Study of Wear in axles and various experimental techniques used for the study with deposition of the coatings to improve wear by using various coating on EN-45 steel

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Abstract- This paper comprises of the various experimental techniques used for the study, selection of materials, deposition of the coatings and their characterization, sliding wear studies and analysis of wear rate of specimens. Dimensions of the samples, equipment's and other instruments used for the present study are also explained in detail. Calculations of wear and friction parameters i.e. wear volume, wear rate and coefficient of friction is also done.

Keywords – EN-45 steel, Haar Wavelet, DWT, PSNR

I. INTRODUCTION

The wear problem is found in axle of light weight truck. The surface of axle is worn out mainly due to abrasive wear, sliding wear and cracking by surface fatigue. In the present research study efforts will be made to reduce the wear rate of axle which is made of grey cast iron with detonation sprayed wear resistant coatings. Standard test methods for wear testing with pin-on disc apparatus, SEM/EDS [1] analysis and XRD analysis has been employed to study the wear behaviour of the uncoated and coated grey cast irons.

II. THE SELECTION OF SUBSTRATE MATERIALS

Selection of the materials for coating has been made after reviewing paper of Cueva 2003 [11], Demir 2008 [12] and Samur 2010 [11]. The selected material is EN-45 which is the grade of steel. This grade shows maximum wear resistant than other grades used in the study of Cueva 2003 [2] therefore these are selected in this study. Table 4.1 shows the chemical composition of the EN-45 steel which is used for axles. Table 4.2 shows hardness values of the substrate material EN-45 steel.

III. FORMATION OF PINS

Cylindrical specimens having diameter equal to 8 mm and length equal to 30 mm were prepared from EN-45 steel. 9 pins from EN-45 steel grade were prepared and were given the Sample No. from 1 to 9. The Grinding of end faces (to be coated) of the specimens done using sand papers of four different grades 220, 400, 600, 1000 in the same order. Grinding was followed by polishing with 1/0, 2/0 and 3/0 grades polishing papers.

Table-1 Chemical composition (Wt %) of the EN-45 steel materials

	C	Si	Mn	P	S
EN-45 steel	0.90	0.35	0.0.85	0.04	0.03

Table-2 Hardness values of EN-45 steel materials

Materials	EN-45 steel
Hardness (HB)	50

Figure-1 Macrographs of pins (specimen) prepared for coatings on end faces

IV. DEPOSITION OF COATINGS

4.1 Detonation Spray Coatings

Two types of coating powders namely (1) TiMo (CN) (2) NiCrAIY+0.4 wt%CeO2 are selected for present study after studying the research papers of Samur 2010 [7], Demir 2008 [8], Murthy 2006 [9] and Sundararajan 2004 [10].

4.1.1 TiMo (CN): TiMo (CN) powder when sprayed using the detonation spray coating process, it produces coatings which are very dense and uniform. The various constituents of the powder are Titanium (72%), Molybdenum (18%), Carbon (10%). The powder particle size is 10-45 microns.

4.1.2 NiCrAIY+0.4 wt%CeO2: NiCrAIY+0.4 wt%CeO2 when sprayed using the detonation spray coating process, it produces coatings, which are very hard, dense and its bonding strength is very high. Coatings can be built up to higher thickness. These coatings provide better protection against wear. The powder particle size is 15-35 microns. The various constituents of the powder are Nickel (73.72 %), Chromium (18.64%), AI (3.45%), Cobalt (2.60%), Carbon (0.55 %), Y (1 %) and CeO2 (0.4%).*Impact*

4.2 Deposition of the coatings by Detonation Gun Spray Process

4.2.1 The Detonation Spray wear resistant coatings are deposited on Grey iron grades GI250 and GIHC with the help of Detonation Gun process. Samples are well polished before the application of TiMo (CN) [5] and NiCrAIY+0.4 wt%CeO2 [6] coatings.

4.2.2 The coatings were deposited at SVX POWDER M SURFACE ENGINEERING PVT.LTD., H-14, Site-C, Surajpur Industrial Area, Greater Noida, UP. The name of D -Gun is Awaaz Detonation [4] Spray Coating System made by International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad in collaboration with the inventors – IPMS, Kiev, Ukraine. The process parameters used during deposition of co*ating are presented in Table 3. Table 4* Shows detonation sprays parameters for two coatings.Abrasion and Impact wear.

Table 3 the process parameters used during Detonation Gun Spray Process

Fuel gas	Oxygen and Acetylene
Carrier gas	Nitrogen
Pressure of Fuel gas (Oxygen)	2-3 bar
Pressure of Fuel gas (Acetylene)	1-1.5 bar
Pressure of Carrier gas (Nitrogen)	2-4 bar
Flow Rate of Fuel gas (Oxygen)	2800-5120 SLPM (Standard liters per minute)
Flow Rate of Fuel gas (Acetylene)	2240-2420 SLPM
Flow Rate of Carrier Gas(Nitrogen)	720-960 SLPM
No of Shots per second	3
Spraying Distance	150-180 mm

Table 4 Detonation Spray parameters for two coatings

(a) TiMo (CN)

Gases	Oxygen	Acetylene	Nitrogen
Flow Rate	2990	2410	720

Spraying Distance 165 mm

(b) NiCrAIY+0.4 wt%CeO2

Gases	Oxygen	Acetylene	Nitrogen
Flow Rate	4350	2300	960

Spraying Distance 150 mm

V. CHARACTERIZATION OF COATINGS

5.1 Sample preparation

Two specimens having dimensions 20mm* 15mm* 5mm were cut from the substrate material. The specimens were grinded using sand papers of 220, 400, 600 and 1000 grit sizes and subsequently polished on 1/0, 2/0, 3/0 grades. Samples were well polished until it shines like mirror. One sample of EN-45 steel substrate was coated with TiMo (CN) coating and other is coated with NiCrAIY+0.4 wt%CeO2 coating.

