MORPHOLOGICAL CHARACTERISTIC OF 60% Mo BASED ALLOY COATING BY APS TECHNIQUE

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ABSTRACT: Efficiency and performance are two critical characteristics of the internal combustion engine. The power generating component required to be efficient so as to increase the overall performance of the vehicle and to make maximum use of the energy. To improve the tribological characteristics of the engine, the thermally sprayed technique are being used for depositing the coating on various parts. In this paper, the effect of 60% Mo and Fe, 20% Mo, 10% NiCr, 10% Mo on cast iron substrate were investigated. The microstructure of the coating is studied with the help of SEM, EDX, and X-ray diffraction.

Key word: thermal spray, piston ring, coating

1.0 INTRODUCTION

The power generating component of a vehicle i.e. the engine is required to be efficient so as toimprove the overall performance of the automobiles engines and to make maximum use of the internal energy generated by the combustion of working fluid. Because of reasons above a lot of research is going on, in this sector to increase as well as maintain the performance of the engine[1].Some research on mechanisms of the damagetopiston has been investigated which mainly involved wear, temperature, and fatigue [2-3]. Since internal combustion engine with high efficiency has tendency to operate at higher temperatures, the heat resisting properties of piston rings have become a major issue,and the demand for better piston rings for internal combustion (IC) engine increases particularly in diesel engine pistons rings for higher heat resistance. The tribological behaviour of piston rings has been recognized as an important influence on the performance of internal combustion engines regarding power loss, fuel consumption, oil consumption, and harmful exhaust emissions. Therefore, 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 [4-5]. In practice, the damage in piston rings attributed first to wear (as there are parts in contact and relative motion), then to lubrication and fatigue.Also, piston assembly accounts for approximately 35–45% of all the internal combustion engine frictional losses[6].In spite of continuous evolution and research on piston rings, its failure is still a common phenomenon. It is the only component of the engine that encounters failure from different origins such as thermo-mechanical stresses, wear, fatigue, extreme temperatures, oxidations, etc. The failures also occur due to the engine working conditions like advanced ignition timing, lean carburetor jetting, foreign material trapped inside, inappropriate piston-to-cylinder clearance, low octane fuel, loss of lubrication, high compression ratio, etc. [7-8]. Different types of coatingsare used on piston rings to improve the characteristic of the piston rings.

Plasma SprayCoatings can act as an effective barrier to minimize the release of ions attributing to tribological failure [9]. The coating can increase the hardness along with excellent surface finishing, thus reducing the friction and wear rate various conventional techniques are being usedfor a long time [10]. Thermal Spray Techniques are widely used over the world. These techniques are categorized into many different methods. One of them is "Atmospheric Plasma Spray Coating (APS)." This process can apply the widest variety of coating materials, by far, of any thermal spray process. APS performs, where other processes cannot, with unlimited coating applications on metallic substrates. The flexibility of theair plasma spray process comes from its capacity to develop sufficient heat to melt almost any coatingpowder(feedstock). The plasma gun utilizes a chamber with one or more cathodes (electrodes) and an anode (nozzle)[11-12].Energy dispersive spectroscopy (EDS), (SEM) Scanning electron microscope, and X-ray diffraction (XRD) did the morphology study of the coating after wear analysis. The XRD studies show the phase composition of the coating prepared at the given spray parameters. This method has analyzed different diffraction peaks of the desired element of the coat.

The purpose of the investigation reported herein was to fabricate the 60%Mo-20%Nicr-10%Crc-10%Mo+Fe composite coating on gray cast iron substrate of the cylinder engine. To characterize these coatings, wear analysis, SEM/EDS and XRD were used.Further, with the help of these techniques specific wear rate, the coefficient of friction, and temperature has been analyzed with different load conditions.

2. Materials and Method

2.1 Substrate Preparation

Piston Rings is always produced in circular shape for the market use. It is very hard to get fresh piston ringsmaterial in our desired shape for the test purpose. As per Pin on Disc tribometer either we have to produce either a pin of circular form or disc of the desired dimension. In this experiment, we decided to create a disc of the well-known composition for the testing purpose.

A metal pattern of the desired dimension based on the constrained of the plasma spray coating machine has been prepared, for the easy removal of the casting, a draft of $½^{0}$ is provided on the pattern. A sand mouldis prepared with the help of the press. Molten metal of the pure constituent powder is made. The powder of **Carbon (C), Silicon (Si), Magnesium(Mn), Phosphorous (P), Sulphur (P),Chromium (Cr) & Copper (Cu)** are used for the preparation of charge for the furnace. For the melting of this powder Induction Arc Furnace (Fig 1) is used at a temperature of 1540 ^{o}C.

