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Microstructure characterization of (CrC)+(Mo+Fe)+NiCrAlloy Coating by Atmospheric Plasma Spraying on Piston Ring with Liner Contact

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Abstract:- *The current study deals with the tribological property of piston rings of cast iron coated with (CrC)+(Mo+Fe)+NiCr alloy with plasma spray coatings.To improve the tribological characerstics of the engine, the thermally sprayed technique are being used for depositing the coating on various parts. To provide a reliable basis for the practical application in automotive industry, a composite powder containing 60% high carbon molybdenum, 20% pure molybdenum, 10% CrC and 10% NiCr deposited on the cast iron substrate by atmospheric plasma sprayedand was characterized by SEM. It was found that coating has structure uniformly dense, laminar structure with an exceptional coating adhesion with the substrate.*

Key-Words: *APS coating; CrC, NiCr, Piston Ring*

INTRODUCTION

Surface engineering is an innovative and enabling technology that can be found in automotive industry and advanced and precision manufacturing sectors that make every effort for efficiencies. The tribological behavior of piston rings has a significant influence on the performance of internal combustion engines regarding power generation, fuel economy, oil consumption and harmful exhaust emissions of gases(Tung and McMillan, 2004). Unfortunately, the piston ring is one of the largest sources of friction in the internal combustion engine over the standard range of engine speeds and loads encountered in service (Cho and Yun, 1998)(Holmberg, Andersson and Erdemir, 2012). Exact figures vary from engine to engine, but typically the piston assembly, comprising both the piston rings and the piston skirt, accounts for 40–50% of total engine friction.Another problem with tribal contact part is wear. The progressive damage caused due to the material loss which occurs on the surface of a part in contact. As a consequence of its motion about the adjacent working, parts has a far-reaching economic impact which involves not only the cost of replacement but also the expenses involved in engine breakdown and loss of time(Kim, 2011)(Kumara and Pandey, 2016).

Thermal spraying is widely accepted and effective technique of coating to suit and improve the wear resistance, thermal barrier and corrosion/oxidation. It includes the ability to deposit high and low melting point material with high deposition rate that exhibits enhanced functionality.
CrC and NiCr have been considering as high-quality materials for different applications, based on their thermodynamic stabilityand thermal shock resistance. In addition, these thermal spray coatings have excellent properties such as high fracture toughness and maintaining their stability at high temperatures. TiC coatings also have unique characteristics like high hardness and high elastic modulus and low coefficient of friction.

The objective of the research is to demonstrate and develop a coating recipe with optimum main constituent % of the coatings that are CrC and NiCr with a binder of Mo+Fe by atmospheric plasma spraying. So that wear resistance and coefficient of friction of coating on cast iron substrate would be improved. With the contact of cylinder liner to replica of engine set conditions and replacement of hard chrome plating. The CrC blends with nickel-chromium powders where the nickel-chromium alloy acts as a matrix and binder that improves, in general, the coating integrity and corrosion resistance, on the other hand,the chromium carbide constituent serve as a hard phase that assures wear resistance. a coating of 60% high iron carbon molybdenum powder blended with 20% pure molybdenum, 10% chromium carbide and 10% Nickel Chromium was sprayed using atmospheric plasma spraying technique on a cast iron substrate. The microstructure and phase of high iron carbon molybdenum based coating were studied in this paper, to provide a reliable basis for the practical application in automotive industry.

2. Materials and method

2.1. Sample Preparation

The cast iron plate was used as substratematerial. The sample plate (90x90x2mm) was plasma sprayed with Sulzer - metco PT-F4 torch in an isolated environment using a robot. The robot ensured control and reproducible trajectories and speeds. Primary gas argon with pressure 95Psi and secondary gas hydrogen with pressure 80psi get mixed inside the chamber and flow through a gun calibre.A high voltage is generated which leads to form a mega spark at the spark plug; themega spark ionises the air between the nozzle and the electrode resulting in electric conduction between them without their contact. The coating microstructurewas further explained in the result section.

2.2. Composition and process parameters

With the two main constituents of the coating Mo+Fe and CrC, Mo+Fe is decreasing from 50% to 10% and CrC is increasing from 10% to 50% successively, we have prepared five samples with a differentcomposition.The powder used in the coating shown in Figure 1 (a, b& c)are characterised by morphological techniques like SEM and EDS. The size of powders is varying in the range from 20 to 60 µm.The shape of Mo+Fe (Figure 1 (b)) is thespherical and NiCr, and CrC (Figure 1 (a, c)) ishaving sharp edges. Substrate material used for the coating is cast iron which is used for the casting of piston rings in industries. The composition of substrate material is given in Table 1.For the stablecomposition of the entiresubstrate,stag casting was used.The whole sample was prepared in one shot. The process parameters of atmospheric plasma spray coatingare shown in Table 2. All substrates were sandblasted using Al_2O_3 powder to clean it before spraying tomaximise coating adhesion. With the SEM &EDS it is clear that powder size is uniform throughout the mixture. Their alloying composition can be verified with the EDS. It gives us clear understanding from SEM that an agglomerated powder with ahomogeneous distribution of screen size distribution is used for the coating.

