Experimental Investigation on Tribological Behavior of Hard Anodized Aluminum

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ABSTRACT

In the present work, the effect of load and sliding distance on the tribological performance of commercially used pure and hard anodized aluminium (Al) was evaluated and compared under dry sliding conditions using a pin-on-disc machine under different loading conditions. Factors and conditions that had significant effect were identified. The results showed that the load and the sliding distance affect the wear rate of the metal and the wear rate increases with increase in load for both the combination. Wear rate also increases almost linearly at low loads and increase to a maximum then attain a plateau with increasing sliding distance. The worn surface and wear debris was characterized by Scanning electron microscope. The worn surface was characterized by surface with shallow grooves at low loads while the groove width and depth increased as the loads increases. It was found that hard Anodizing on Al decreases the wear rate and friction effect which can lead to decrement in heat dissipation during sliding motion under different loading conditions.

Keywords: Tribology; Aluminium; Wear; Friction; Hard anodizing

1- INTRODUCTION

Aluminium (Al) is the second-most plentiful element on earth and it became an economic competitor in the ngineering applications as early as the end of the 19th century. The emergence of three important industrial revolutions would, by demanding material characteristics consistent with the unique qualities of Aluminium and its alloys, greatly benefit growth in the production and use of the metal [1]. Among the most striking characteristics is its versatility. The range of physical properties that can be developed-from refined high-purity Al to the most complex alloys-is remarkable. Aluminium and its alloys are extensively used as the materials in transportation (aerospace and automobiles), engine components and structural applications [2]. Thus it becomes all the more vital to study the tribological characteristics of Aluminium and its alloys. Addition of Silicon to Aluminium gives high strength to weight ratio, low thermal expansion coefficient, and high wear resistance. These alloys also show improved strength and wear properties as the silicon content is increased beyond eutectic composition. Such properties warrant the use of these materials as structural components in automotive industries [3]. The wear properties of three Aluminium alloy samples have been studied viz. Al -7wt% Si, Al- 10%Si and Al-14%Si here. The principal wear mechanisms in these alloys and abrasive and sliding wear which have been dealt with in the later part of this work [4].

2- TRIBOLOGY

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of principles of friction, lubrication and wear. The tribological interactions of a solid surface's exposed face with interfacing materials and environment may result in loss of material from the surface. The process leading to loss of material is known as "wear". Major types of wear and cohesion, include, adhesion and corrosion [5]. Wear can be minimized by modifying the surface properties of solids by one or more of "surface engineering" processes (also called surface finishing) or by use of lubricants (for frictional or adhesive wear) [6]. Estimated direct and consequential annual loss to industries in the USA due to wear is approximately 1-2% of GDP. Engineered surfaces extend the working life of both original and recycled and resurfaced equipment, thus saving large sums of money and leading to conservation of material, energy and the environment. Methodologies to minimize wear include systematic approaches to diagnose the wear and to prescribe appropriate solutions [7, 8].

A. Hard Anodizing

Aluminium alloys are anodized to increase corrosion resistance and allow to dyeing (colouring), improved lubrication, or improved adhesion. However, anodizing does not increase the strength of the aluminium object. The anodic layer is non-conductive. When exposed to air at room temperature, or any other gas containing oxygen, pure aluminium self-passives by forming a surface layer of amorphous aluminium oxide 2 to 3nm thick, which provides very effective protection against corrosion. Aluminium alloys typically form a thicker oxide layer, 5-15 nm thick, but tend to be more susceptible to corrosion. Aluminium alloy parts are anodized to greatly increase the thickness of this layer for corrosion resistance. The corrosion resistance of aluminium alloys is significantly decreased by certain alloying elements or impurities: copper, iron, and silicon, so 2000, 4000, and 6000-series Al alloys tend to be most susceptible.

Some aluminium aircraft parts, architectural materials, and consumer products are anodized. Anodized aluminium can be found on mp3 players, smartphones, multi-tools, flashlights, cookware, cameras, sporting goods, window frames, roofs, in electrolytic capacitors, and on many other products both for corrosion resistance and the ability to retain dye. Although anodizing only has moderate wear resistance, the deeper pores can better retain a lubricating film than a smooth surface would.

3- EXPERIMENTAL PROCEDURE

A. Preparation of Sample

Two types of samples was prepared

1. Pure aluminium sample
2. Hard Anodized Aluminium

A1. Preparation of Aluminium sample

- Aluminium rod was purchased from the market.

