Wear behavior of GI250 grade of grey cast iron coated by WC–12CO and Stellite-6 coatings

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ABSTRACT: *The wear is very severe problem in industry. It leads economic loss to society. In the present research study efforts will be made to reduce the wear rate of Braking Disc Rotor with surface modifications techniques and comparison of wear properties grade of cast iron GI250 coated by WC–12CO and Stellite-6 deposited by Detonation spray processes is presented. The results show that the WC-12CO on GI250 grey cast iron performs slightly better than the Stellite-6 coating. The WC-12CO-GI250 coating substrate combination has shown minimum Cumulative Volume loss among all the two combinations. The wear resistance for coating–substrate combinations in their decreasing order is WC-12CO-GI250>Stellite6-GI250.*

Keywords: *Wear, Detonation spray, Brake disc wear resistance.*

I. INTRODUCTION

The optimization of automotive vehicles braking systems, subjected to mechanical and thermal stresses, depends on a combination of properties. In general, a complex state of stress is found and it is practically impossible to select a material and design a component based only on one of these properties. The material used in brake rotors should be able to bear thermal fatigue and should absorb and dissipate, as soon as possible, the heat generated during braking [1].

2.2. PREPARATION OF SAMPLES

Small cylindrical pins having diameter of circular cross-section equal to 8mm and length equal to 30 mm were prepared from GI250 grey irons. A total of 9 pins of GI250 grade were prepared. Pins were given the Sample No. from 1 to 9. The grinding of end faces (to be coated) of the pins done using emery papers of five different grades 220, 400, 600, 800, 1000 in the same order . Grinding was followed by polishing with 1/0, 2/0, 3/0 and 4/0 grades polishing papers.

Table 2.1 Chemical composition (Wt %) of the GI250 grey iron

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
GI250	3.35	2.16	0.53	0.118	0.127	0.658	0.025	0.293	0.250

Table 2.2 Hardness values of GI250 grey iron

Material	GI250
Hardness (HB)	285

2.3. DEPOSITION OF COATINGS

2.3.1 Detonation Spray Coating Powders

Two types of coating powders namely (1) Stellite-6 (2) WC-12CO are selected for Detonation Spray Coating Process after the literature survey. Research papers shows that the above coatings have excellent wear resistance.

(1) Stellite-6: Stellite powder when sprayed using the Awaaz Detonation spray coating process, it produces coatings which are very dense and homogeneous. The various constituents of the powder are Carbon (1%), Tungsten (6 %), Fe (5%), Chromium (30%), and Cobalt (58%). The powder particle size is 10-45 microns.

(2)Tungsten carbide (WC-12CO): WC-12CO when sprayed using the Awaaz Detonation spray coating process, it produces coatings, which are very hard, dense and excellent bonded. Coatings can be built up to higher thickness. WC-12CO 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 are coatings which are gives better protection against wear. The powder particle size is 15-35 microns. The various constituents of the powder are Chromium (32.72%), Cobalt (46.58%) and Tungsten (20.70%).

Table 2.3 Detonation Spray parameters for two coatings

(a) Stellite-6

Gases	Oxygen	Acetylene	Nitrogen
Flow Rate	2990	2410	720

Spraying Distance 165 mm

(b) WC-12CO

Gases	Oxygen	Acetylene	Nitrogen
Flow Rate	4350	2300	960

Spraying Distance 150 mm

2.4 CHARACTERIZATION OF COATINGS

2.4.1Specimen preparation

Two specimens having dimensions 20mm* 15mm* 5mm were cut from the substrate material GI250. 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 GI250 substrate was coated with Stellite-6 coating and other is coated with WC-12CO coating.

2.5 SLIDING WEAR STUDY USING PIN- ON -DISC CONFIGURATION

2.5.1. Experimental Set Up

Dry sliding wear tests for the uncoated and detonation spray coated cylindrical specimens were conducted using a pin-on –disc machine (Wear and Friction Monitor Tester TR-201made by M/S DUCOM, Bangalore, INDIA) conforming to ASTM G 99 standard . The tests were conducted in air with a room temperature of 30-32°C. Wear tests were performed on the pin specimens that had flat surfaces in the contact regions and the rounded corner. The pin was held stationery 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. The composition of the material of the steel disc is given in Table 2.4.