The induction arc furnace is preferred because it provides uniform melting of the charge. Stag Casting is done for the preparation of the entire sample at one shot to get the stable composition of the whole slab. The composition of the plateis controlled as per the following table- 1

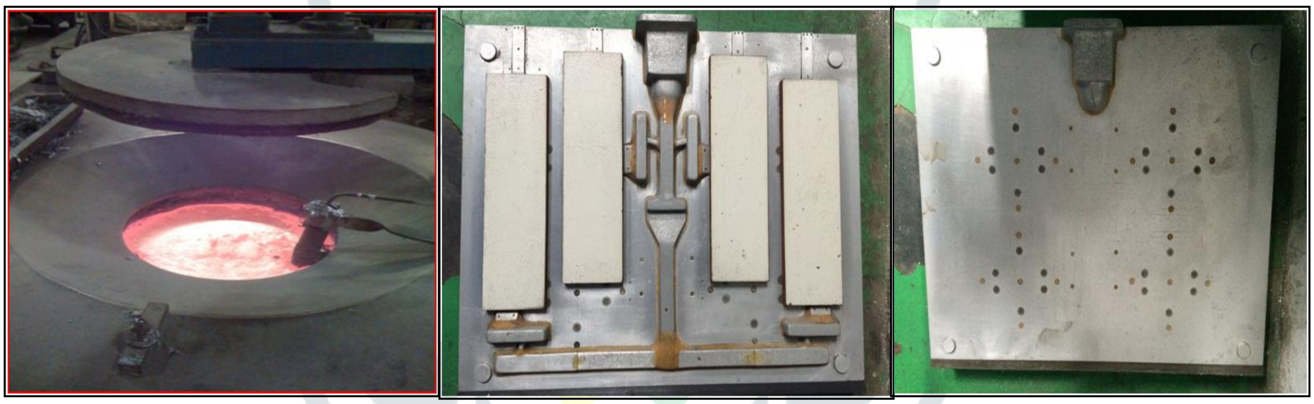

Figure 1 (A) Induction Arc Furnace Used for the Melting of Charge (B& C) Pattern used for casting of substrate

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

2.2 Coating Preparaton

The casting is removed from the mould, and sandblasting operation was performed. Finally, the casting is cleaned and is sent for further operation, i.e., grinding process. Thisoperationwas performed because the casting material contains irregularities with the poor surface finish and we want a smooth and cleaner surface with minimum possible defects. These abnormalities may cause wearing of both the pistons and the rings

Plate made of Piston Rings material (90x90x2 mm) was plasma sprayed with feedstock material materials Mo+Fe(20%), Molybdenum (20%), NiCr (10%) & CrC (10%) with a Sulzer-Metco PT-F4 torch in an isolated environment using a robot. The robot ensured controlled and reproducible trajectories and speeds. The plasma gas was containing 20-25 (Volume %) of hydrogen. The coating feedstock material was vertically injected into the plasma jet by argon carrier gas for primary flow and hydrogen for the secondary flow. Primary gas, Argon and secondary gas, Hydrogen, 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. The mega spark ionizes the air between the nozzle and the electrode resulting in electric conduction between them without their contact. Due to this high-temperature mega spark, the moving hot gasses turn into plasma. Different combinations of spraying parameters (pressure, input power, standoffdistance and substrate cooling) were selected; a plasma torch suitable for N_2 based plasma gasseswere used, Table-2

Table 2.2- Atmospheric Plasma spraying 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.

The powder feeding system was a single bowl apparatus, and the powder feed rate was fixed at 50±5gm/min. The plates were sandblasted with Al_2O_3 powder before spraying. During spraying, a cooling system consisting of air jets and Venturi nozzles was applied.Special attention was paid to the dependency of micro- structure and chemical composition of coatings on the nature of the plasma gas: Ar: H or Ar: He, the power ofthe plasma jet: 13–19.5 kW and the cooling machine.

2.3 Powder Characterisation

SEM of the coating particles, NiCr, CrC, Mo, and Fe-Mo are shown in figure 2. The morphology of Mo particles was nearly in aspherical shape with asize of the sphere varying from 50µm-100µm. The size of CrC powders was smaller than that of Mo with sharp edges with average particle size of 41µm. Compared to Mo particles, the NiCr powders were almost in an irregularshape. No aggregate of Mo, NiCr, CrC powders canbe seen from SEM micrographs. This feature is asignificant issue during plasma spraying.