- Then it was machined on lathe machine to obtain diameter of sample 12 mm and 25 mm length as shown in Figure 1 below. These samples are also tested for composition.

Figure 1 (a) Pin on disc machine (b) Prepared samples for testing

A2. Preparation of Hard Anodized Aluminium

- Material of required specifications was procured from the supplier
- Then it was machined on lathe machine to obtain diameter of sample 12 mm and 25 mm length.
- Coating of hard anodizing was applied on different samples

B. Hardness Test

The hardness values of these samples were determined by using Vickers's hardness tester with an applied load of 100 kgf as shown in Table 1.

S No.	Sample	VHN
1	Pure Al	250
2	Hard anodized Al	742

Table 1. Hardness values of prepared samples

4- WEAR TEST PROCEDURE

A. Abrasive wear test apparatus: Pin-on-disc manufactured by Contech Microsystems, the experiments were conducted as per ASTM G99-90 standard, using counter face of steel disk 316L/EN-32 hardened to 62-65 HRC.

B. Wear Test Procedure: During wear test, the load was applied on the pin, normal to the sliding contact for different loads and the track radius was kept constant at 60 mm
and the rotating speed of the disc was maintained at 600 rpm, which corresponds to a linear speed of 3.769 m/s at the track. In the present investigation, a brush of camel hairs was used to remove wear debris

from the track during sliding. This was carried out with the aim to prevent the debris from getting easily trapped between the worn surface of the pin and the counter face. During pin-on-disc wear tests, the coefficient of friction was continuously monitored and the material removed was determined by weighing machine which measured weight loss (in gram) at specific intervals of time. Wear tests were carried out for a total sliding distance of about 3393 m for each specimen.

C. Wear Measurement Parameters: The variables involved in wear test are:

- Normal load
- Sliding velocity
- Sliding distance

In the present investigation, experiments on all samples are carried out at 5N and 10N. Sliding velocity is kept constant as wear track radius and rotation speed in rpm is kept constant. Sliding speed is varied as times of experiments are taken as 5 minute, 10 minutes and 15 minutes respectively. The materials and parameter settings are enlisted in Table 2.

D. Experiment details

S No	Material and parameters	Specification/magnitude
1	Materials	Pure Al and hard anodized Al
2	Diameter	6-12 mm
3	Applied load	5-10 N
4	RPM	600-1000
5	Radius of disc	60mm
6	Sliding Speed	3.77 m/s

Table 2. Materials and parameter settings

5- ANALYSIS AND RESULTS

A. Wear Loss Vs sliding Distance

Wear loss increases with increase in sliding distance. However, its value is lower in case of anodized Al in comparison to pure Al as shown in Figure 2.

B. Wear rate Vs sliding distance

Wear rate decreases with increase in sliding distance. However, its value is lower in case of anodized Al in comparison to pure Al as shown in Figure 3.

C. Coefficient of friction Vs. sliding distance

Coefficient of friction increases with increase in sliding distance. However, its value is lower in case of anodized Al in comparison to pure Al as shown in Figure 4.

