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Study of sliding wear rate of hot rolled steel specimen subjected to Zirconia coating of various thickness

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ABSTRACT

Wear is nothing but loss of material by usage. In a mechanical industry mechanical components will operate under severe load, temperature and high speeds. Under such a type of situation, when metal to metal contact take place the surfaces that comes in contact is subjected to wear. These should be considered as a serious affair in an industry because if the process of wear continues it can reduce service life of the component and also to the entire mechanical system to which the component has been used. In the light of the above the present work mainly deals with the study of wear behavior of hot rolled steel with and without zirconia coating on the contact surface and the effect of zirconia coating with varying thickness.

Keywords - Wear, Friction, Surface coatings, sliding velocity, Sliding distance

I. INTRODUCTION

Engineering components are subjected to several modes of failure, fatigue, excess deflections and wear. Of these wear is the least predictable using current design methodologies [1]. Till date the process of wear continues to be a threat to many manufacturing industries, because, in industries mechanical components have to operate under severe conditions such as load, speed or temperature [2]. Under such circumstances when two or more metals are in sliding contact with each other loss of material takes place at the contact surface of the material due to high temperature involved. If this process continues for a long time then it can reduce the life of the component and also can have devastating effects on the entire mechanical system. This can even result in huge economic loss if the mechanical system fails.

There is constant demand in engineering industry to improve the performance of the machinery while maintaining or reducing the manufacturing cost. In many types of industrial machinery surface damage generated by abrasive or sliding contact limits the durability and product reliability. This drives the implementation of intelligent surface coatings [3] and films which enables to improve the performance of engineering components under contact loading, while retaining or reducing the material and manufacturing requirements of engineering components for the base material. These criteria can me met by providing surface coatings at the point of the contact of the 2 specimens. Coatings are coverings that are applied to the surface of the object, usually referred to as substrate. In many cases coatings can act as best method to increase wear resistance and decrease the temperature at the contact surface of the two metals that are subjected to sliding action. Coatings are expected to meet stringent requirements such as reducing the temperature of the material at the contact surface and providing wear resistance, thereby increasing their performance and efficiency.

Wear may be defined as surface damage or removal of material from one or both of two solid surfaces in sliding, rolling or impact motion to one another as a result of mechanical action [4]. The working life of an engineering component comes to an end when dimensional losses have exceeded the tolerance limits. The failure of components in service can often be contributed to wear, corrosion-enhanced wear or erosion. The phenomenon contributing to failure under all these conditions are complex and often specific to particular application [5]. Material properties determining resistance to wear and erosion are complex making it difficult to predict the service behavior of a particular material. The reduction in wear depends on several factors such as normal load, surface temperature, sliding velocity and surface roughness [6].

The adhesive wear is one of the most prevailing wears. It forms 15% of the total industrial wear [7]. According to R.L.Deuis et al [8] adhesive wear occurs when surfaces slide against each other and pressure between the contacting asperities is sufficiently high enough to cause local plastic deformation. The two modes of abrasive wear are two bodies and three body abrasive wear. The two modes of abrasive wear are shown in the above Fig (2.2). Two body abrasive wear occurs when the grits or hard particles removes materials from the opposite surface L.P.Ward et al [9] have shown that clinical wear Rate of Ultra High Molecular Weight polyethylene (UHMWPE) in contact with316 L Stainless steel was ten times higher than laboratory wear rate. After approximately seven years of use, the superior part of socket was so deeply worn that wear scar was visible to naked eye. It was observed that initial wear was caused by abrasive wear mechanism although there existed other wear mechanism too. The erosion of ceramic coating is highly influenced by both coating properties and impacting particle conditions including its size. To obtain the best functional output of coatings exhibiting selected in- service properties the right combinations of operating parameters are to be known. The less erosion rate is main requirement of a coating sprayed by the plasma spray process. In order to get the desired result the influencing parameters of erosive wear rate has to be controlled accordingly since the number of parameters are too large [10]

II. II MATERIALS SECTION

Stainless steel usually contains 10.5 to 16 % chromium content by mass. Standard mill finishes have been applied to flat rolled stainless steel directly by the rollers and mechanical abrasives. Steel is first rolled to required size and thickness and then annealed to get the part of final material. When steel is worked below recrystallisation temperature (below 750oC) it is called cold rolled steel and when it is worked above recrystallisation temperature (above 750o C) it becomes hot rolled steel.

