Research & Reviews: Journal of Material Sciences

e-ISSN: 2321-6212
p-ISSN: 2347-2278

DOI: 10.4172/2321-6212.1000203

Comparison of the Effects of Surface Roughness of Wrought Aluminium Alloys on the Surface of Steel

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Research Article

Received: 13/10/2017

Accepted: 06/11/2017

Published: 12/11/2017

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Keywords: Roughness, Friction, Wear, Surface analysis

ABSTRACT

The effect of roughness of wrought aluminium alloys on the surface of steel is investigated. Roughness average (*Ra*) was a fixed polishing at 14 ± 0.05 μm. Also was using a pin–on disc, made of AISI 1045 steel and *Ra*=0.15 ± 0.05 μm, *Hv*=312 ± 20 kg/mm^2. All tests were carried out as per ASTM G-99 standard. The angular speed of the disc was a fixed 200 rpm and a load range of (5, 10, 15) N, and relative humidity 65%. The microstructure for samples and worn surfaces were analyzed and characterized using X-ray diffraction the residual voltage (XRD), energy dispersive spectroscopy (EDS), scanning of electron microscopy (SEM) and atomic force microscopy (AFM), respectively. It was noticed that the dry sliding wear of aluminium alloys against a steel counterface resulted in severe wear for all alloys. At a load of 10 and 15 N, performs a better effect of wear resistance of A 6092 alloy and was wear reduction is 18% comparison with A5056 and A 3003 alloys and reduce friction. However, at a heavy load of 15 N, only the pattern can effectively reduce friction. The maximum reduction rate of the average wear depth is 20% of A 6092 alloy while a reduce 29% and 40% in A5056 and A3003 alloys respectively. However, there was correlation between roughness and wear rate. In all cases, a mechanically mixed layer was formed. Deformation below worn surface and wear resistance is discussed.

INTRODUCTION

Surface roughness is a major problem during the production process and greatly affects the quality of the product [1]. One of the factors that affect the age of surfaces is the roughness which is inherent to the process of friction; also high roughness means increasing the proportion of friction, adhesion and thereby increases the rate of shear connections between surfaces [2]. The wear behaviour of wrought aluminum alloys has received substantial attention and attractive alternatives to ferrous materials for tribological applications due to their high thermal conductivity and low density. However, their uses have been limited by their inferior strength, rigidity and wear resistance [3,4]. In general, several factors affect the wear equations, such as operational parameters, topography of the surface contact, geometry, speed, load, and coefficient of sliding friction. In addition, material and environmental parameters, various material hardness, temperature, elasticity, breakage, as well as thermal properties, also affect wear [4]. The properties of wrought aluminum alloys can be constructed precisely to the requirements of particular applications by the industry through the choice of alloy composition, heat treatment, and the manufacturing process. The main characteristics of wrought aluminum alloys used in industry are light weight, forming and fabrication, high strength to weight ratio, resistance to corrosion, recyclability, heat the conductivity and reflectance [4-6]. To understand roughness and the coefficient of friction it is better to know effect on roughness, through contact between surfaces and leads to deformity, causing economic loss [7,8]. This has created the need to understand tribological properties at low load conditions, mimicking the evolution during normal operation of conditions. Anasyida et al. [9] investigated the dry sliding wear behavior of Al-4%Si-4% mg alloy by addition of cerium with changes to the worn-out look of the surface. It has also been found to change the morphology of wear. Reduction of friction or wear by a lubricant film separates two contacting bodies in relative motion. This situation can occur at a high viscosity lubricant or at low loads, a condition known as hydrodynamic or full-film lubricant; and it is a desirable situation in all bodies in contact, because it

e-ISSN: 2321-6212
p-ISSN: 2347-2278
DOI: 10.4172/2321-6212.1000203

provides a low coefficient of friction and high wear resistance. Miyajima and Iwai [10] investigated the surface chemistry of aluminum alloy with organic friction modifier in the hydrocarbon oil lubricated importance of the discovery that the addition of improved working conditions and boundary lubrication bulk alloy formation depends not only on reducing the burden, but also on a change in behavior. It can be constructed as a transfer layer; however, it can lead to a low viscosity lubricant surface to surface roughness. However, the wear behavior of these alloys depends on a number of material-related mechanical properties (i.e. hardness, toughness and ductility), microstructure (i.e. shape, size, composition, type and distribution of micro constituents) in addition to the service conditions such as load, sliding speed, temperature [11,12].

Most researchers agree that the sliding surface topography has important role in understanding the nature of the surface. As a result, microtopography, contact between two moving surfaces is an important basis for the development of basic concepts [13]. Many studies have been conducted mainly in the lubricant friction morphology Al alloys with the effect of friction and wear resistance of these alloys. However, most of these studies were conducted under conditions of dry friction. In addition, studies of friction and wear tests were conducted mainly in the air. It is known that the environment around these contacts have a significant impact on the tribological performance [14], modern technologies and the size and the availability of digital computers have allowed us to describe and measure the surface shape. This paper is divided as; section 2 presents the experimental procedure, followed by results and discussion that detailed in section 3. The conclusions are outlined in section 4.