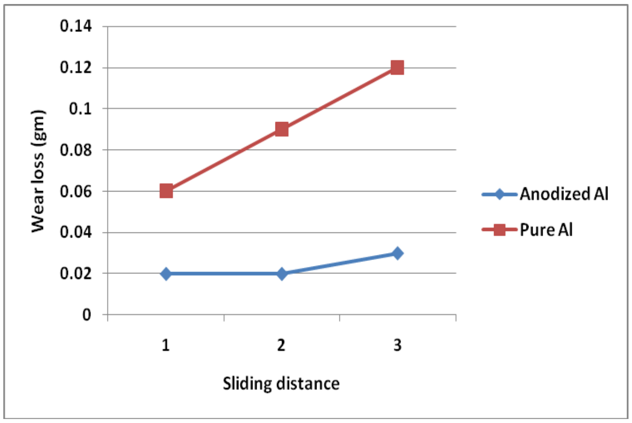

Figure 2. Wear loss Vs sliding distance at 5N

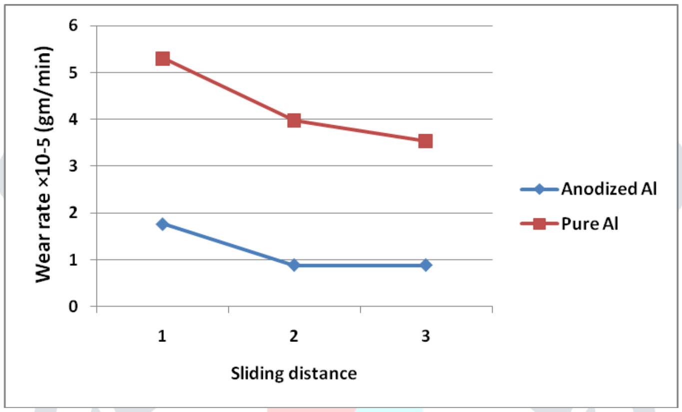

Figure 3. Wear Rate Vs Sliding Distance at 5 N

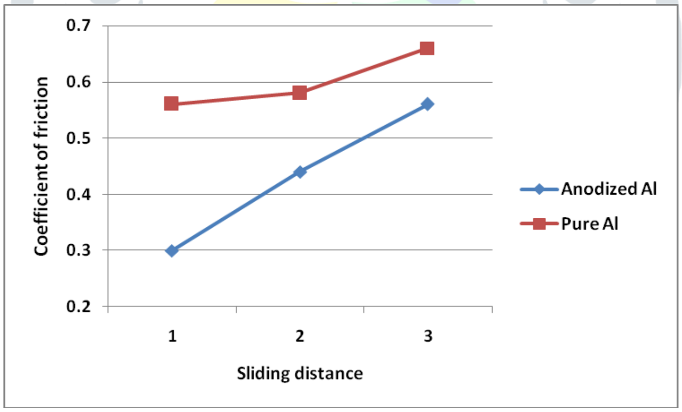

Figure 4. Coefficient of friction Vs Sliding Distance at 5 N

D. Visualization study

Some scanning electron microscope (SEM) images were captured for better understanding of microstructures of various coated/uncoated Al alloy samples as shown in Figures 5 and 6. Oxidative wear was found to be the predominant mechanisms in the dry sliding of Al at low loading conditions.

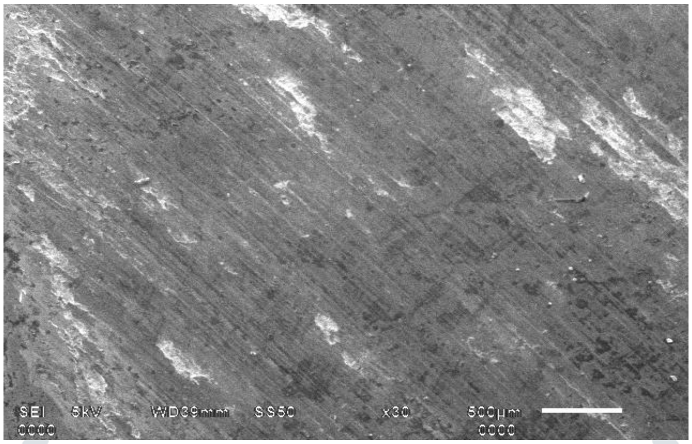

Figure 5. Pure Aluminium

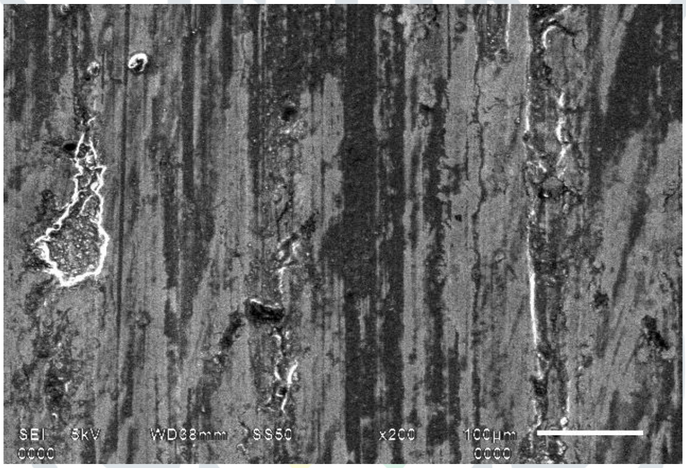

Figure 6. Hard Anodized Aluminium

6- CONCLUSIONS

There is significant decrement in wear rate and coefficient of friction in anodized aluminum as compare to other samples. So, it can be concluded that Anodizing is very beneficial for aluminum metal when they are subjected to sliding at very high speed and also when in contact with very hard material.

Analysis from experimental details can be summarized in following points.

- Anodised Al will provide very higher life in mechanical applications when compared to uncoated Al.
- Anodizing not only decreased the wear rate but also coefficient of friction which has lead to the decrement in heat dissipation during sliding motion.

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