DRY SLIDING WEAR BEHAVIOUR OF PLASMA SPRAYED Al_2O_3-30%Mo, Mo & WC-12%Co COATINGS

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Abstract-- The use of hard coatings to improve wear resistance of mechanical components is now well established. Of the advanced deposition techniques, plasma spraying is one of the most efficacious and adaptable process. Over the years, a variety of plasma sprayed ceramics, carbides and cermets have been tried as a replacement for the conventional coatings. The Molybdenum(Mo) is now being considered to be a future coating material for automotive engines. The WC–12%Co is well known for its high strength, hardness, toughness and wear resistance up to 5000C. The WC–Co coatings are widely used for tools, dies and wear resistant parts in variety of applications including machining, mining, metal cutting/forming, construction and other applications in the form of bulk parts or coatings. The fracture toughness of ceramics like Al2O3 can be enhanced by the addition Mo as a second phase. Due to its hardness and improved toughness Al2O3-Mo generally used in wear resistant components, such as water pump seals.

In this paper, the powders of Mo, WC-12%Co and Al2O3-30%Mo were plasma sprayed on AISI1045 steel substrates to produce coating. The wear behaviors of plasma sprayed samples were investigated. The worn surface failure and the microstructure of the coatings were analyzed using a scanning electron microscope (SEM). The wear test results indicated that wear volume loss of the all coatings increases with increasing the applied load and sliding speed. The Al2O3-Mo coatings exhibits higher wear volume loss due to de-bonding of the Mo particles from the matrix and formation of MoO3. The plasma sprayed WC-12%Co coatings reveals the best wear resistance because it contained a larger amount of hard carbides

***Keywords*- plasma spray, coating, molybdenum**

I. INTRODUCTION

Wear and abrasion are the unprecedented hitches of more or less all branches of engineering. Lubrication, which was thought to be one of the most effective solutions for Combating wear, is certainly not perfect, and situations can arise where metal to metal contact exist which results in scuffing. This was the fact lies behind the continuing improvement of surface modification techniques, so as to mitigate friction and wear losses and to improve the material performance in specific working conditions [1].

The use of hard coatings to improve the friction response and wear resistance of mechanical components is now well established. Of the advanced deposition techniques, plasma spraying is one of the most efficacious and adaptable because of the wide range of coating materials and substrates that can be processed. In a plasma spray process, a material, often in the form of powder, is heated rapidly above the melting point by insertion in a hot gaseous medium and simultaneously projected at high velocity onto the substrate, generating the coating upon solidification [2].

Over the years, a variety of plasma sprayed ceramics, carbides and cermets have been tried as a replacement for the conventional coatings. Molybdenum (MO) is now being considered to be a future ring coating material for automotive engines, in order to overcome the problem of premature coating failure [3]. WC–12%Co is well known for its high strength, hardness, toughness and wear resistance up to 5000 C. It has a combination of high hardness, high ductility and high Young's modulus. In addition, it forms strong bonds with cobalt. By combining WC as the hard constituent with Co as the ductile binder, plasma sprayed coatings of WC–Co exhibit excellent wear resistance and are widely used for tools, dies and wear resistant parts in variety of applications including machining, mining, metal cutting/forming, construction and other applications in the form of bulk parts or coatings

[4,5]. Brittleness is the key technical limitation to a wide use of advanced ceramics. Inspite of this, they are among the most wear resistant materials due to the high values of hardness, Young's modulus and fracture strength. The fracture toughness of ceramics like Al_2O_3 can be enhanced by the addition Mo as a second phase. Due to its hardness and improved toughness Alumina generally used in wear resistant components, such as water pump seals [6–8].

Plasma spraying permits the combination of coating alloys with substrate materials [9]. In this paper, the powders of Mo, WC-12%Co and Al_2O_3-Mo were plasma sprayed on AISI1045 steel substrates to produce coating. The wear behaviour of plasma sprayed samples was investigated. The worn surface failure and the microstructure of the coatings were analyzed using a scanning electron microscope (SEM).