Table 2.4.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)

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 tests for coated as well as uncoated specimens were conducted under three normal loads of 40 N, 50 N and 60 N and a fixed sliding velocity of 1 m/s. 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. 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 (6 cycles of 5min, 5min, 10min, 10min, 20min, 40min duration), so that only top coated surface was exposed for each detonation sprayed sample. Tangential force was monitored continuously during the wear tests. 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, weighed and fixed again in exactly the same position in the holder so that the orientation of the sliding surface remains unchanged. The weight was measured by a micro balance to an accuracy of 0.0001 gm. The coefficient of friction has been determined from the friction force and the normal loads in all the cases.

2.5.3. Wear rate

The wear rate data for the coated as well as uncoated specimens were plotted with respect to sliding distance to establish the wear kinetics. The specific wear rates for the coated and uncoated material were obtained by

$W = \delta w / L\rho F$ Where W denotes specific wear rates in, Bowden (B) ($1B=10^{-6} mm^3/N\text{-}m$)

[Recommendation from IRG OECD meeting with about 30 participants to introduce a new unit for wear rate: Bowden (B) equal to $10^{-6} mm^3/N.m$]

δw is the weight loss measured in, g

L the sliding distance in, m

ρ the density of the worn material in g/mm^3 and

F the applied load in N.

2.5.4. Wear volume

The wear volume loss was also calculated from the weight loss and density of the coatings as well as substrate material for all the investigated cases. These data were reported 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 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/mm^3

2.5.5. Coefficient of friction

The coefficient of friction (μ) determined from the frictional force and the normal load has been plotted against the sliding time to give the friction behavior of the coated as well as the uncoated material. The coefficient of friction (μ) was calculated as below:

μ = Frictional Force (N) / Applied Normal Load (N)

III. RESULTS AND DISCUSSION

Characterization, Wear behaviour and SEM/EDAX analysis of Detonation sprayed Stellite-6 and WC-12 CO coatings deposited on grey cast irons has been described. Wear behaviour and SEM/EDAX analysis of bare grey cast irons has also been described and compared with that of coatings.

3.1 RESULTS

3.1.1 Characterization of Coatings

3.1.1.1 SEM/EDS analysis of the D-gun as sprayed coatings

The Scanning electron microscope micrographs as well as Energy Dispersive Spectrum (EDS) with element composition for Detonation sprayed Stellite-6 and WC-12CO coatings on GI250 shown in Figure (3.1). The microstructure of these coatings is hardly bonded, homogeneous and free from surface cracks, pores and voids. The SEM/EDS analysis of the stellite-6 coating showed in Figure (3.1(a)).The elements for stellite-6 coating corresponding to (spectrum 1) for load 40N and 50N are C, O, Cr, CO Si etc. The color of the surface at this spectrum is dull grey and near this point surface is white which may be due to presence of oxygen and at (spectrum

4) the coating is more uniform. The elemental composition for WC-12CO coating corresponding to spectrum 1 & 4 for load 40N and 50N is shown in (Figure 3.1(b)). The spectrum 4 of WC-12CO coating also confirms the presence of desired coating elements Chromium (32.72%), Cobalt (46.58%) and Tungsten (20.70%). At (spectrum 4) the color is naturally white which is may be due presence of excess oxygen on the surface.

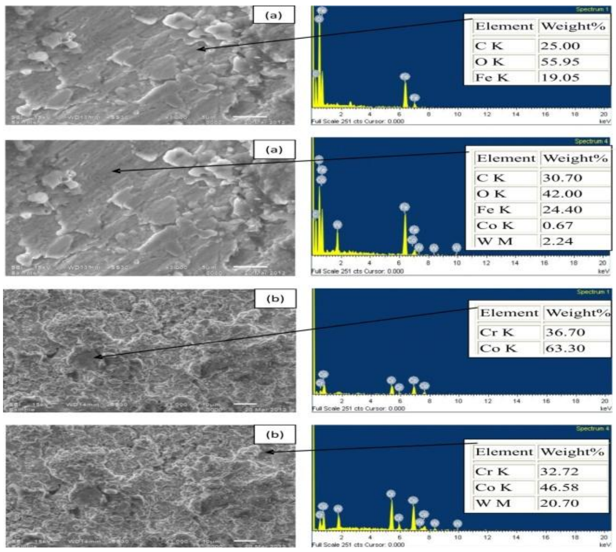

Figure 3.1 Surface Morphology and EDS patterns from different spots on as coated samples (a) Stellite-6 (b) WC-12CO.

