Microstructural behavior of CrC Based Alloy Coatings by Atmospheric Plasma Spraying on Piston Ring with Liner Contact

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Abstract

The current study deals with the study of tribological property of piston rings of cast iron coatedwith CrC based alloy coatingsfrom 10% to 50% by weight and Mo+Fe is decreasing from 50% to 10% by weight in each sample by alloying Mo and NiCr composition same in every sample.In this paper microstructure and phases analysis of the deposited coating by scanning electron microscope and X-ray diffraction was performed. The results show that the obtained composite coating has a uniform, laminar and dense microstructure with good coating adhesion with the substrate. The thickness of the composite coating on the substrate is about 371μm.

Key-Words: Thermal spray, CrC Alloy, Wear. Friction, Temperature

Introduction-

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 gasses(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 and The progressive damage caused due to material loss and wear 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 loss of time(Kim, 2011)(Kumara and Pandey, 2016). It is reported that the performance of the mechanical seal improves substantially with surface textured faces compared with untextured seals(Manjunatha and Basavarajappa, 2015). Among the physical parameters, the aspect ratio of pores was found to be the most important, whereas the effect of texture area density was the most insignificant. The number of pores and aspect ratio are critical parameters about the area density and inertia of the piston ring(Gangatharan *et al.*, 2016). One the promising coating for reducing wear and friction is hard chrome coating which is achieved by electroplating that gives better lubricant and wears resistance. However hard chrome traditionally coated by electroplating process gives waste of cryogenic and unfriendly environmental hexavalent chromium which is banned throughout the world(Houdková *et al.*, 2011)(Guilemany *et al.*, 2006). Alternative solutions are searched which are more challenging and costly. Thermal spray is a solution to maintain the parts or free standing parts where thin layers of coatings were deposited on the parts by melting the desirable metals or alloys through HVOF or plasma heat and then accelerating the droplets to form splats upon collision—later, the splats will solidify, and the coating is created(Bolelli, Lusvarghi, Manfredini, Mantini, Turunen, *et al.*, 2007). The advantage of thermal spray technique is that no replacement of spare parts is required and the maintenance is a lot more convenient with lower cost. Many researchers have studied tribological properties of thermally sprayed coatings as a replacement of hard chrome plating(Picas, Forn and Matthäus, 2006)(Henderson, 2003)(Guilemany *et al.*, 2006)(Romero *et al.*, 2003)(Friedrich *et al.*, 1997)(Sen, 2006). They concluded to replace hard chrome plating with tungsten carbide and chromium carbide based hard materials used to spray by HVOF or plasma(Bolelli, Lusvarghi, Manfredini, Mantini, Turunen, *et al.*, 2007)(Bolelli, Lusvarghi, Manfredini, Mantini, Polini, *et al.*, 2007).

The selection of CrC coating on piston rings due to its unique physical and chemical properties of chromium carbides like high melting point, extreme hardness, low coefficient of friction and chemical inertness make them candidates for wearing corrosion-resistant coatings(Su *et al.*, 2006).

A lot of researchers (Lih *et al.*, 2000)(Bolelli *et al.*, 2016)(Sharma, 2014)(Guilemany *et al.*, 2002)(Lih *et al.*, 2000) used HVOF spray to deposit CrC alloy coatings on different substrate to examine wear properties such as (Picas, Forn and Matthäus, 2006) demonstrated that CrC–NiCr HVOF coatings are equivalent or better in performance than chrome plating to coat different type of critical mechanical components (valves, pistons, piston rings, rods, hydraulic components) with a capable and economical "clean" HVOF technology(Picas *et al.*, 2003). characterized the mechanical and wear behavior of HVOF Cr3C2–NiCr coatings from sintered nano-composite Cr3C2–NiCr powders, to improve the lifetime of coated materials. They showed nano-structured coatings suffer greater levels of reaction and as a result, show lower hardness than a standardcoating. However, to achieve the superior wear resistance from CrC–NiCr coatings would require an optimization of the powder preparation, an adaptation of the spray process, the chance of oxidation, porosity and a lot of fuel gasses(Jiang *et al.*, 2012)(Wu *et al.*, 2016)(Peat *et al.*, 2016).