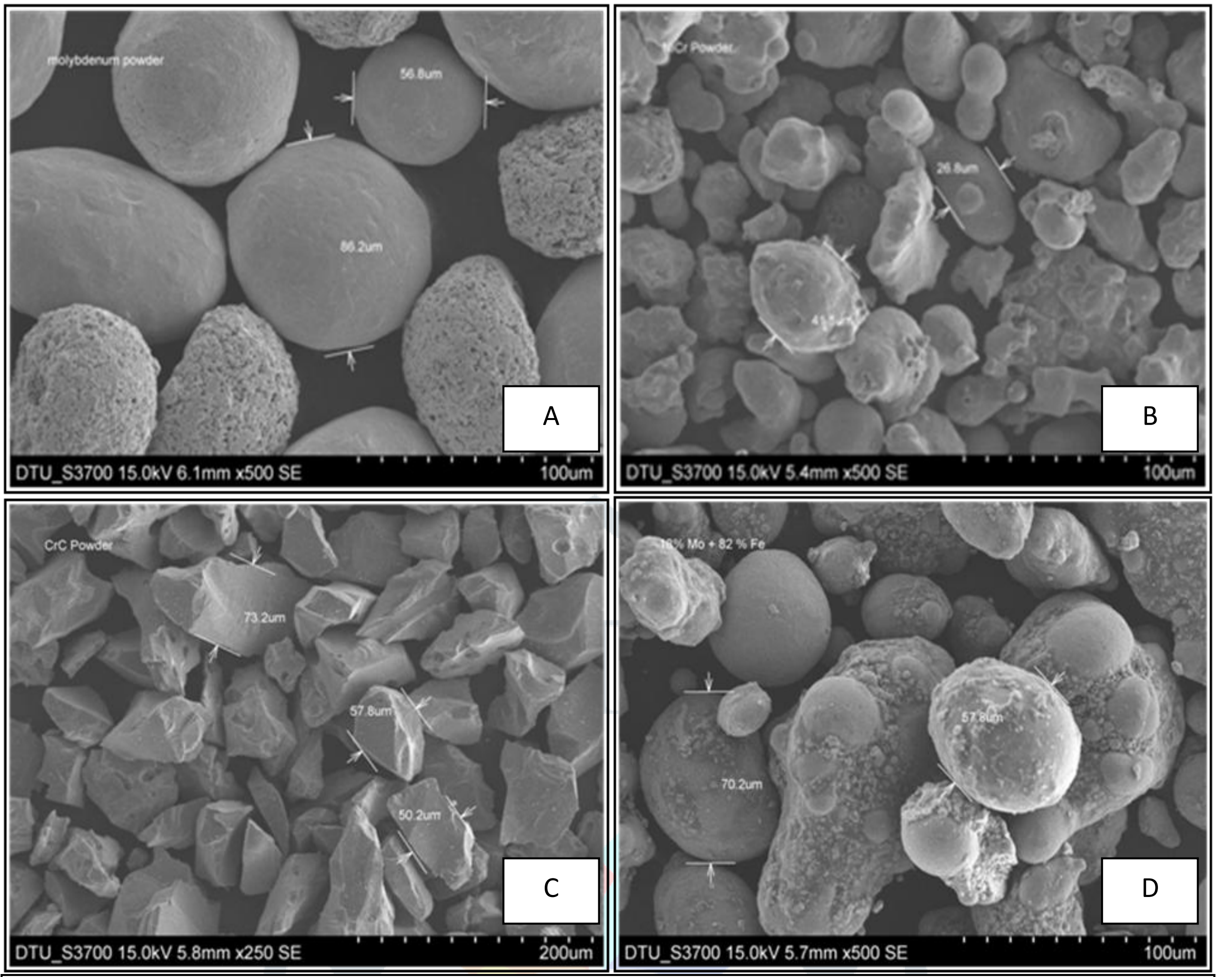

Figure 2 Morphology of powders used for coating (A) Mo Powder (B) NiCr Powder (C) CrC Powder (D) Fe-Mo powder

2.4 Characterization Atmospheric Plasma Sprayed Coating

Microstructure investigations of coatings by scanning electron microscopy of 60% Mo+Fe, 20% Mo, 10% NiCr, and 10% CrC are reported in Figure-4. It is analyzed that spray coating consisted of an elongatedsplat of molten powder which formed a curved laminar structure and oxides layer in between, and evidence of oxide layer formation can be confirmed by the presence of oxygen in EDS. EDS analysis has been used for the analysis of mass percentage. Figure-5 is showing the graphical representations of the elements present in the sample whereas some elements which are lighter, EDS analysis of graph does not capture them. No cracking and peeling were observed at the interface between the coating and the substrate. Based on image analysis of micrograph the presence of fully melted (Figure.3), unmelted particle (Figure.4D), and porosity of irregular shape (Figure. 3, 4) were detected.

