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Study and Comparison of Tribological Wear Behavior Characteristics of Titanium Dioxide Coated Mild Steel

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Abstract -Mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through Coating.During working, the parts fabricated using these metals inevitably make contact with other metal surfaces resulting in wear and reduction of life. To enhance life of these parts, their mechanical properties and tribological properties should be improved. Wear is the removal of material from a solid surface due to rubbing action of another solid. This can be done by reinforcing the metal parts with metal composites or by coating these surfaces with other hard substrates. Therefore, coating is better method as it improves properties only at surface. Hence in the above two methods, surface coating method is a popular way of improving tribological properties at the surfaces. So in this work titanium dioxide Coating on Mild Steel by plasma spray coating and the test was conducted by Pin on disc wear test (for adhesive wear testing).
Keywords- Adhesive wear, Plasma spray coating, titanium dioxide, pin on disc machine, Microstructure.

I. INTRODUCTION

Mild Steel and its alloys are finding enormous applications in the field of automobile engineering for manufacturing of axles, crankshafts, steering, steering shaft, levers, aircrafts and heavy vehicle components and building constructions. During working, the parts fabricated using these metals inevitably make contact with other metal surfaces resulting in wear and reduction of life. To enhance life of these parts, their mechanical properties and tribological properties should be improved. Reinforcing the metal parts with metal composites or coating these surfaces with other hard substances are two methods used popularly to improve the tribological properties.

A. Mild Steel (Base metal)

Mild Steel is an alloy with carbon, manganese, Nickel, silicon and balance is iron as the alloying elements. It has generally good mechanical properties and is heat treatable and weld able. It is one of the most common alloys of mild steel for general purpose use

B. Properties of Mild Steel

1) Density is approximately -7.85 g/cm3
2) Young's Modulus is- 210 GPa
3) Ultimate compressive strength in t/cm^2 - 4.75
4) Hardness, tempering and hardening is-tougher and more elastic than other alloy.
5) Ductility and malleability –moderately ductile and malleable.
6) Shock absorption-it absorb shocks
7) Corrosion –Rusts readily
8) Effect of salt water- not affected

A coating is a covering that is applied to an object to protect it or change its appearance. They may be applied as liquids, gases or solids. The material on which the coating is deposited is usually referred to as a substrate. Properties such as adhesion, corrosion resistance, wear resistance, scratch resistance, etc can be improved.

C. Advantages of coatings

Coating on substrate makes the material,

1) Wear resistance.
2) Corrosion resistance.
3) Friction control
4) Hard facing
5) Fouling protection.
6) Oxidation protection

D. Plasma Spray

Plasma spraying, [2]a method of thermal spraying, is a material processing technique for producing coatings and free-standing parts using a plasma jet. Deposits having thickness from micrometers to several millimeters can be produced from a variety of materials - metals, ceramics, polymers and composites.

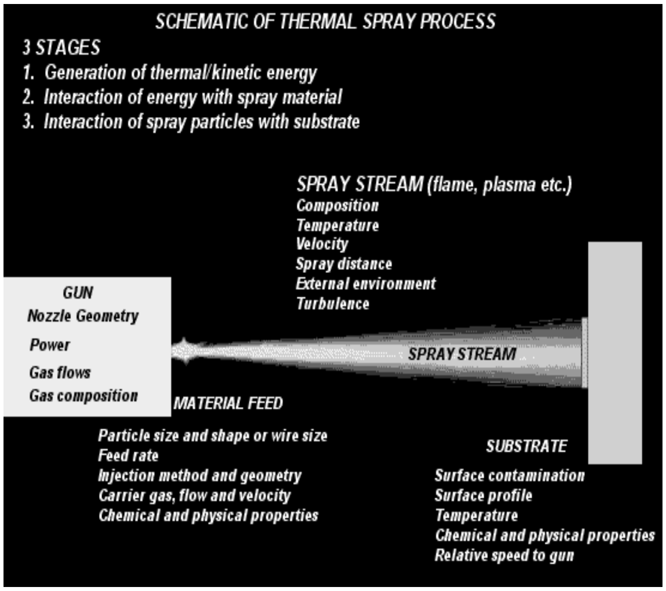

Fig2.5: Schematic of thermal spray process

The material to be deposited (feedstock) [5]- typically as a powder, sometimes as a liquid, suspension or wire - is introduced into the plasma jet, emanating from a plasma torch. In the jet, where the temperature is on the order of 10 000 K, the material is melted and propelled towards a substrate. There, the molten droplets flatten, rapidly solidify and form a deposit.