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Table 1 - Composition of substrate material (cast iron) used for coatings

Element	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cr (%)	Cu (%)
Target	3.75±0.05	2.70±0.05	0.53±0.01	0.36±0.02	.06±0.005	0.04±0.01	0.035±0.03

Figure 2.1: SEM results of powder; (a) SEM of CrC Powder; (b) SEM of Mo+Fe; (c) SEM of NiCr Powder

Table 2 - Process parameter of Atmospheric Plasma spray coating parameters

Sr. No	Process Parameter	Specification	Unit
1	Powder Port I.D.	2.2	mm
2	Water Flow Rate	4.0	Liter/min
3	Temperature of chiller	62	0F
4	Distance between spray gun & mandrel	140(At gun angle 300)	mm
5	Argon Flow Rate	112	m3/min
6	Hydrogen Flow Rate	13	m3/min
7	Argon Pressure	95	psi
8	Hydrogen Pressure	80	psi
9	Powder flow Rate	50	gm./min
10	Voltage	70	volt
11	Current	460	ampere
12	Gun Feed	10	mm./min
13	Gun Angle during spray	30	degree
14	Cooling air pressure	47	kgf
15	Powder driving temperature	120	0C
16	Powder mixing	90	Min.

3.0 Results and Discussion

3.1 Microstructural Characterization of Coating

Morphological techniques used to characterize the coatings by formation of splats, complete melting and bonding conformity by scanning electron micrograph (Secondary electron) as shown in figure-2. Melting of the powder was perfect (figure 2a) except very few example of partially melted powder. The surface of a thermally sprayed coating is composed of lamellae formed of molten, partially molten & unmelted particles as shown in figure 2b. In the other section of thermally sprayed coating displays many lamellae piled up one upon another as shown in figure 2a. With the help of scanning electron micrograph of the coated surface identified different type of splat observed in the coating, few common splatare as-sprayed splat(figure 2b), splash splat(figure 2c) and disc splat (figure 2d). These splats are clear indication of proper coating and uniform bonding of the sprayed material (figure 2d). Top view of the coated surfaces as seen with scanning electron micrograph (secondary electron), shows flattened and solidified droplet and crack generated by tensile quenching stress originating from the large temperature drop during coating. The microstructures of the coating suggest that the splat of the sprayed material does not seem to form a continuous layer but at the cross section, it was observed that the coating was more homogeneous and regular. The spraying torch moves with regards to the substrate and coating grows more slowly. In fact a typical torch moves over the substrate with certain linear velocity. The number of lamellae in one layer, deposited during one torch pass depends on the velocity.

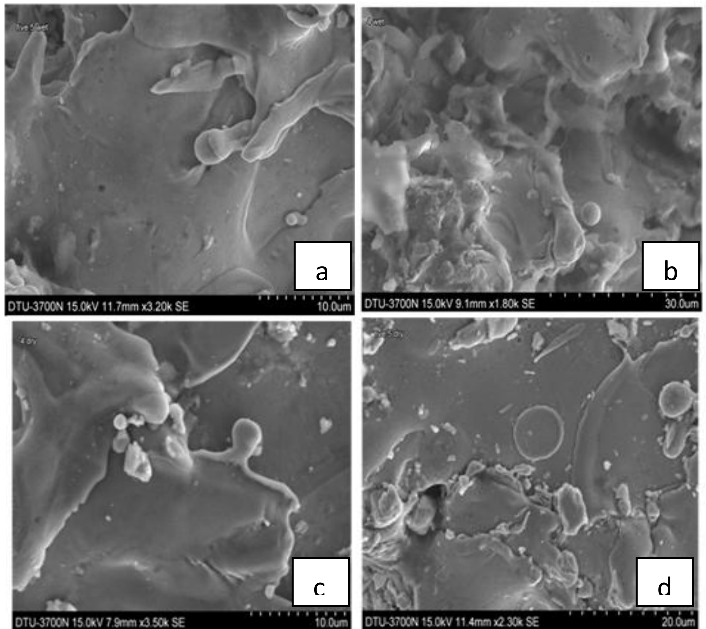

Figure 2 : Scanning electron micrograph (Secondary electron) of different types of splat (a) Flash & splash splat (b) Melting & bonding (c) Splash splat of splat (d) Disc splat

Conclusions

$(CrC)_X$+(Mo+Fe)+$NiCr_X$coating was fabricated with the help of hydrogen and argon by using plasma spraying on the piston ring material (cast iron) is investigated by scanning electron microscope and X-ray diffraction. The following points are concluded from the experimental results are as follows:

- The grain size of the different powder varies from 10-50 µm
- The X-ray diffraction results of the coated sample show the sharp peaks of Cr_2C_2, $Fe_{0.875}Mo_{0.125}$ and $Cr_{0.5}Mo_{0.5}$; it can be inferred that Cr_3C_2 decomposed during plasma spraying, forming carbides of Cr element. This is the clear evidence for the formation of the different structure in the coating.
- The microstructure of the plasma sprayed coating shows a uniformly dense, laminar structure with an exceptional coating adhesion with the substrate. It also shows Unmelted Mo and partially melted Mo particle. With some disc splat, and an irregular layers of coating at some places as investigated by SEM results.
- The observed coating thickness of the coating was found to be about 371 µm, as observed by SEM.

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