In the present experiment cold rolled steel is used for the wear testing purpose. The class of steel used is 316-grade steel. Any oxidation layer is removed by pickling and a passivation layer is created on the surface. A final finish can be applied to get the desired aesthetic appearance. Fig 4.1 shows cold rolled uncoated specimens and specimens coated with zirconia.

III. III COATING MATERIAL USED

Zirconia is selected as the Coating Material. It is selected mainly because of its

- ♣ High temperature applications of even up to 1900 ^{o}Celsius.
- ♣ Good chemical stability.

Table- 1 Composition of Zirconia Coating

ZRO_2	$Al_2 O_3$
98%	2%

IV. IV PROCESS INVOLVED FOR SPRAYING PROCESS

Zirconia coating is sprayed on to the specimen using thermal spray process. Plasma spray is the generally used thermal spraying process. The non-transferred plasma arc within the torch creates a high transferred plasma stream. Many gases can be ionized this way.

V. V WEAR TEST

The wear test is carried out on a standard TR-20 test PIN ON DISC wear tester. It records friction and wear when the sliding action takes place. The parameters involved in the wear test are

- ¬ Speed in RPM
- ¬ Load in Newton
- ¬ Coating thickness in Microns.
- ¬ Frictional Force in N.
- ¬ Wear, height Loss in microns