XRD and their peaks analyzed the phase composition of samples and confirming the formation of different phases. It is seen from the X-Ray diffraction pattern; the splitting of the diffraction peak at two-theta angles 40.42^0, 43.97^0, and 73.69^0 characteristics of the orthorhombic structure is evident from the insert of Figure-6. First one is carbide phase showing Cr_2C_2,and the other two are $Fe_{0.875}$ $Mo_{0.125}$ & $Cr_{0.5}$ $Mo_{0.5.}$ The major one is the formation of carbide that increases the hardness of the coating by which the specific wear rate also decreases. Increasing intensity of the peaks is shows ahigher probability of the spraying powders that are melted completely inside the flame of plasma spraying gun.

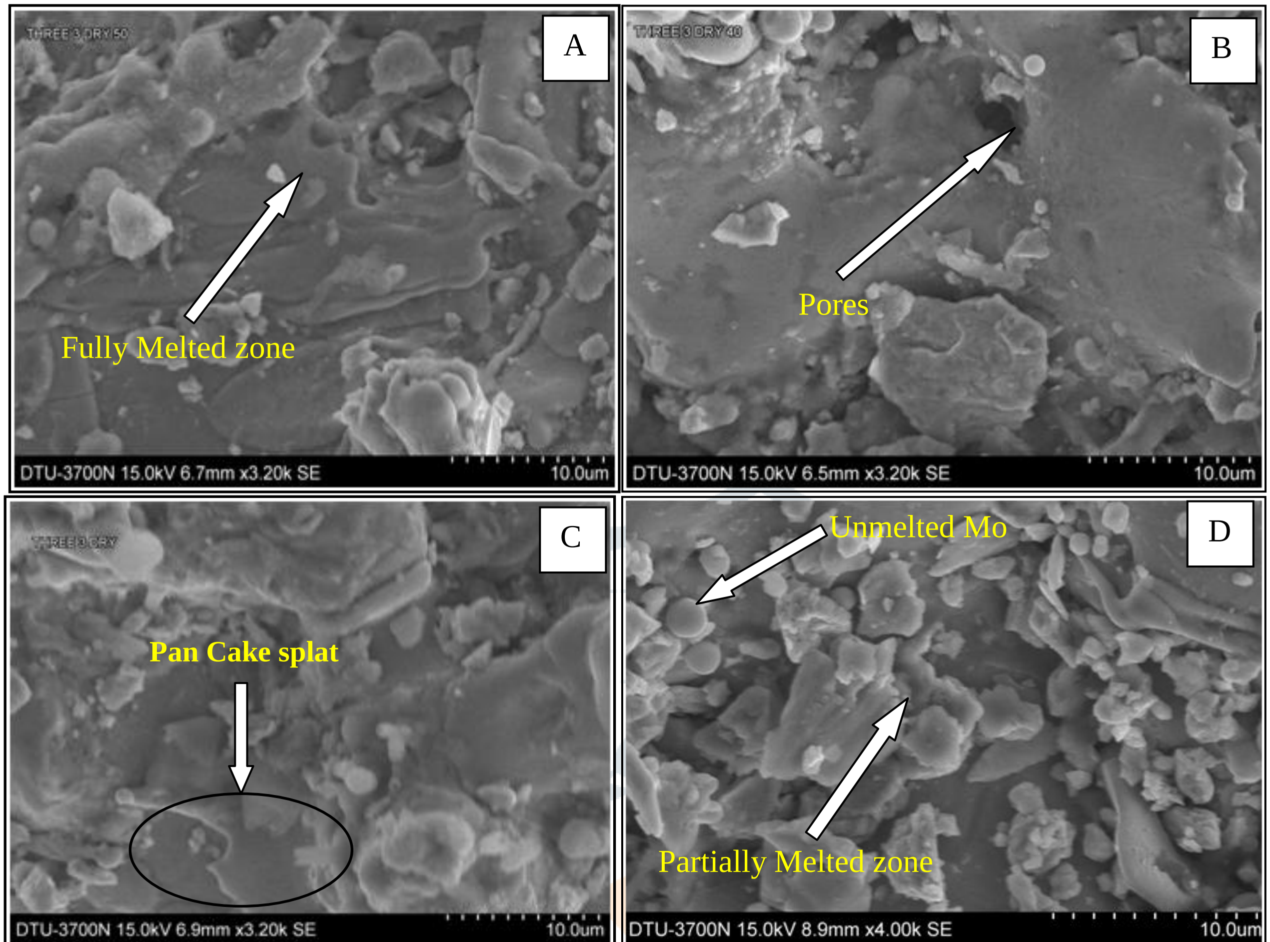

Figure-3Scanning Electron micrograph of solidified splat on surface of the coating (A)Fully melted zone (B) Pores (C) Pan cake splat (D) Partially Melted and Unmelted Particle