5.2 Measurement of Coating Thickness

The coating thicknesses were measured during the process of Detonation Gun Spray with a Minitest-600B thin film thickness gauge (made in Germany and supplied by Elektro Physik, precision ± 1microns).

5.3 X-Ray Diffraction (XRD) Analysis

XRD analysis was carried out for the coated specimens to identify the various phases present on their surfaces. The X-ray diffraction patterns were obtained by an X'Pert PRO (MPD) (PANalytical) Netherland, with CuK_{α} radiation and nickel filter at 40 mA under a voltage of 45 kV. The specimens were scanned with a scanning speed of 2^o/min in 2θ range of 20^o to 120^o and the intensities were recorded. Assuming height of the most prominent peak as 100%, the relative intensities were calculated for all the peaks.

5.4 Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDAX) Analysis of as coated pins

The surface morphology and microstructure of coated pins were studied with the help Scanning Electron Microscope (Model-JSM6610 Low Vacuum) fitted with EDAX Inca software attachment (made by Jeol, Japan) 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 is useful to understand the presence of desired compositions in the coatings.

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VI. WEAR STUDY OF SAMPLES USING PIN ON DISC MACHINE

6.1 Set up of Pin on disc machine

Wear tests for coated samples were conducted using a pin- on –disc machine (Wear and Friction Monitor Tester TR-201made by M/S DUCOM, Bangalore, INDIA) available at Shaheed Bhagat Singh State University, Ferozepur. The tests were conducted in air with a room temperature of 34-36°C. The pin was held stationary against the counter face of a rotating disc made of carbon steel (EN-31) at 40 mm track diameter. EN-31 steel is a plain carbon steel; case hardened 62 to 65 HRC as provided with the pin-on-disc machine. Some photographs of the set up of the machine and carbon steel disc with pin hold into it are shown in Fig 4.2.The composition of the material of the steel disc is given in Table

Table 5 Chemical composition (wt %) of the EN-31 carbon steel disc

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

6.2 Procedure of sliding wear studies

6.2.1 First of all the uncoated as well as coated pins were prepared for sliding wear studies. The pins were polished with sand paper and both disc and the pin were cleaned and dried before carrying out the test.

6.2.2 Then the pins were loaded against the disc through a dead weight loading system. The wear tests were conducted under three normal loads of 40 N, 50 N and 60 N and a fixed sliding velocity of 1 m/s.

6.2.3 Set the track radii for the pins were kept at 40 mm. The speed of the rotation of the disc 477 rpm for all the cases was so adjusted so as to keep the linear sliding velocity at a constant value of 1 m/s.

6.2.4 Wear tests have carried out for a total sliding distance of 5400 m (6 cycles of 5min, 5min, 10min, 10min, 20min, 40min duration), so that only top coated surface was exposed for each sample.

6.2.5 Tangential force was noted continuously during the wear tests.

6.2.6 Weight losses for pins were measured after each cycle 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 with clothes, weighed and fixed again in exactly the same position in the holder.

6.2.7 The weight was measured by a micro balance to an accuracy of 0.0001 gm.

6.2.8 The coefficient of friction has been determined from the friction force and the normal loads in all the cases so that friction can be calculated for each load.

6.3 Determination of wear

The specific wear rates were obtained by

$W = \delta w / L\rho F$

Where W denotes specific wear rates in, Bowden (B) (1B=10-6 mm3/N-m)

δw is the weight loss measured in, gm.

L the sliding distance in, meter.

ρ the density of the worn material in gm/ mm3

F the applied load in N.

6.4 Calculation of wear volume

The wear volume loss was calculated from the weight loss during each cycle and density of the coated as well as uncoated calculated for all samples. These results were drawn in the form of plots showing the cumulative wear volume loss Vs sliding distance for all the cases. Bar charts were also drawn to show net wear volume loss for all the specimens. Volume = mass / density.

Wear Volume Loss = $(\delta w/9.81) /\rho$

Where δw is the weight loss in, g

And ρ is the density of material, g/mm3

6.5 Calculation of coefficient of friction

The coefficient of friction (μ) determined from the frictional force and the normal load. Frictional force is achieved during each test which is divided by load to obtain coefficient of friction (μ):

μ = Frictional Force (N) / Load (N)

VII. CONCLUSION

7.1 Visual Inspection of samples

In visual examination after coating, the color of specimens turns grey and on the samples small particles of coating was seen clearly with naked eyes. Wear debris were also observed on the surface of samples.

7.2 Scanning Electron Microscopy and EDAX analysis

Some of the worn out specimens were studied with the help of a Scanning Electron Microscope fitted with EDAX Inca software attachment (made by Jeol, Japan) available at Indian Institute of Technology Ropar, Punjab (India); for the characterization of coatings; to identify cracks, voids and change in elemental composition. SEM/EDS analysis of the worn out specimens is reported in Chapter 5 of the present study.

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