E. Factors effecting bonding and subsequent build up of the coating

1) Cleanliness
2) Surface area
3) Surface topography or profile
4) Temperature (thermal energy)
5) Time (reaction rates & cooling rates etc.)
6) Velocity (kinetic energy)

II. TITANIUM DIOXIDE

Titanium dioxide, also known as titanium (IV) oxide or Titania, is the naturally occurring oxide of titanium, chemical formula TiO_2. When used as a pigment, it is called titanium white, Pigment White 6. It is noteworthy for its wide range of applications, from paint to sunscreen to food coloring.

Titanium dioxide occurs in nature as the well known naturally occurring minerals rutile, anatase and brookite. The most common

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form is rutile and this is also the most stable form, anatase and brookite both convert to it on heating. Rutile, anatase and brookite all contain 6 coordinate system of titanium. Additionally there three metastable forms produced synthetically and five high pressure forms

Properties	
Density	4 g/cm^3
Compressive Strength	680MPa
Poisson's Ratio	0.27
Fracture Toughness	3.2 $Mpa.m^{-1/2}$
Modulus of Elasticity	230GPa
Micro hardness (HV0.5)	880
ThermalConductivity (25°C)	11.7W/mK

III. WEAR

In materials science, wear is the erosion of material from a solid surface by the action of another solid. Wear can also be defined as a process in which interaction of the surfaces or bounding faces of a solid with its working environment results in dimensional loss of the solid, with or without loss of material. Aspects of the working environment which affect wear include loads (such as unidirectional sliding, reciprocating, rolling, and impact loads), speed, temperature, type of counter body (solid, liquid, or gas), and type of contact (single phase or multiphase, in which the phases involved can be liquid plus solid particles plus gas bubbles).

A. Adhesive wear

Adhesion is the phenomenon resulting in of attractive forces between two surfaces in close contact. Interfacial adhesion may[3] be due to ionic, covalent, metallic, hydrogen and Vander Wall's bonds. Adhesive bonding is favored by plastic deformation and cleanliness.

Adhesive wear is also known as scoring, galling, or seizing. It occurs when two solid surfaces slide over one another under pressure. Surface projections, or asperities, are plastically deformed and eventually welded together by the high local pressure, temperature and velocity. As sliding continues, these bonds are broken, producing cavities on the surface, projections on the second surface, and frequently tiny, abrasive particles, all of which contribute to future wear of surfaces and thus increasing the co-efficient of wear

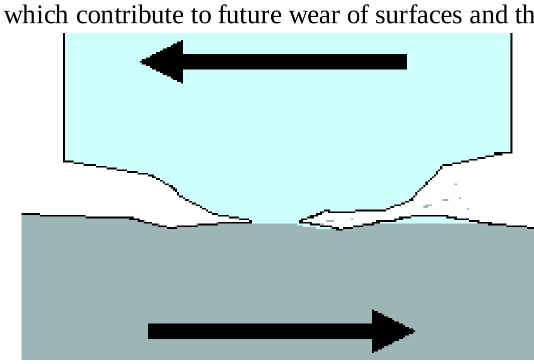

Fig 3.1Adhesive wear

IV. METHODOLOGY

A. Specimen and Surface Preparation

Preparation of specimen by firstly cutting, then turning and then finishing by filing process in workshop and the coating material was plasma sprayed on to the base metal to a thickness of 100µm.The specimen is cleaned to remove all dust particles. It is then grit blasted before plasma spraying to create enough surface roughness to ensure a strong mechanical bond between coating and substrate. Then a layer of bonding agent is applied to the base metal to provide good bonding for the coating material on base metal. the coating material was plasma sprayed on to the base metal to a thickness of 100µm

B. Measurement of Wear Rate Using Pin on Disc Wear Tester

Wear test of Titanium Dioxide (TiO2) coating on Mild Steel specimens of diameter 10mm and height 20mm, were studied using

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standard pin on disc wear test rig. Firstly clean the surface of the disc and specimen by acetone and fix the specimen (Pin) on the disc horizontally measure the track radius by a scale. Set the time to zero and fix the speed of disc (RPM) by digital tachometer and adjust the displacement sensor to read zero. For every five minutes note down the following readings. a) Wear in microns. b) Frictional Force. c) Temperature. Repeat the above procedure on the other specimen for a given period at constant sliding velocity and increasing load.