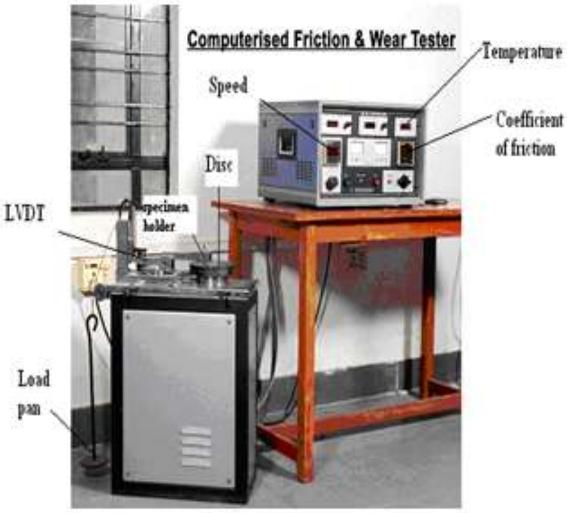


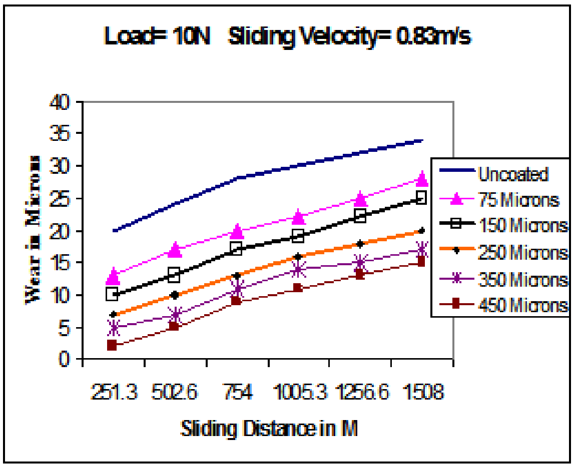
Fig-1 Pin on disc wear tester

VI. RESULTS AND DISCUSSION

6.1 Wear Studies

6.1.1Effect of Sliding Distance

Case 1: For a Constant Sliding velocity



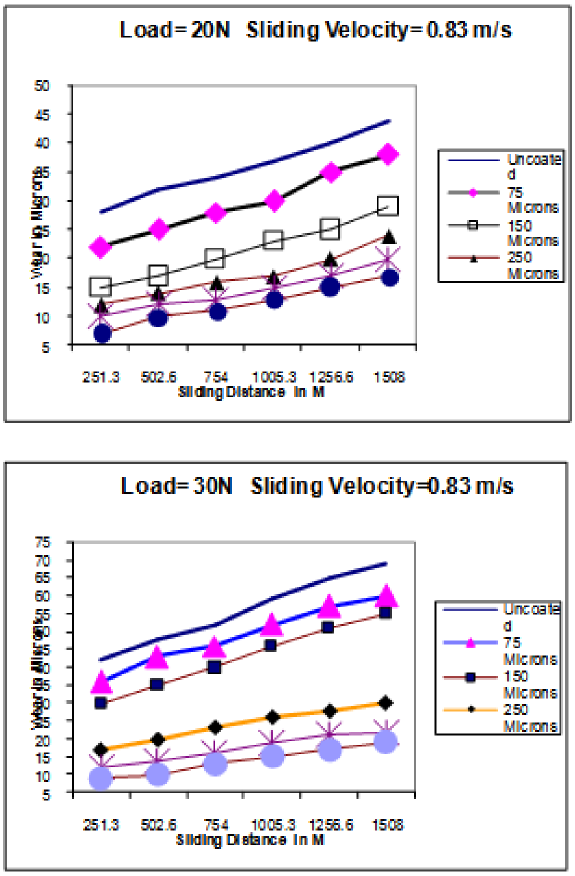


Fig-2 (a, b and c) Variation of Wear with Sliding Distance for a Given Load

Fig. 2 shows the variations of wear with sliding distance under the constant sliding velocity of 0.83 m/s. It is evident from all three cases 2(a), 2(b), and 2(c) that increase in the sliding distance resulted in the increase of wear for all the specimens studied. However at all the sliding distances studied the wear of coated specimens are less compared to the uncoated specimen.

From Fig 2 (a) it is clearly evident that the uncoated specimen wears out considerably as the sliding time increases, but the wear decreased as the thickness of coating increased. This can be attributed to the fact that the increased thickness of coating results in increased resistance to wear. Also from the graph it is evident that at a sliding distance of 1508 meters the wear is 34 microns for the uncoated specimen. The 75 microns coated specimen showed a drastic decrease in the wear. For the same sliding distance of 1508 meters the wear for the 75 microns coated specimen is 28 microns, which is nearly 17.6% decrease in wear when compared to an uncoated specimen. Similarly when the thickness of coating further increased the wear reduces gradually. Minimum wear is observed when the thickness of coating is to the maximum extent. For the same sliding distance of 1508 meters the wear for the 450 microns coated specimens is 15 microns, which is nearly 55.8 % decrease in wear compared to the uncoated specimen.

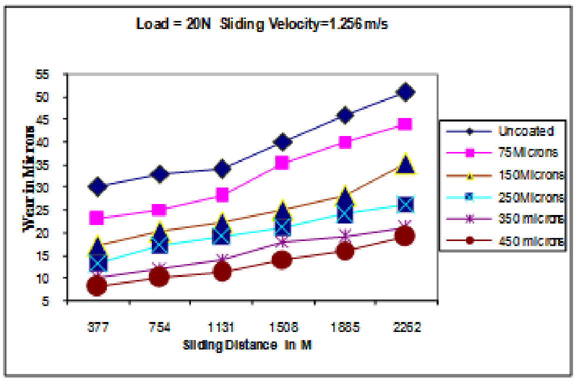
Similar results are observed for 20N load (Fig 2(b)) and 30N load (Fig 2(c)) also. In the case of 30N load there is a decrease in wear, but not to a larger extent up to 150 microns coated thickness. Whereas for the coating thickness of 250 microns and above reveals considerable reduction in wear. For the sliding distance of 1508 meters the wear for the 250 microns coated thickness is 30 microns, which is nearly 56% decrease in wear compared to an uncoated specimen. The 450 microns coated specimen experienced the least wear compared to all other coated specimens. For the same sliding distance of 1508 meters the wear for the 450 microns coated specimen is just 19 microns which is nearly 67% decrease in wear compared to an uncoated specimen as shown in Fig 2(c).

