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Surface Modification of Cast Iron to Improve Wear Resistance in Engine Piston Rings Application by Coating of WCN

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ABSTRACT: WCN was deposited on the surface of piston rings by PVD method. The phase microstructure, hardness and wear rate were analyzed by XRD, SEM, and pin on disc to investigate the properties of WCN coated pistons rings. It is found that the hardness of piston ring was increased by coating WCN. The wear of uncoated piston rings is high and that of WCN coated piston rings is low. The wear resistance of the piston rings is improved by coating WCN on the surface due to the higher hardness and this could prolong its service life.

KEYWORDS: Piston rings, PVD, Hardness, Wear, WCN.

I. Introduction

Internal combustion engine, piston rings are primary components and the tribological performance has long been recognized as important in achieving desired engine efficiency and durability [1]. In general, the excellent tribological features for piston rings would decrease the energy consumed by friction and improve the overall emission and performance values [2]. However traditional piston rings usually undergo too much wear on surfaces which shorten their service life due to their excessive surface roughness and inadequate strength of the used material (eg.cast iron). In recent year there have been more attention to further improve the wear resistance of piston rings to lengthen their service life and then to lengthen the life of engine. One effective way is coating the piston rings surface with various materials to improve the tribological features

II. LITERATURE REVIEW

Among different coating, nitrides and carbides have attracted attention due to their high hardness and excellent wear resistance [3-7]. Especially WCN are potential candidate for various future applications, such as Cu diffusion barriers[8] protective coatings and electrodes for metal-insulator-metal structures [9] due to high hardness and excellent wear resistance. Most studies reported recently with specific regard to the tribological properties of WCN coatings, which have been carried out by changing the synthesis parameters and laboratory test conditions. Yu L H et al. [10] prepared WCN coating by magnetron sputtering and investigated the effects of bias voltage on the tribological properties.They found that the increase of bias voltage could improve the surface quality and decrease the friction coefficient and wear rate. R.Ospina et al. [11] prepared WCN with pulsed vacuum arc physical vapor deposition by varying the substrate temperature to study the tribological properties. They found that the film grown at 150°C exhibited the highest degree of hardness, the lowest friction coefficient and highest adhesive and abrasive load. Hanbey [12] coated MoN on the piston rings surface by using the arc PVD method and investigated the tribological properties. They found that the coated piston rings had a higher surface hardness and wear resistance. WCN coatings have a higher hardness and wear resistance over a wide temperature range compared with MoN.

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In this study WCN coatings were deposited by thermal spray coating process on the piston rings surface. The aim of this study is to improve wear resistance of surface coated piston rings.

III. EXPERIMENTAL WORK

WCN coatings with a thickness of about 250 µm were deposited on the surface of the substrate by a high velocity oxy-fuel spraying. The spraying parameters are mentioned below. The reactive gas flow rate is 253 lpm and powder feed rate is 35 g/min, spray distance 227 mm and deposition time is 30 min.

Wear Test

Wear test of Uncoated and coated substrate were done under the different load conditions (at 1, 1.5 and 2 kg load). The test specification are listed in table 1.

Parameter	Set value
Applied load	1, 1.5 and 2kg
Velocity	1 m/s
Track diameter	80 mm
Time	60 min
Speed	477 rpm

Table 1. Wear Test parameters

The friction and wear behaviour of the uncoated specimens were evaluated by wear friction monitor Ducom-TR LT, under unlubricated contact condition at room temperature and relative humidity 65%. There are three parameters followed on wear monitoring: track diameter 80mm, sliding speed 477 rpm and load 1, 1.5 and 2 kg. The wear test was carried out as per ASTM standard G99 at a constant velocity of 1m/s.

XRD and SEM Analysis

The structure of the coatings were explored by X-ray diffraction (XRD) with a Cu Kα source, at 40 kV 30 mA. The scanning angle ranged from 30 to 65 ℃ at scanning speed of 4℃/min with 0.02 ℃ step size. Scanning electron microscopy (SEM) was used to investigate the cross-sectional microscopy and wear tracks of the coatings.

Microhardeness Measurement

The hardness measurements were conducted using Vickers hardness tester which is equipped with a diamond indenter tip. The indenter made up of diamond is used to apply the load.

IV. RESULTS AND DISCUSSION

The coated specimen were analysed using Scanning Electron Microscope to study the adhesion of the coating. The image of WCN-coated specimen is shown in Fig. 1

Fig 1. Coated Specimen

The cross-sectional SEM micrograph of the specimen in Fig.1 is shown in Fig.2. It can be found that there is no space or cracks in the interface between the coating layer and the substrate, which suggests that the adhesion between coating and the specimen is good.

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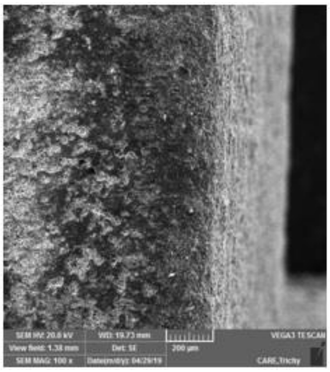