V. RESULTS AND DISCUSSION

A. COF (Coefficient of friction) =Frictional Force\Normal Force
B. Sliding Velocity (V) =ΠDN\60,000 where D=Track Radius in m, N=Speed in rpm
C. Sliding Distance (L) = Sliding Velocity*Time (V*t) in m
D. Wear Rate= (Wear*Area)/(Sliding Distance*Normal load)

Results are tabulated for constant speed, track radius and varying load.

Fig 5.1(a) and 5.1(b) shows as the load increase wear also increase but the wear of uncoated specimens are more when compared to specimens

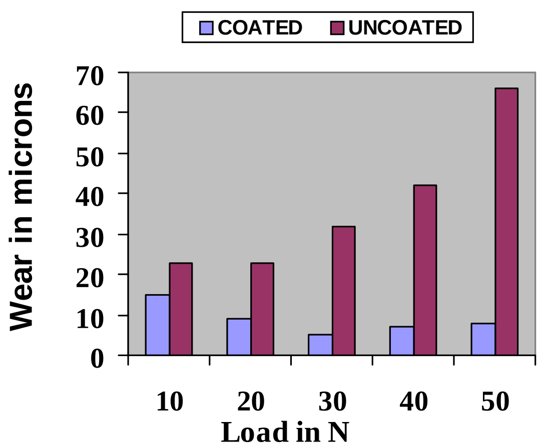

Fig5.1(a)WEAR V/s LOAD(200rpm)

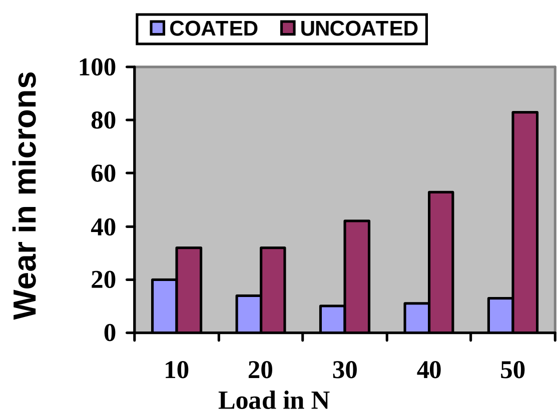

Fig5.1(b) WEAR V/s LOAD(at400 rpm)

Fig5.2(a) and 4.2(b) shows as the wear v/s sliding distance for 10N for 200 rpm & 400rpm. In this fig wear is less as sliding distance increases when compared to uncoated specimens.

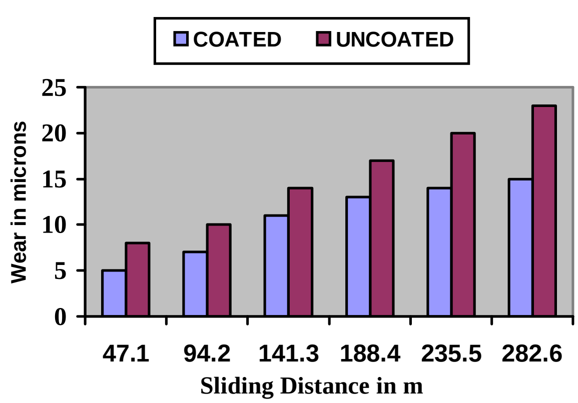

FIG5.2(a) Wear V/s Slidingdistance (10N 200rpm)

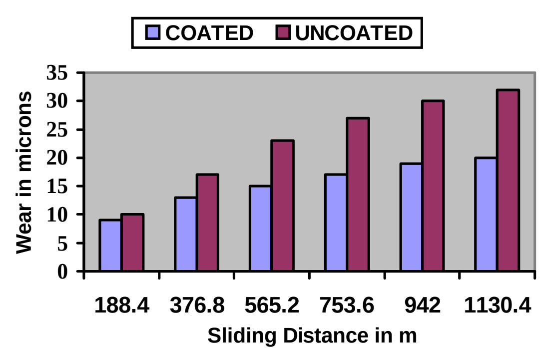

Fig5.2(b) Wear V/s Sliding distance (at10N 400rpm)

Fig 5.3(a) and (b) shows the time in minute's v/s wear rate for 10N & 20N.In these graph as time increases wear rate for coated

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decreases as compared to un coated specimen.