3.1.1.2 X-ray Diffraction (XRD) analysis

The X-ray diffraction patterns for detonation sprayed stellite-6 and WC-12CO ON GI250 are shown in Figure 3.2. Figure 3.2 (a) shows the X-ray diffraction patterns for as coated samples of Stellite-6 coating on GI250 and Figure 3.2(b) shows the X-ray diffraction patterns for as coated samples of WC-12CO coating on GI250. From Figure 3.2 (a) it is identified that coating stellite-6 shows the excess of desired coating elements such as C, Cr, O, Co and small amount of Fe and Si. Similarly, from Figure 3.2(b) it is evident that coating WC-12CO shows the major phases of tungsten which is desired element of coating and minor phases of C and O which together to make Co which is also desired element of coating WC-12CO. The no. of peaks corresponding to elements of coatings can be seen from diffraction patterns of different coatings for GI250.

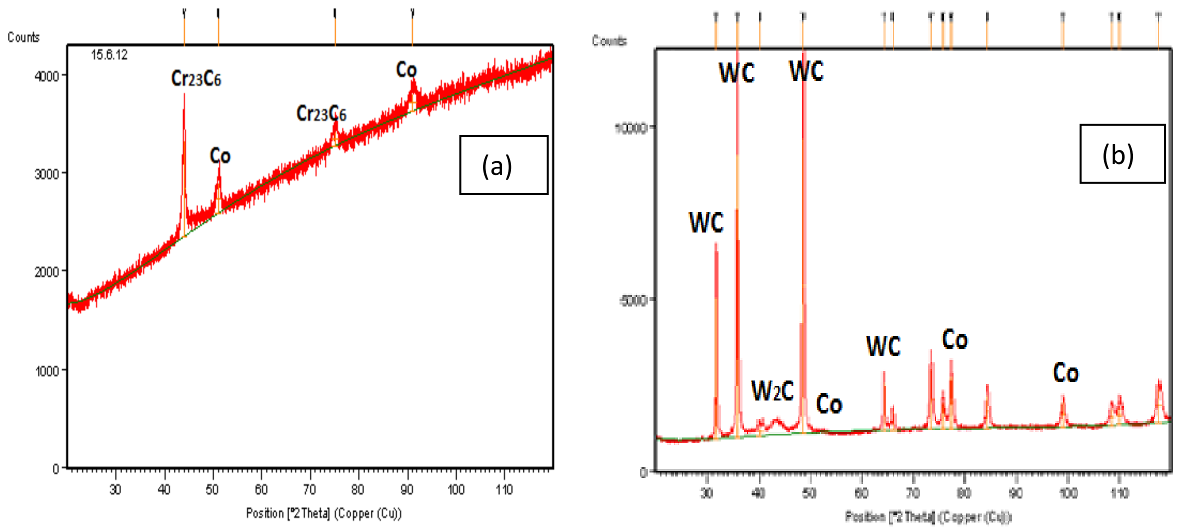

Figure 3.2 X-ray Diffraction patterns of as coated GI250 material; (a) Stellite-6 (b) WC-12CO

3.1.2 Wear Behavior

3.1.2.1. Substrate GI250

3.1.2.1.1. Wear Behavior of Two coatings vs GI250

Three samples of each coating i.e. Stellite-6 and WC-12CO on GI250 were subjected to wear on Pin-On–Disc-wear test rig at normal loads of 40N, 50N and 60N respectively. Three samples of bare GI250 substrate were also subjected to wear on Pin-On Disc-wear test rig at the same loads. The cumulative volume loss vs time for each coating is plotted as shown in Figure 3.4. From the results of (Figure 3.4) it is investigated that cumulative volume loss for two detonation sprayed wear resistant coatings show better wear resistant in comparison to bare GI250. The bar chart (Figure 3.5) showing the Cumulative Volume Loss (CVL) in one complete cycle (90 min) is also drawn for each coating and bare GI250 substrate. From (Figure 3.4 & Figure 3.5) it is observed that with increase in load wear loss increases for the detonation sprayed coatings Stellite-6 and WC-12CO and bare GI250 the observation is same as that of the observation of (Cueva, 2003).