2. Experimental Details

2.1 Materials

Materials used are commercially available WC-12%Co, Mo, Al2O3-Mo powder with a particle size of ranges from 40–90μm. The substrate material for the coating was AISI 1045 steel was selected because this material is widely used for variety of general engineering and construction applications including pins and chains, shafts, hard wearing surfaces, axles and automobile parts. AISI1045 steel was prepared as pin with a size of 10mm diameter and 30 mm height. The counter face disc is made of from material EN-32 steel plate to a size of 100mm diameter and 4mm thickness.

2.2 Plasma spraying

The pins were grit blasted to improve the adherence. The spraying was conducted in open atmosphere by means of the plasma spray gun (ALT-F 3MB) which was stationery and the specimen was mounted on a rotating table. The plasma gas was Ar+ 20to25 vol. % H2. The coating feedstock material was injected vertically in to the plasma jet by argon (Ar) carrier gas for primary flow and hydrogen (H2) for secondary flow. The plasma spraying was performed with a parameter combination shown in Table 1. The coating thickness of the sprayed specimens was controlled to 300μm.

Table 1 Process parameters for plasma spraying

Parameters		*Range*
Plasma system Gun		*ALT-F 3MB*
Plasma gases	*Pressure(Psi) -Argon &Hydrogn*	*100-120*
	Flow rate (Scfm) Argon	*80-90*
	Hydrogn	*20-25*
Power	*Current(A)*	*490*
	Voltage(V)	*70*
Powder feed rate (gms/min)		*40-50*
Spraying conditions	*Nozzle dia(mm)*	*8*
	Distance(inches)	*3-5*

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2.3 Wear tests

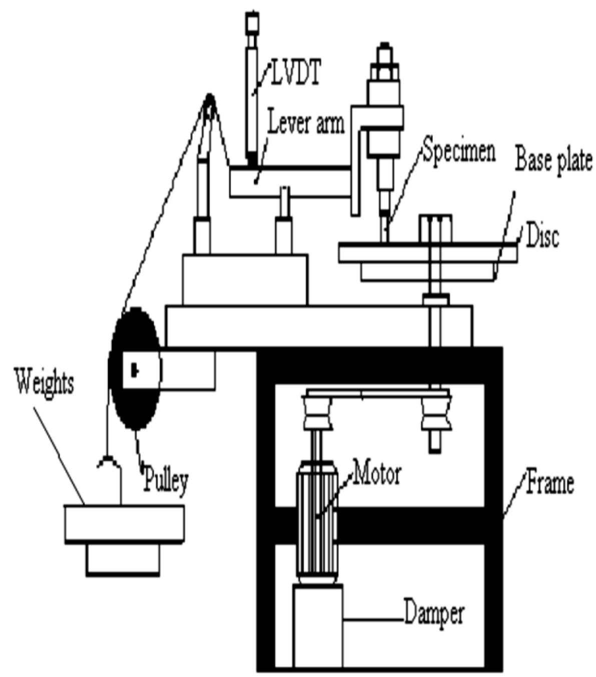

Fig 1.Schematic Diagram of the pin-on-disc wear tester

The Sliding wear tests were performed on a pin-on-disc machine; schematic diagram is as shown in fig.1.Tests were carried out by sliding the coated pin against the EN32 steel disc, under dry conditions by varying the applied load, sliding distance and sliding speed. The wear of the coated pin is calculated by the conventional weight loss technique. The data regarding wear of the coated pins obtained from interfacing a machine to computer terminal. Prior to any experiments, the plasma coated pin surfaces were thoroughly cleaned with help of acetone.