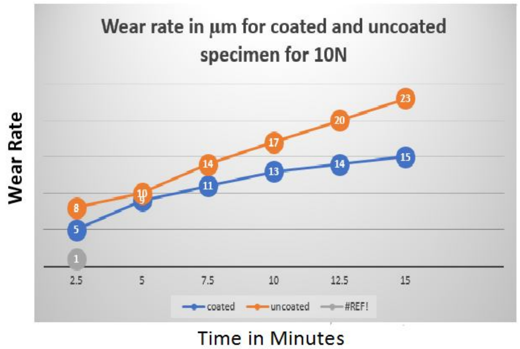

Fig 5.3(a) Time in minute's v/s wear rate for 10N

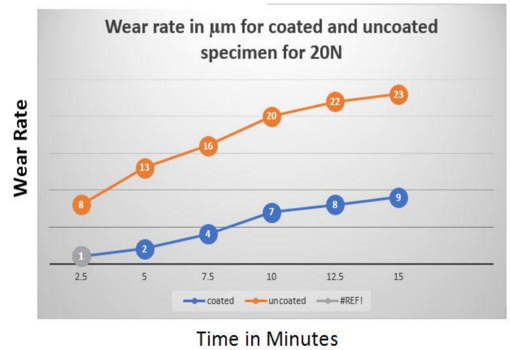

Fig 5.3(b) Time in minute's v/s wear rate for 20N.

Fig 5.4(a) and (b) shows the load v/s wear rate for 200rpm & 400rpm.In these graph as load increases wear rate for coated decreases as compared to un coated specimen.

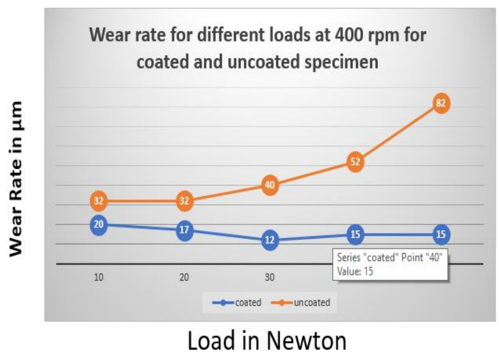

Fig 5.4(a) load in Newton v/s wear rate for 200rpm.

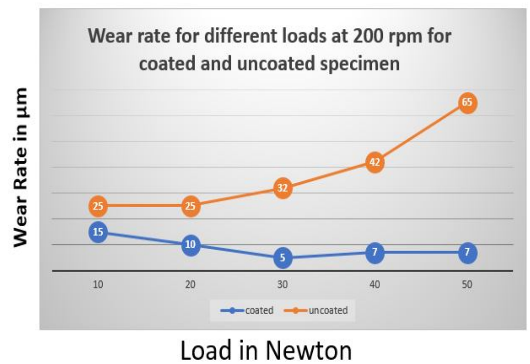

Fig 5.4(b) load in Newton v/s wear rate for 400rpm.

VI. MICROSTRUCTURE

Microstructure samples is roughened with belt polish, and fine polished with various emery sheets from 80, 120, 220, 320, 400, 600, 800 , 1200 and fine polished using Lavigated Alumina and structure observed.

Fig 6(a) Un coating surface before testing

Fig 6(b) Un coating surface after testing

Fig 6(c) Coating surface before testing

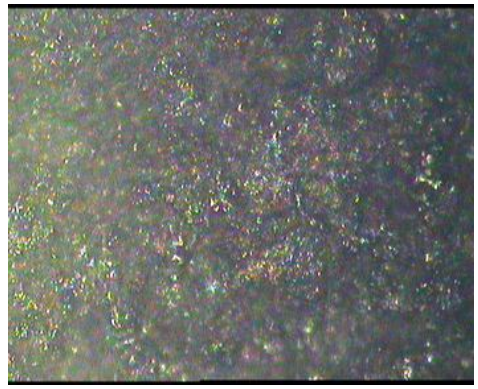

Fig 6(d) Coating surface after testing

From the above pictures we can notice that the uncoated specimens have worn out to a greater extent than the TiO_2 coated specimens. After testing coated surface having small cavities indicates the porosity .This porosity occurs due to delamination.

VII. CONCLUSIONS

Based on the tests carried out to study the effect on wear, Mild Steel coated with titanium dioxide as explained in the previous chapter and within the scope of this investigation the following conclusion have been drawn.

A. Plasma spray coating of Titanium Dioxide on Mild Steel is effectively done for the thickness of 100microns.
B. Wear loss of the specimens decreases effectively when compared to uncoated specimens.
C. Increase in speed of the disc wear rate of uncoated specimen increases. Whereas coated specimen decreases.
D. By increasing the load on the specimen wear rate increases. of uncoated specimen increases whereas coated specimen decreases.

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