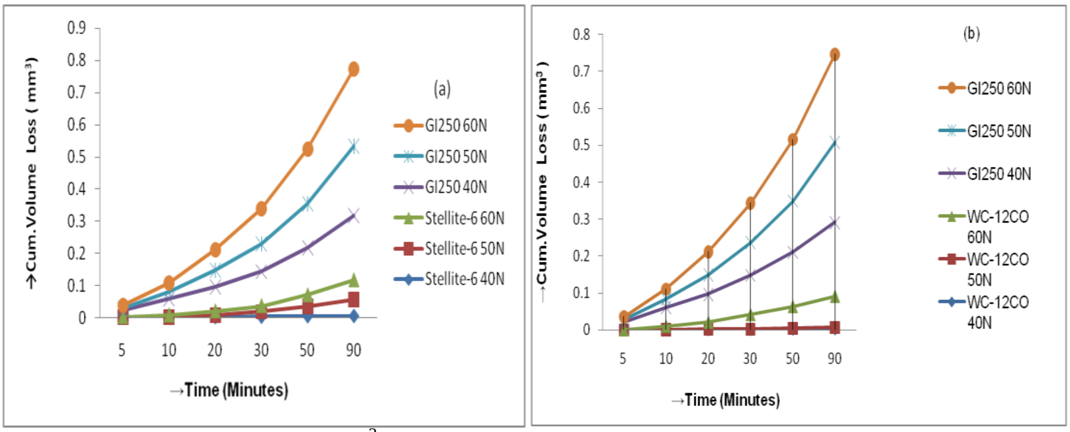

Figure 3.4 Cumulative Volume Loss (mm^3) with time for (a) Stellite-6 (b) WC-12CO coatings and GI250 substrate.

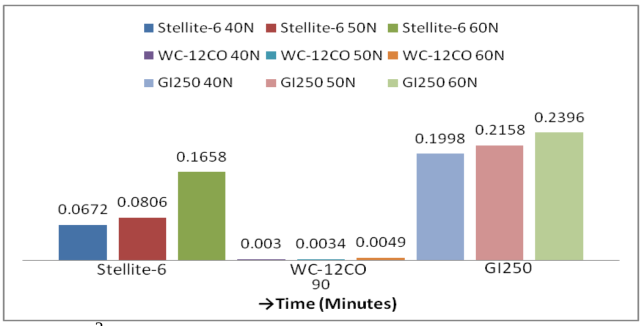

Figure 3.5 Cumulative Volume loss (mm^3) in one cycle for D-gun sprayed coatings and bare GI250 at 40N, 50N and 60N.

3.1.2.1.2 Comparative Wear Behaviour for two coatings

Figure 3.6 shows Comparative Volumetric Wear Loss (mm^3) for two coatings at (a) 40 N (b) 50 N and (c) 60 N. It is also observed from the results that WC-12CO is showing the minimum cumulative volume loss as compared to other two coatings. Therefore the wear resistance of Detonation sprayed coatings on GI250 in their decreasing order can be given as WC-12CO>Stellite-6.