3. Results and Discussion

3.1 Effect of Load on Wear Volume Loss

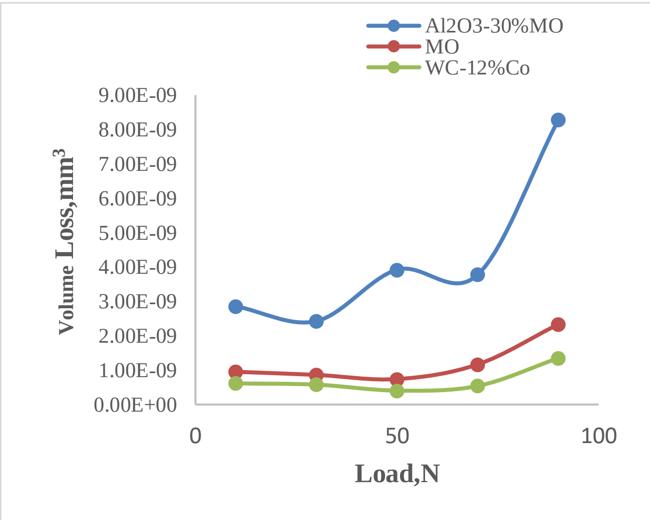

Fig.2 Wear behavior of plasma sprayed Al_2O_3-30%Mo, Mo, WC-12%Co coatings at varied loads.

The variation of wear volume loss with applied load at a constant sliding speed of 540rpm and sliding distance of 5000 m is shown in Fig. 2. The wear volume loss for all the sprayed coatings increases as the applied load increases. For Al_2O_3-30%Mo coating, the wear volume loss increases unexpectedly at load of 70 N. the wear volume loss of WC-12%Co coating is very low compared to the other coatings.

The complete surface of the pin is in contact with the surface of the counter face during the early stages of wear. The whole contact between the pin and the counter face consequences in severe stress on the pin's surface. Figure 3(a) and (b),Fig.4(a) and (b)Fig.5(a) and (b) shows the micrographs of the worn surfaces of Al_2O_3-30%Mo,Mo,WC-12%Co coated pin at an applied load of 30N and 70N, speed of 540rpm and a sliding distance of 5000m. The Figures.3, 4 and 5 shows the grooves, de-lamination and fractured splats formed on the surface of the pin. At lower loads the wear debris trapped between the pin and the counter face. As the load increases to higher values, the morphology of the worn surfaces gradually changes from fine scratches to distinct grooves. The hard particle in the form of wear debris between the pin and the counter face act as an abrasive medium and ploughs the surface of the pin, causing de-lamination of the coated material.

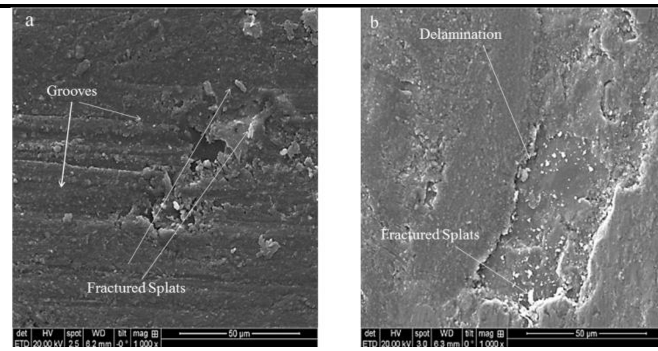

Fig.3 SEM micrographs showing(a) Worn surface of Al_2O_3-30%Mo coated pin at 30N (b) Worn surface ofAl_2O_3-30%Mo coated pin at 70N

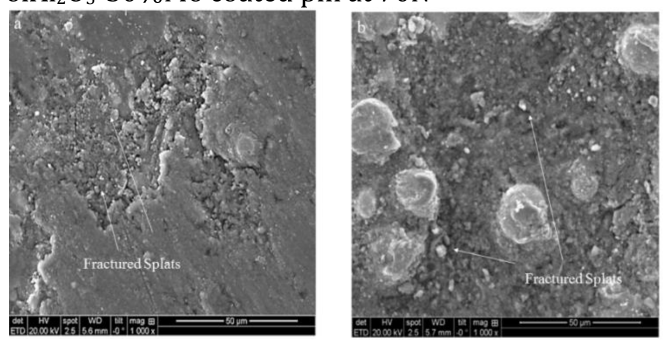

Fig.4 SEM micrographs showing(a) Worn surface of Mo coated pin at 30N (b) Worn surface of Mo coated pin at 70N