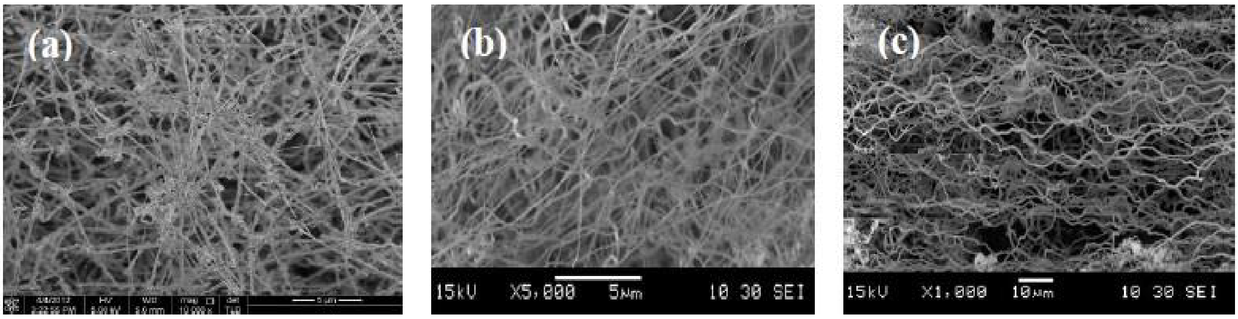

Figure 1. SEM microstructure of (a) A 6092, (b) A5056 and (c) A 3003 alloys.

EXPERIMENTAL PROCEDURE

Experimental methods used for the preparation of testing a surface roughness under dry sliding. The effect of load and sliding speed on the wear and damage mechanisms were analyzed and discussed for aluminum alloys. Roughness average (Ra) was a fixed polishing at 14 ± 0.05 µm. Also was using a pin–on disc, made of AISI 1045 steel and *Ra*=0.15 ± 0.05 µm, Hv=312 ± 20 kg/mm^2. All tests were carried out as per ASTM G-99 standard at a fixed sliding speed of 200 rpm and a load range of (5, 10, 15) N, diameter of track diameter: 90 mm and relative humidity 65%. Vickers microhardness was used to measure hardness (ASTM E-384 Std) (Load: 80gF, time 10 seconds). The specimen was 10 mm diameter. The effect of wear on the surface was analyzed using X-ray diffractometer (Philips PW 1710, USA) within 40 kV and 30 mA and characterized by scanning electron microscopy (SEM JSM-6010LV, USA) and Atomic Force Microscopy (AFM) (SPA 400, Seiko Instruments Inc., Japan). The microstructure was observed using an optical microscope. The microstructure of Al alloys is shown in **Figure 1a, 1b and 1c** respectively. These alloys compositions are given in **Table 1**:

Table 1. Chemical compositions of wrought aluminium alloys (wt%).

IADS designation	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Ni	Al
A 6092	0.31 ± 0.02%	0.05 ± 0.02%	1.01 ± 0.02	<0.02	1.05 ± 0.02%	<0.02 %	<0.02	<0.01	<0.02	Balance
A 5056	<0.05	<0.02	0.05 ± 0.02%	0.12 ± 0.02%	4.95 ± 0.04	<0.02%	0.09 ± .02	<0.01%	<0.02	Balance
A 3003	<0.05	0.38 ± 0.02%	<0.02	1.08 ± 0.02%	<0.02	<0.02	<0.02	<0.01	<0.02	Balance

RESULT AND DISCUSSIONS

Wear Rate and Friction Coefficient

Both A 6092, A5056 and A3003 alloys were tested with surface roughness in dry sliding. Wear test was conducted with parameters: the applied load, and sliding distance and a variety of them at three levels. **Figure 2** show the variation of wear rate with sliding distance for different loads (5, 10, and 15) N at 200 rpm of the both A 6092 (a), A5056 (b) and A 3003 (c) alloys. An increase of the sliding distance leads to the wear rate decrease and then it almost remains same for the entire test period. It is

e-ISSN: 2321-6212
p-ISSN: 2347-2278
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noted at 15 N, Ra=14 ± 0.05 µm gives the highest wear rate, a decrease of these values with A 6092 alloy, in both cases with the load increases weight loss at the first hour of testing and then goes down a little. The wear rate of A 6092 alloy decreases comparison with A5056 and A3003 alloy, generally results in higher friction and wear but longer distances, at lower loads, abrasion was the dominant mechanism of wear for both alloys. At higher loads, adhesion was found to be dominant for the monolithic alloy the type of domination. The ultra-mild wear mechanisms (UMW) observed in dry sliding produced lower wear rates for those A6092 alloy compared with A5056 and A3003 alloys.