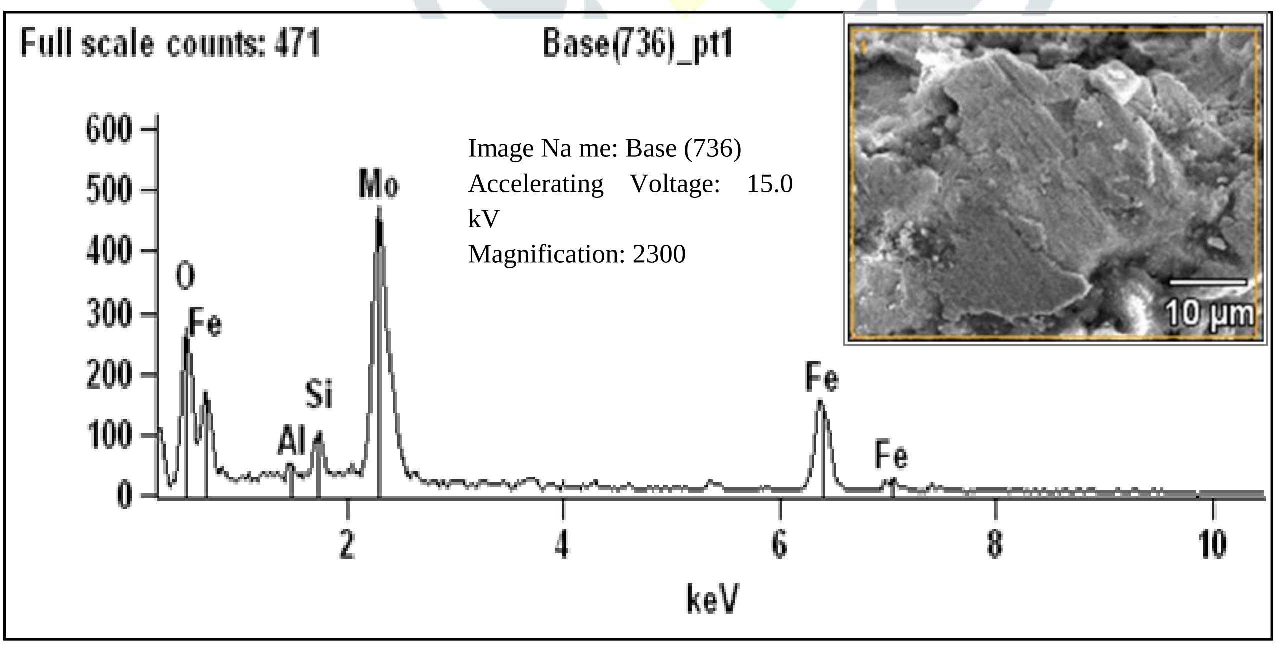

Figure-4Graphical Representation of EDS (mass %) of coated plate

Table3 -Volume percentage (element) of coated sample

Element	Net Counts	Weight %	Weight % Error (+/- 1 Sigma)	Atom %	Atom % Error (+/- 1 Sigma)
Aluminum	150	0.48	+/-0.09	0.73	+/-0.14
Molybdenum	7749	39.04	+/-0.94	16.79	+/-0.41
Iron	2430	38.67	+/-1.10	28.58	+/-0.81
Silicon	685	2.11	+/-0.17	3.10	+/-0.25
Oxygen	2168	19.69	+/-0.64	50.80	+/-1.64
Total		**100**		**100**	

4. CONCLUSION

Chromium carbide,nickel chromium, molybdenum, Mo+Fe,based alloy the coating was fabricated with the help of hydrogen and argon by using plasma spraying powder as feedstock. After exhaustive experiments we can predict:
All the coating shows a complete melting layer with small amount of partially melting regions as which is generally formed inside the hot zone located in front of the plasma spraying gun. Some pores also observed, and splat boundaries are not clearly visible.
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.

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