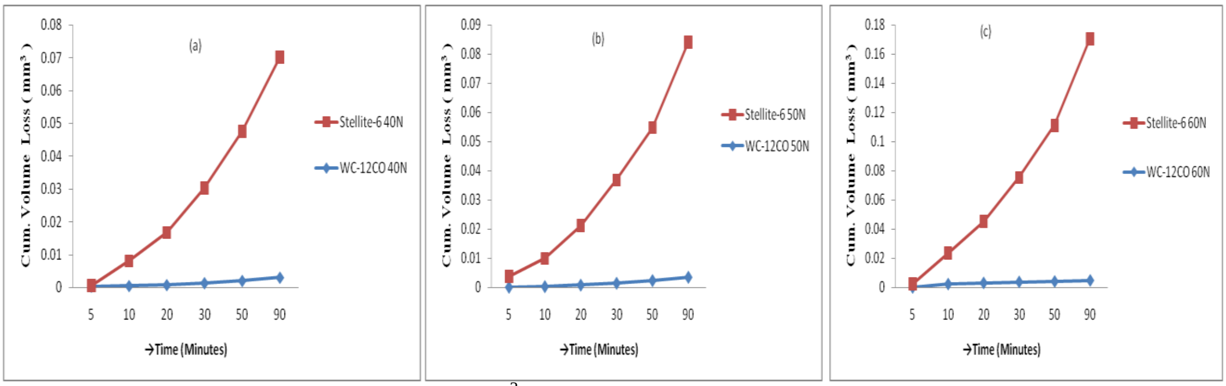

Figure 3.6 Comparative Volumetric Wear Loss (mm^3) for two coatings on GI250 substrate at (a) 40 N (b) 50 N and (c) 60.

3.2 DISCUSSION

Selection of material, coating and the wear behaviour of the uncoated GI250 and detonation sprayed Stellite-6 and WC-12CO coatings have been discussed. From the study of Mohanty, 1996 it was observed that it is possible to deposit almost any material on any substrate by D-gun spray process to considerably extend the life of parts, also it is observed in the present study that the Stellite-6 and WC-12CO coatings powders have been successfully deposited on GI250 substrate by the detonation spray process. It was further confirmed by characterization of coatings using SEM and EDAX analysis of as coated specimens. SEM/EDAX results of WC-12CO and Stellite-6 (Figure 3.1 (a&b)) shows the presence of O and C on the surface which may be due to formation of carbide. Also XRD analysis of study did (Figure 3.2) which supports the results of scanning electron microscope (SEM). There is always the material loss of bare material greater than the as coated material. From (Figure 3.4) it is observed that the detonation sprayed wear resistant coatings Stellite-6, WC-12CO coated GI250 specimens showed significantly lower cumulative volume loss as compared to bare GI250 material under the normal load of 40N, 50N and 60N. It is investigated with the help of Pin-on-Disk Wear testing machine. There are many studies; Murthy & Venkataraman, 2006, Sundararajan, 2005 and Jun Wang 2000 which support the above finding that Detonation sprayed coatings increases the wear resistant and wear loss of bare material is always greater than the as coated material which is also found in present study in (Figure 3.4).Also Figure 3.6 shows comparison of two coatings in which WC-12CO has minimum wear loss as compared to Stellite-6 and therefore WC-12CO can be used for coating the grey cast iron material which is used in light truck pads. WC-12CO coating has more bonding strength than stellite-6. From (Figure 3.6) it is observed that the wear loss is increase with increase load. From this figure it is clear that the wear loss for two coatings and bare GI250 also increases with load which is same observation as Cueva (2003), The CVL for WC-12CO coating was found to be minimum in present study as shown in Figure 3.5 and Figure 3.8.it is may be due to the presence of W, CO, FE and O also tungsten and carbide increases the property of wear resistant. Identical results have been reported by Mohanty, 1996. It may be due to carbide formation due to diffusion of the Fe from the substrate. The WC-12CO-GI250 coating substrate combination has shown minimum wear loss among all four combinations as shown in Figure 3.6.

IV. CONCLUSIONS

Based upon experimental results obtained in the present study, the following conclusions have been drawn:

1. GI250 is best grade of grey cast iron.
2. Stellite-6 and WC-12CO are best coating powders to deposit on grey cast irons (GI250).
3. Stellite-6 and WC-12CO wear resistant coatings have successfully been deposited on GI250 grade of grey cast iron.
4. The Stellite-6 and WC-12CO coating based GI250 specimens showed lower cumulative volume loss as compared to bare GI250 specimens.
5. Wear loss for detonation sprayed wear resistant coatings Stellite-6 and WC-12CO coated samples and bare GI250 samples increases with increase in load.
6. The Cumulative Volume loss for WC-12CO coating was minimum in the present study. Therefore WC-12CO is best coating to deposit on GI250 grade of grey cast irons.
7. The wear resistance for coating–substrate combinations in their decreasing order is WC-12CO-GI250>Stellite-6-GI250. Therefore out of these combinations WC-12CO-GI250 coating substrate combination is the best combination.

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