology along with oxide phase in D-Gun sprayed Stellite-6 coating have reported by Singh B. et al. [10]

XRD analysis of as sprayed Stellite-6 coating deposited by D-Gun on SS-310 depicts the formation of Co and Cr as prominent phase along with CrO and $Cr_{22}C_6$ as secondary phase which are in good agreement with finding Singh B. et al. [10] and Rocco et al. [11] have also reported similar phase in laser deposition of Stellite-6 coating.

Table 4: Results of Micro-hardness

Nomenclature of Sample	SS-310 (Base)	ST-6 (Coated)
HV	221	560
HV	220	555
HV	219	554
HV	220	560
HV	223	563
HV Average	221	558

The micro-hardness value of as sprayed Stellite-6 coating of the order of 558 Hv and micro-hardness of the substrate steel is of 221 Hv. The increase in micro-hardness may be perhaps due to high speed impact of coating particles as reported by Vuoristo et al. [12], Chen and Hutchings [13] and Westergard et al. [14]

Utu et al. [15] discussed the application of scratch testing method in order to determine the critical load Lc_1- Lc_4 that permit the adherence strength evaluation of coating deposited on low carbon steel substrate.

5. CONCLUSION

1. Stellite-6 coatings could be successfully obtained by deposited Detonation gun spray process on the given hydro turbine blade steels (SS-310).
2. The SEM/EDS revealed cloudy morphology and the as sprayed coatings are hardly bonded with substrate, homogenous and free from gaps and pores, which is a characteristic feature of good adhesion between the coating and the substrate.

3. The XRD analysis for Stellite-6 coating showed the presence of Cr and Co present as higher phase and CrO as lower phase. The XRD results were in good agreement with EDS analysis of the coatings. X-ray mapping confirmed that the elements are coexisting in the splats.
4. The scratch test results and micro-hardness of the coatings was recorded higher as compared to micro-hardness of the substrate which is reported as beneficial for wear related applications.

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