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SURFACE ANALYSIS OF EN8 SUBSTRATE MATERIAL USING DETONATION SPRAY COATING PROCESS BY DIFFERENT ALLOY POWDERS

Engineering

KEYWORDS: Detonation Gun Spray, Wear, Pin-on-Disc Rig, CWR

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ABSTRACT

In the present paper, detonation gun spray surface modification technique has been used to enhance the wear resistance of EN8 steel substrate. After an exhaustive literature survey, alloy powders WC – 10Co -4Cr and Al2O3-13TiO2 have been selected to deposit on the substrate steel specimens with the help of detonation gun spray process. The surface analysis of the coated and uncoated specimens was investigated with the help of Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray (EDAX). On the basis of SEM/EDAX analysis of the coatings after the sliding wear at a normal load of 70N, sliding velocity of 1m/s after a total sliding distance of 5400 meters. It may be concluded that the both the coatings (Al2O3-13TiO2 and WC–10Co–4Cr) could reduce the extent of wear damage as compared to the uncoated EN8 steel.

1. INTRODUCTION

Wear and Friction are responsible for many problems and large costs in a modern civilization and engineers and designers always must take these factors into account when constructing different equipments [1]. The economic losses due to friction and wear amount to about 1 to 2.5% of the gross national product [2]. In year 2002, More than 50 % of all wear-related failures of industrial equipment are caused by abrasive wear. The estimated costs of abrasive wear are between 1 and 4 % of the gross national product of an industrialized nation. [3].

When two surfaces rub against each other, wear occurs. Individuals and industry tend to focus on the wearing surface that has the greatest impact on their own economic situation. Therefore, as the wear is a surface phenomenon and occurs mostly at outer surfaces, therefore it is more appropriate and economical to use latter method of making surface modification i.e. surface engineering than using the former one [4]. Surface engineering is an economic method for the production of materials, tools and machine parts with required surface properties such as wear resistance. The wear process of rollers is integrally affected by various factors such as abrasive wear, oxidation wear, cracking by thermal fatigue, heat impact, fatigue wear and sticking of rolled material onto the roller surface. Wear also involves microscopic and dynamic processes occurring at interfaces between the roller and the rolled material and is almost impossible to observe directly [5].

1.1 Thermal Spraying

Thermal Spraying is a family of processes that use combustion or plasma energy to heat and accelerate the millions of particles, which impact onto the surface of a target/forming remarkable continuous uniform solid layer [6]. Coatings are used in a wide range of applications including automotive systems, boiler components, power generation equipments, chemical process equipments, aircraft engines, pulp and paper processing equipments, rollers and concrete reinforcements, orthopaedics and dental, land-based and marine turbines and ships [7]. Heath et al. [8] have summarized the thermal spray processes that have been considered to deposit the coatings are enlisted below:

i. Flame spraying with a powder or wire,
ii. Electric arc wire spraying,
iii. Plasma Spraying
iv. High Velocity Oxy-Fuel (HVOF) spraying,
v. Spray and Fuse.
vi. Detonation Gun Spray Process

1.2 Detonation Spray Process:-

D-gun spraying is one of the most promising thermal spray techniques and was originally developed and patented by Union Carbide (now Praxair) Since then, the D-gun coating process has been used for wide applications such as in the aircraft industries of the United States, Japan, and the former Soviet Union [9].A detonation gun consists of a water cooled barrel several feet long and about one inch in diameter with some associated valving for gases and powder, as shown schematically in Fig.1 [10]. A carefully measured mixture of gases, usually oxygen and acetylene, is fed to the barrel along with a charge of powder (usually with a particle size less than 100 microns). A spark is used to ignite the gas and the resulting detonation wave heats and accelerates the powder as it moves down the barrel.

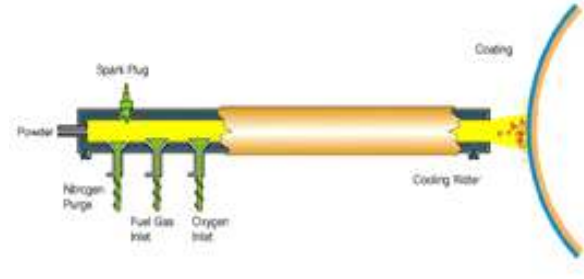


Fig. 1 Schematic Diagram of the D-gun Spray Process [10]

2. Material and Methodology:-

2.1 Selection of the Substrate Materials

Selection of the substrate material for the present study has been made on the basis of applications for bulldozer rollers. The chosen materials are two carbon steels, designated as mild steel MS and En8. Table 1 shows chemical composition of the MS and EN8 steels substrate.

Table 1 Chemical Composition (Wt %) of the EN8 Substrate

	C	Mn	P	S	Si	Ni	Cu	Fe
EN8	0.40	1.03	0.027	0.01	0.31	0.13	0.22	Bal.