The objective of the research to demonstrate and develop a coating recipe with optimum main constituent % of the coating that are CrC and Mo+Fe with binder of NiCr by atmospheric plasma spraying to improve wear resistance and decrease in coefficient of friction of cast iron substrate that is piston ring material 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

2.0 Experimental Details

2.1 Materials

Two main constituent of the coating are Mo+Fe which is decreasing from 50% to 10% and CrC which is increasing from 10% to 50% successively prepared in five types samples. Used powder are shown in Figure by morphological techniques like SEM and EDS. Figure-1 (a&b) is the SEM & EDS of CrC powder, which indicates the size of powders are varying in the range from 20 to 60 µm and their edges are sharp whereas Figure-1 (b& c) is showing Mo+Fe is in spherical shape and NiCr are in large and thin in shape as shown in figure-1(b&c).These materials are very efficient for various sliding component in automobile industry and CrC-NiCr coatings can be used in corrosive resistant environment like automobile and aerospace industries. Substrate material used for the coating is cast iron which is specifically used for the casting of piston rings. To achieve uniform composition of the entire slab, stag casting was used for the preparation of the entire sample at one shot.All substrates were sand blasted using Al_2O_3 powder to clean it before spraying in order to maximize coating adhesion.Composition of substrate material has been given in table 1.

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

With the SEM & EDS it is clear that powder size is uniform throughout the mixture. There alloying composition can be verified with the EDS. It gives us clear understanding from SEM that an agglomerated powder with homogeneous distribution of screen size distribution is used for the coating.

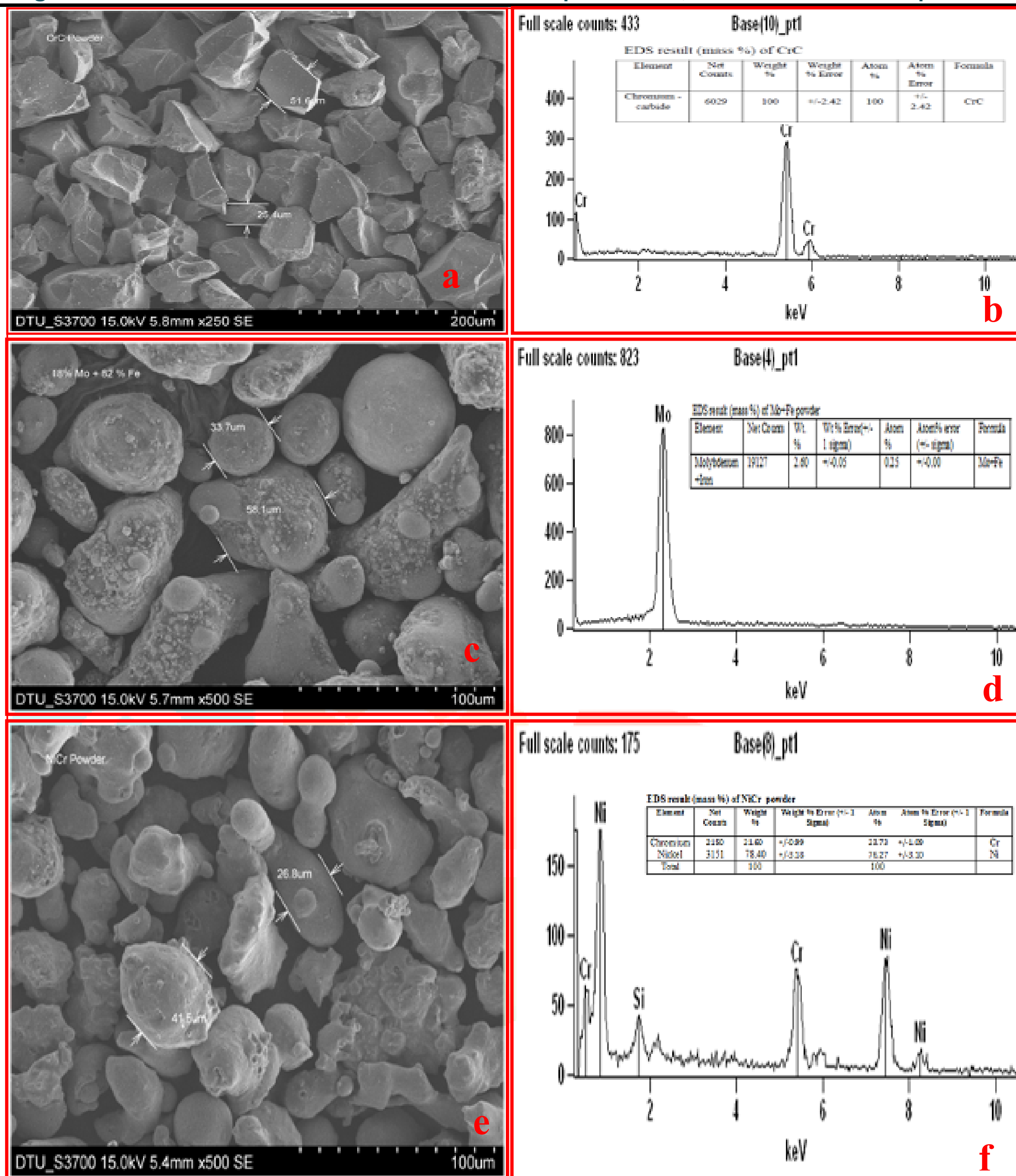

Figure 1: SEM & EDS results of powder; (a, b) SEM & EDS of CrC Powder; (c, d) SEM & EDS results of Mo+Fe; (e ,f) SEM & EDS results of NiCr powder

2.3 Microstructural Characterization of Coating

Morphological techniques are 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 we were able to 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 2e).