Fig.2 SEM image of the coated specimen

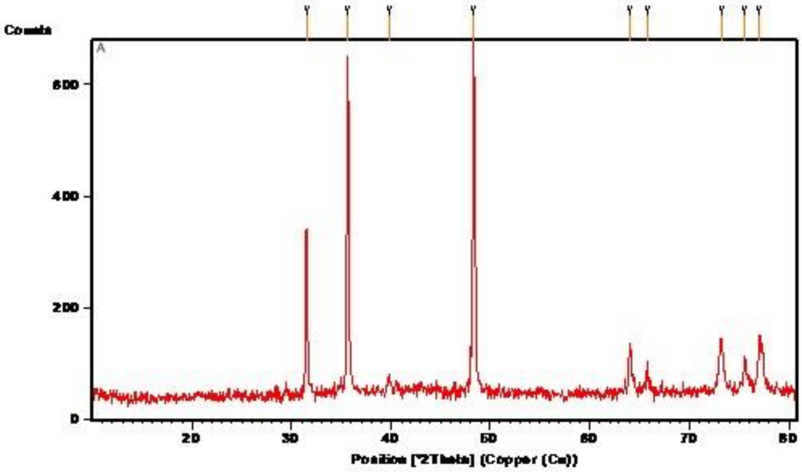

Fig.3 XRD pattern of the coated specimen

The XRD pattern of WCN coating is presented in Fig. 3. According to the XRD pattern shown in Fig.3 WCN coating exhibits a cubic structure with slight preferential orientation, originated by a cubic lattice whose positions lie intermediate between those for bulk W_2C and W_2N phase. These peaks correspond to a β -WCN phase. These suggest that W_2C and WCN phases coexist in the coatings. XRD observation of WCN coating reveals that the coating consists of a mixture of WCN, amorphous WC and C phases.

In order to investigate the wear resistance of WCN-coated specimen, the abrasive wear test result are listed in table 3(a) & (b). The maximum wear of uncoated is 2078µm (a) and that of WCN –coated specimen is 68µm.(b).The high temperature wear test result are listed in table 4 (a) & (b). The maximum wear of uncoated specimen is 785µm (a) at 245°C and that of WCN-coated specimen is628µm(b) at 245°C. AS can be concluded from these results the wear resistance of the specimen is improved by coating WCN on surface

Load (kg)	Wear Track Diameter (mm)	Speed (rpm)	Wear in (micrometer)			
			Normal Wear Test		High Temperature Wear Test	
			Uncoated Specimen	Coated Specimen	Uncoated Specimen	Coated Specimen
1	80	477	1758	53	345	199
1.5	80	477	1888	54	546	403
2	80	477	2078	68	785	628

Table 3. Normal and High Temperature Wear test results

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The images of the surfaces of the uncoated (a) & (c) and WCN coated (b) & (d) specimen after the wear test are shown in Fig.3

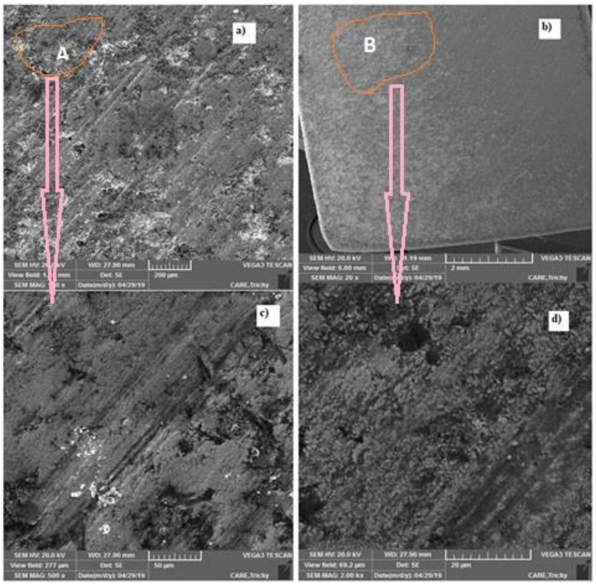

Fig.3 Images of the surfaces after wear test of (a) uncoated specimen (b) coated specimen
(c) Enalrged view of portion of uncoated specimen (d) Enlarged view of portion of coated specimen

As shown there is still a metallic lustre on the surface of the coated specimen (Fig.3b) and a severe wear is found on the surface of uncoated specimen (Fig.3a). This suggests that the WCN coating could reduce the wear effectively. In order to better observe the wear conditions the partial enlarged pictures taken from Fig. 3(a) (part A) and 3(b) (part B) are shown in Fig. 3(c) and 3(d) respectively. In Fig. 3(c) there is a deep wear line and obvious deformation. Additionally some wear debris are observed from the enlarged region of part C in Fig. (c). In Fig.3(d) the WCN coating in the wear track has developed cracks and this suggests that the coating would lead to spllaing failure if the substrate was run longer. Comparing Fig. 3(c) and 3(d) it can be seen that the WCN coated specimen has fewer deformation and wear debris. This is mainly due to the higher hardness of the coated specimen compared to the uncoated specimen.

As listed in Table.2 the hardness of WCN-coated and the uncoated specimen are found to be 1175 HV and 358 HV respectively. For WCN coated specimen the load capacity is increased due to the higher hardness compared to the uncoated specimen and then the crack resistance is increased. During the test the debris is difficult to generate on the surface of WCN-coated specimen under the same loading force compared to the uncoated specimen.

S.No	Load in kg	Sample Name	Trial 1 (HV)	Trial 2 (HV)	Trial 3 (HV)	Average (HV)
1	0.5	Uncoated specimen	356	355	365	358.88
2	0.5	Coated specimen	1226	1153	1146	1175

Table.2 Micro Hardness test values of coated and uncoated specimen

V. CONCLUSION

In this investigation WCN was coated on the surface of cast iron to improve its wear resistance and then to prolong its service life. The major conclusion drawn from this study is as follow:

The SEM analysis shows that no space or cracks to be found in the interface between the coating layer and the substrate which suggests that the adhesion between coating and the substrate is good. The coated specimen showed improved hardness than the uncoated specimen and hence improved tool life under similar loading and service conditions. Also the normal and high temperature wear tests add to the fact that the coated specimen shows improved performance than the uncoated specimen.

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