2.2 Preparation of Substrate Material

Small cylindrical pins having circular cross-section of 8 mm diameter and length 30 mm were prepared from EN8 materials. These pins were required to perform pin-on-disk experiment at room temperature. The faces of the pins were grinded, followed by polishing with emery papers down to 1000 grit.

2.3 Deposition of Coatings:-

2.3.1 Detonation Spray Coatings Powders

Two types of coating powders namely (1) Tungsten Carbide (WC) + (10%) Cobalt (Co) + (4%) Chromium (Cr), (2) Aluminum Oxide (Al2O3) + (13%) Titanium Oxide (TiO2) was chosen for detonation spray deposition on the MS and EN8 substrate specimens. The particle size for both these powders was 25㎛ ± 10㎛.

2.3.2 Formulation of the Coatings

The WC – 10Co -4Cr and Al2O3-13TiO2 powders were successfully deposited on EN8 substrate steel by the detonation spray process. The coatings were deposited at SVX Powder M Surface Engineering Private Limited, Greater Noida, UP, India.

2.4 Characterization of Coatings

2.4.1 Measurement of Coating Thickness

The thickness of coatings was monitored during the processes of detonation spraying with a thickness gauge; Minitest-2000 made in Germany. Efforts were made to obtain coatings of uniform thickness. A uniform thickness coating of 250 ㎛ ± 10 ㎛ was deposited in all the cases of WC – 10Co -4Cr and Al2O3-13TiO2 powders for EN8 substrate steel.

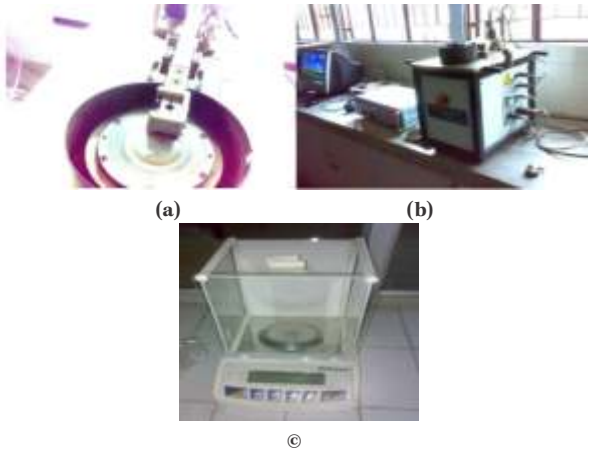
2.4.2 Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray (EDAX)

The surface morphology and microstructure of coated pins were studied with the help of Scanning Electron Microscope fitted with EDAX Genesis software attachment available at Indian Institute of Technology Ropar, Punjab (India) with an aim to identify cracks, un-melted, melted particles and pores in the as sprayed coatings. Although the composition correspond to selected spectrums on the as sprayed coatings, it is useful to understand the presence of desired compositions in the coatings.

2.5 Wear Study

2.5.1 Experimental Set Up of Pin on Disc Machine

Dry sliding wear tests for the uncoated and detonation sprayed MS AND EN8, were conducted using a pin- on –disc machine [Model: Wear and Friction Monitor Tester TR-20]. Some photographs of set up of the machine are shown in Fig 2. The tests were conducted in air having relative humidity in range from 40 to 75 %. Wear tests were performed on the pin specimens that had flat surfaces in the contact regions and the rounded corner.



(a) (b)

©

Fig. 2 (a) Pin-on-disc wear test machine (b) Control Unit with computer interface (c) Weighing apparatus.

The pin was held stationery against the counter face of a rotating disc made of En-32 steel at 40 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. The composition of the material of the steel disc is given in Table 2.

Table 2 Chemical Composition (Wt %) of the En-32 steel disc

C	Si	Mn	S	P
0.42 (max)	0.05-0.35	0.40-0.70	0.05 (max)	0.05 (max)

2.5.2 Sliding Wear Studies

The pins were polished with emery paper and both disc and the pin were cleaned and dried before carrying out the test. The pin was loaded against the disc through a dead weight loading system. The wear test for coated as well as uncoated specimens was conducted at constant velocity i.e. at 1ms-1 and at different loads i.e. 50N, 60N and 70N. The track radii for the pins were kept at 40 mm. The speed of the rotation (478 rpm) of the disc for all the cases was so adjusted to keep the linear sliding velocity at a constant value of 1 m/s. A variation of ± 5 rpm was observed in the rpm of the disc. Wear tests have been carried out for a total sliding distance of 5400 m, so that only top coated surface was exposed for each detonation sprayed sample. Weight losses of each sample were measured after 5, 5, 10, 10, 20, 40 minutes to determine the wear loss. The pin was removed from the holder after each run, cooled to room temperature, brushed lightly to remove lose wear debris, weighed and fixed again in exactly the same position in the holder so that the orientation of the sliding surface remains unchanged. The weight has been measured by a micro balance to an accuracy of 0.001 g.