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 (figure 2f) 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.

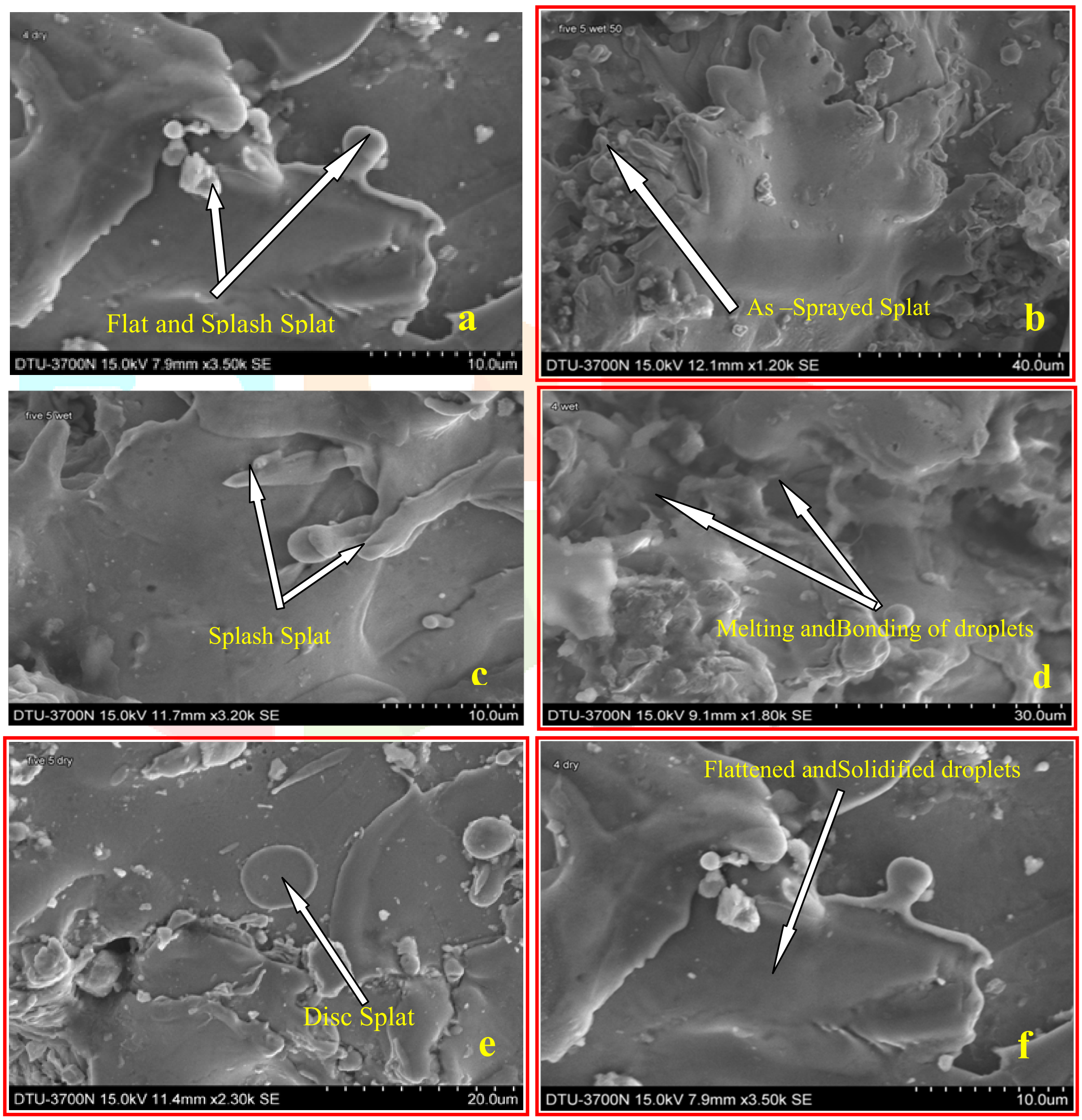

Figure 2: Scanning electron micrograph (Secondary electron) of different types of splat (a) Flash & splash splat (b) As – sprayed splat (c) Splash splat (d) Melting & bonding of splat (e) Disc splat (f) Flattened & solidified droplet

Conclusions

Chromium carbide based alloy coating was fabricated with the help of hydrogen and argon by using plasma spraying powder as feedstock. After exhaustive experiments we are able to predict some conclusions

- The grain size of the different powder vary 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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