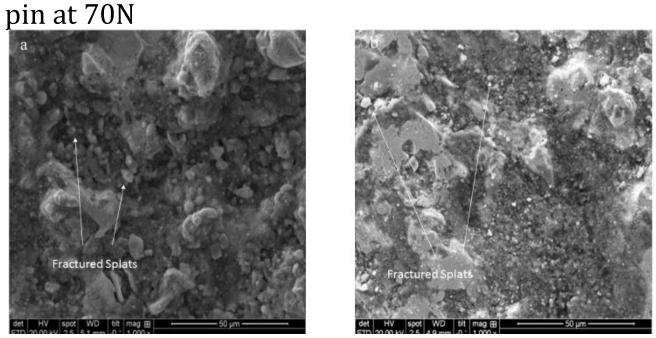

Fig.5 SEM micrographs showing (a) Worn surface of WC-12%Co coated pin at 30N (b) Worn surface ofWC-12%Cocoated pin at 70N

The two wear mechanisms are responsible for highest wear volume loss of plasma sprayed Al2O3-30%Mo coating compared to the other plasma sprayed coatings. One is related to the removal of metal particles from the matrix and the second one is the oxidation of Mo at relatively low temperature. The main wear mechanisms can be attributed to the removal of the Mo dispersoids in the composite as shown in Fig.3. Many author [10–12] observed that, in general Mo particles exhibited brittle like behaviour and only few of the smaller ones showed a heavy plastic deformation. so the fracture occur also in the metal particles besides the particle/matrix in interface. Due to this the de-bonding occurs between the Mo particles and Al_2O_3 matrix[3,5]. An additional mechanism which accounts for the heavier wear of Al_2O_3-30%Mo coating is associated with the formation of MoO_3. This oxide volatile at relatively at low temperature[6].when the oxide volatizes, part of the Mo is removed and the interface between the metal phase and the matrix becomes more week allowing an easy removal of the particles as shown in Fig.3

The wear volume loss of the Mo coatings increases with increasing an applied load as shown in Fig.2. The plasma sprayed Mo coating composed of Mo splats is brittle due to high hardness of splats. Consequently, interfaces between splats can be easily separated or splats can be fractured in some areas as shown in Fig.4. Such phenomenon of fracture and de-lamination vary with wear load and sliding distance and considerably affect the wear rate of the coating [7,13,14].

The WC-12%Co plasma sprayed coating showed higher wear resistance because of complex carbide phase present within the coating. This phase is characterized by a higher hardness values which impart the necessary wear resistance [1,15]. In the sliding wear tests the WC-12%Co coating is subjected to alternatively tensile and compression stress and cracks will initiate and propagate through the wear surface of the coating, then cause coating layer spallation and/or de-lamination, where they suffer maximum shear stress. When these subsurface cracks propagate through the bind phase or along the splat boundary where the brittle decarburized phases exist, material removal occurs [16–18]. With the WC-12%Co coating, no grooves can be found in the wear scar of the conventional coating, which indicates that plastic deformation has not occurred and wear volume loss of WC-12%Co coating is mainly due to spallation and de-lamination as shown in Fig.5.The high wear resistance of WC-12%Co coatings can be attributed to their improved hardness, toughness and homogeneity compared to the Al2O3-30%Mo, Mo.

4. Conclusions

1. The wear volume loss rate of all coatings increases with increasing the applied load.

1. The Al_2O_3-30%Mo coatings exhibits higher wear volume loss due to de-bonding of the Mo particles from the matrix and formation of MoO_3
2. No grooves found in the wear scar of WC-12%Co coating, which indicates that plastic deformation has not occurred and wear volume loss of WC-12%Co coating is mainly due to spallation and de-lamination.

3. The plasma sprayed WC-12%Co coating shows the best wear resistance as compared to Al2O3-30%Mo, Mo and WC-12%Co coating.

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