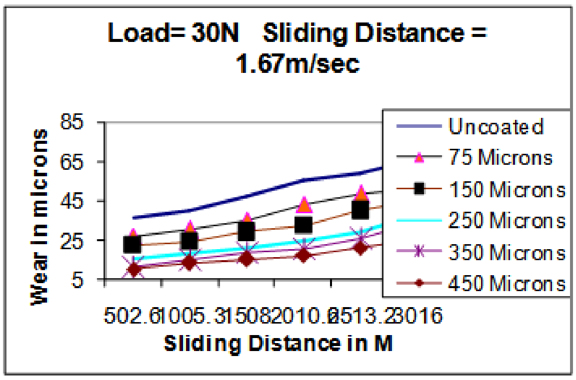
Case 2: For a Constant Sliding velocity

Fig 3 shows the variations of wear with sliding distance under the constant load of 20N. It is evident from all the three cases 3(a), 3(b), and 3(c) that increase in the sliding distance resulted in the increase of wear for all the specimens studied. However at all the sliding distances studied the wear of coated specimens are less compared to an uncoated specimen.

From Fig 3 (a) it is clearly evident that the uncoated specimen wears out considerably as sliding distance is increased, but the wear decreases as the thickness of coating is increased. This can be attributed to the fact that the increased thickness of coating results in increased resistance to wear. Also from the graph it is clearly evident that at a sliding distance of 2262 meters the wear is 51 microns. The 75 microns coated specimen shows gradual decrease in the wear. For the same sliding distance of 2262 meters the wear for 75 microns coated specimens is 44 microns, which is nearly 13.7% decrease in wear when compared to an uncoated specimen. Similarly when the thickness of coating is further increased the wear reduces gradually. Minimum wear is observed when the thickness of coating is to the maximum extent. For the same sliding distance of 2262 meters the wear for the 450 microns coated specimens is 19 microns, which is nearly 62.7 % decrease in, wear when compared to the uncoated specimen.

Similar results are observed for the sliding velocities of 1.67m/sec (Fig 3 (b)) and 2.09m/sec (Fig 3(c)).





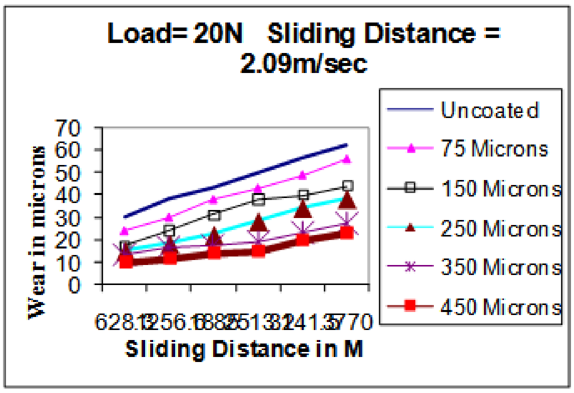


Fig 3: (a, b and c) Variation of Wear with Sliding Distance for a given sliding velocity

6.1.2 Effect of Load

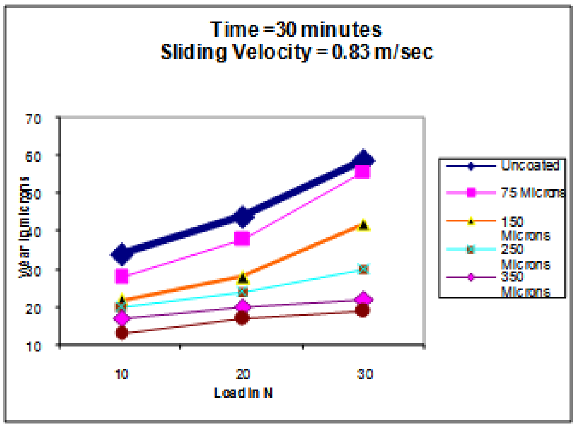


Fig 4: Variation of Wear with Load

Fig 4 shows the variations of wear with load under the constant sliding velocity. It is evident from the figure that increase in the load resulted in the increase of wear for all the specimens studied. However at all the loads studied the wear of coated specimens are less compared to an uncoated specimen.