3. Results and Discussion

3.1 Visual Examination (SEM/EDAX Analysis of the Coatings After Wear)

The SEM micrographs showing the morphology of the bare, as well as, detonation sprayed Al2O3-13TiO2, WC–10Co–4Cr coated MS and EN8 steel substrates subjected to wear testing at a load of 70N with a sliding velocity of 1m/s for a total sliding distance of 5400 meters have been shown from Fig. 3 to Fig. 5.

3.2 Discussion

It is clear from the Fig. 3 that the surface of the uncoated EN8 steel has suffered a tremendous damage due to the wear testing. This damage is both along as well as, to the direction of sliding of the disc. Whereas the wear damage is comparatively lower in the coated cases. The wear craters are comparatively larger in size in the case of uncoated EN8 steel, followed by Al2O3-13TiO2 and WC–10Co–4Cr coated EN8 steel in that order. On the basis of the above discussion on SEM analysis of the coatings after the sliding wear, it may be concluded that the both the coatings could reduce the extent of wear damage of the given steels.

EDAX analysis of the surfaces of the uncoated EN8 specimen indicates higher peaks of Fe and O, whereas for detonation sprayed WC–10Co–4Cr coated specimens, there is the presence of unmelted particles of the coating powders. The worn area analyzed to have higher amount of tungsten (W) in case of WC–10Co–4Cr coatings which are responsible for increased wear resistance of the specimen. During EDAX analysis of detonation sprayed Al2O3-13TiO2 coated specimens; the peaks are of Aluminium (Al) and Titanium (Ti). From the microstructure of worn out surface, Fig. 3 (Uncoated EN8) shows that there is significant damage as compared to detonation sprayed Al2O3-13TiO2, WC–10Co–4Cr coatings where there is a very dense layer of coating is observed showing negligible wear. The presence of W along with carbon indicates the formation of carbides at the surface which is responsible to increase the wear resistance in WC–10Co–4Cr coatings and the presence of Al and Ti along with carbon and oxygen indicates the formation of Oxides at the surface which is responsible to increase the wear resistance in Al2O3-13TiO2 coatings.

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4. Conclusions

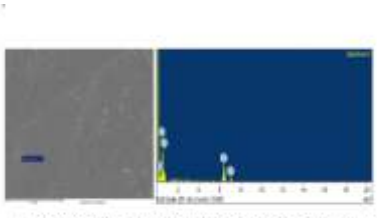
1. The Al2O3-13TiO2 and WC–10Co–4Cr powders were successfully deposited EN8 substrate steels by the detonation spray process.

2. Improvement in wear resistance of EN8 steel was observed after the deposition of detonation sprayed Al2O3-13TiO2, WC–10Co–4Cr coatings.

3. Detonation spray process provides the possibility of deposition of Al2O3-13TiO2, WC–10Co–4Cr powders on the EN8 steels. A uniform coating thickness of 250+10 micrometer was achieved.

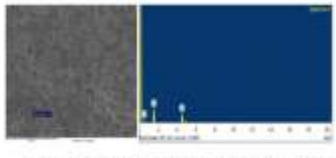
4. The surface analysis of the coated and uncoated specimens was investigated with the help of Scanning Electron Microscope (SEM) and Energy Dispersive Spectroscopy (EDAX).

5. After SEM/EDAX analysis of the coatings after the sliding wear at a load of 70N, it may be concluded that the both the coatings (Al2O3-13TiO2, WC–10Co–4Cr) could reduce the extent of wear damage as compared to uncoated EN8 steels.



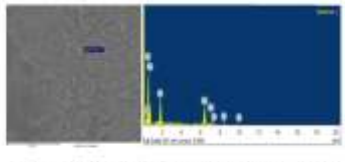
Element	Weight%	Atomic%
C K	23.64	35.67
O K	48.96	55.45
Fe K	27.40	8.89
Totals	100.00	

Fig. 3 SEM/EDAX analysis of uncoated EN8 subjected to wear at a normal load of 70 N and sliding velocity of 1 m/sec. after a sliding distance of 5400m



Element	Weight%	Atomic%
Al K	43.63	57.87
Ti K	56.37	42.13
Totals	100.00	

Fig. 4 SEM/EDAX analysis of detonation sprayed Al_2O_3-13TiO_2 coated EN8 subjected to wear at a normal load of 70 N, sliding velocity of 1 m/sec. after a sliding distance of 5400m



Element	Weight%	Atomic%
C K	17.48	27.40
O K	47.49	63.18
Fe K	19.32	7.37
W M	17.73	2.05
Totals	100.00	

Fig. 5 SEM/EDAX analysis of detonation sprayed Wc-10Co-4Cr coated EN8 subjected to wear at a normal load of 70 N, sliding velocity of 1 m/sec. after a sliding distance of 5400m

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