From the above graph it is clearly evident that the uncoated specimen wears out drastically as load is increased, but the wear decreases as the thickness of coating is increased. This can be attributed to the fact that the increased thickness of coating results in increased resistance to wear. It can be cleanly observed that at a load of 30N the wear is 59 microns for the uncoated specimen. The 75 microns coated specimen shows a gradual decrease in the wear. For the same 30N load the wear for 75 microns coated specimen is 56 microns, which is only 5.08% decrease in wear when compared to an uncoated specimen. This can be attributed to the fact that the coating thickness of 75 microns is too small to handle a load of 30N. Similarly 150 microns coated specimen experiences only a gradual increase in wear up to 20N load, but the wear has increased considerably as the load is further increased from 20N to 30N. When the thickness of coating is further increased the gradual decrease in wear is experienced. The minimum wear is observed for the 450 microns coated specimen. Even for 30N load the wear for the 450 microns coated specimen is just 19 microns. So the wear for the 450 microns coated thickness has decreased nearly to 67.7% when compared to an uncoated specimen.

6.2 Wear Rate
6.2.1 Effect of Load

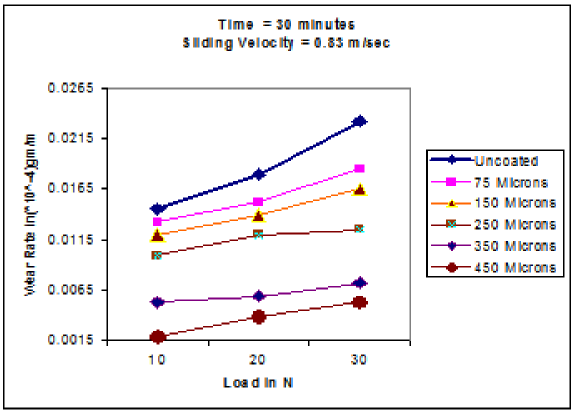


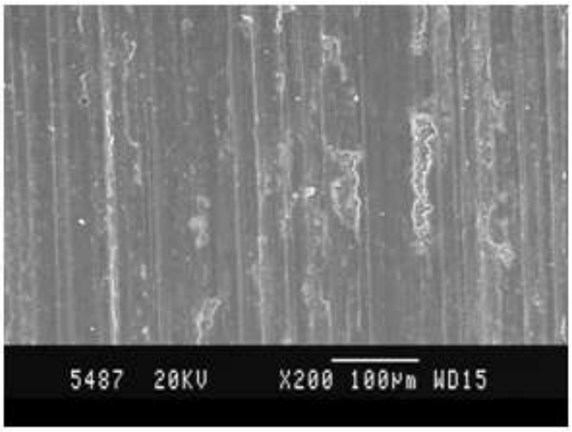
Fig 5: Variation of Wear Rate with Load

Fig 5 shows the variation of wear rate with load under the constant sliding velocity. It is evident from the figure that increase in the load resulted in the increase of wear rate for all the specimens studied. However at all the loads studied the wear rate of coated specimens are less compared to the uncoated specimen.

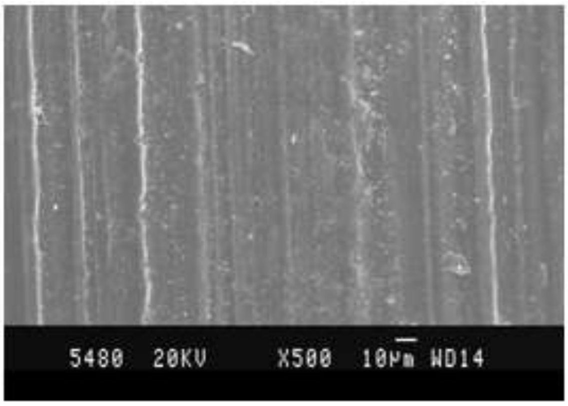
From the graph it is clearly evident that the uncoated specimen wears out considerably as load is increased, but the wear rate decreases as the thickness of coating is increased. This can be attributed to the fact that the increased thickness of coating results in increased resistance to wear rate. Also from the graph it is observed that at a load of 30N the wear is 0.0232 * 10-4 gm/m for the uncoated specimen. The 75 microns coated specimen shows a gradual decrease in the wear rate. For the same 30N load the wear for 75 microns coated specimen is 0.0185 * 10-4 gm/m, which is only 15% decrease in wear rate when compared to an uncoated specimen. When the thickness of coating is further increased there is gradual decrease in wear rate. The minimum wear is observed for the 450 microns coated specimen. For the same 30N load the wear rate for the 450 microns coated specimen is 0.0053 *10-4 gm/m, which is nearly 77% decrease in wear rate when compared to uncoated specimen.

6.3 Wear Track

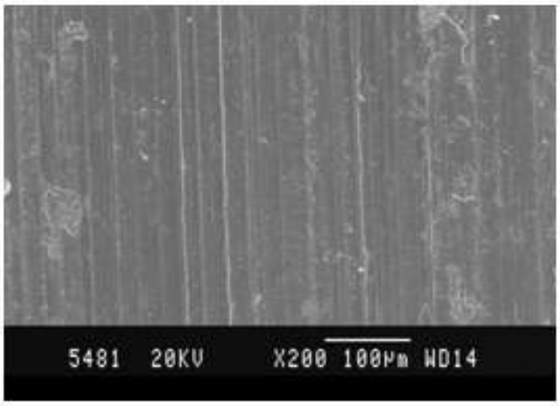
Fig 6 shows the SEM photographs of wear tracks of uncoated and coated cold rolled steel alloys for a given load, sliding velocity and sliding distance. It is clearly observed that extent of grooving is more in the case of an uncoated specimen when compared to the coated specimen. However the extent of grooving reduces as the thickness of coating is increased. This attributes to the fact that the coating acts as a substrate and prevents direct contact of sliding surfaces. This observation supports the lower wear rate of coated specimens when compared to uncoated specimens. So obviously the extent of grooving for the coated specimen decreases. The 75 microns coated specimen shows a gradual decrease in the extent of grooving when compared to an uncoated specimen as shown in Fig 6. The 450 microns coated specimen shows that the extent of grooving is least when compared to other coated specimens. So thickness of coating plays a major role in decreasing the wear rate



Uncoated



75microns



150microns

Fig 6 : SEM Photographs of Uncoated and Coated Cold Rolled Steel Alloy at a load of 20N and a sliding velocity of 2.09 m/sec

VII. CONCLUSION

- In the present study the dry sliding wear behavior of cold rolled stainless steel with and without zirconia coating of different thickness was investigated. The parameters set for the present investigation are sliding velocity, sliding distance and the applied load.
- Wear of an uncoated specimen increased considerably with the increase in sliding distance and load, but decreased with increase in the coating thickness.
- Frictional force also increased considerably with increase in sliding distance, but decreased with increase in coating thickness.
- Co-efficient of friction reduced for increase in load for the uncoated specimen, but the minimum co-efficient of friction will be observed only when the thickness of coating is to the maximum.
- The coatings of 450 microns thickness showed least wear compared to all other coated specimens studied.
- Wear rate of coated specimens was very less than that of an uncoated specimen.
- SEM Wear tracks clearly revealed that as the

coating thickness is increased, the wear rate decreases.

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