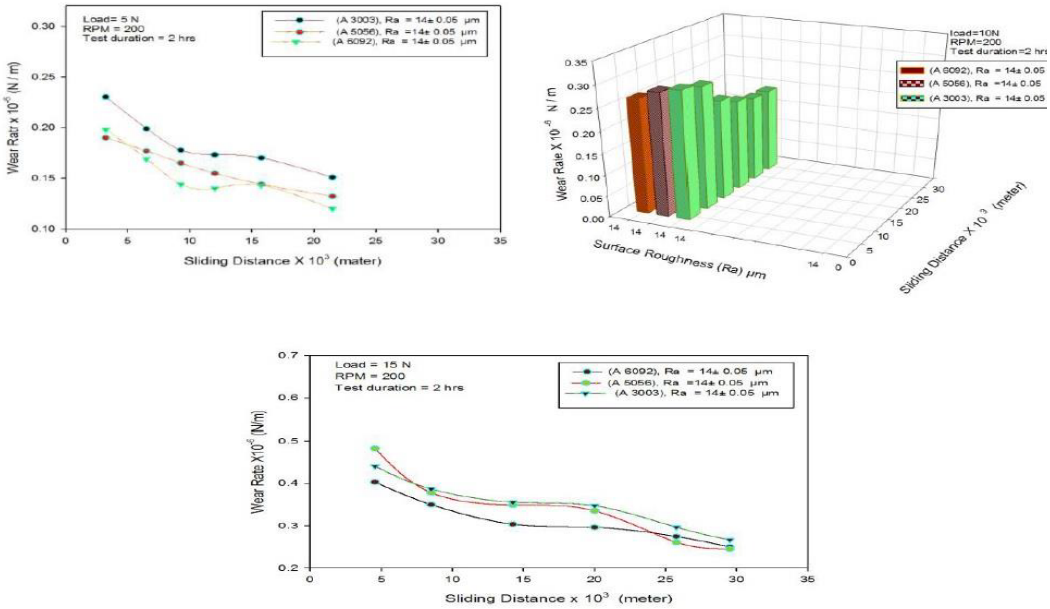

Figure 2. Wear rate loss as a function of sliding distance (200 rpm) for A 6092, A5056 and A 3003 alloys at (5,10 and 15) N loads.

Figure 3 shows the friction coefficient at 200 rpm, a load of 10 N a direct connection between the friction coefficient and the surface roughness of the alloys. It shows the change in the coefficient of friction at a normal load of friction coefficient about 0.26. This shows that the coefficient of friction in all cases decreases with the increase of normal load. This decrease in value occurs likely as a result of particulate standing above the surface making contacting area of the specimen smaller. Two important factors, including adhesion and deformation, are responsible for dry friction between surfaces in relative motion; adhesion occurs in the contact area between the surfaces. For same speed. When steady-state conditions are reached, the coefficient of friction is lower when roughness (*Ra*) is low by friction between the surfaces, so the correlation between roughness parameters and tribological behaviour is strong. However average roughness is the dominant on tribological behaviour properties of contact surfaces, under dry conditions [13].

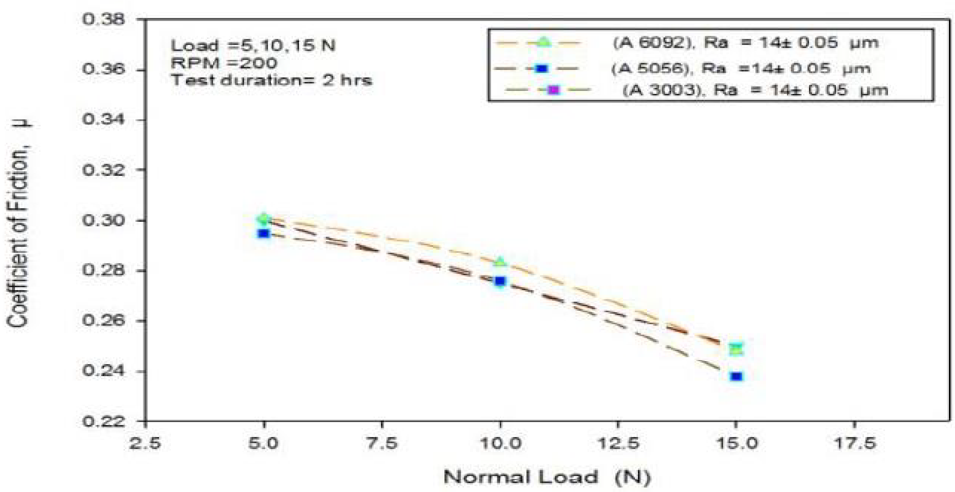

Figure 3. Coefficient of friction vs. load range of (5, 10, 15) N.

e-ISSN: 2321-6212
p-ISSN: 2347-2278
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Figure 4 shows the hardness vs. roughness (*Ra*) for A 6092, A5056 and A 3003 alloys under dry sliding conditions. It is observed that the hardness increases linearly with an increase in the Si content. This increase in the hardness observed in dry sliding produced lower wear rates for those A6092 alloy compared with A5056 and A3003 alloys.

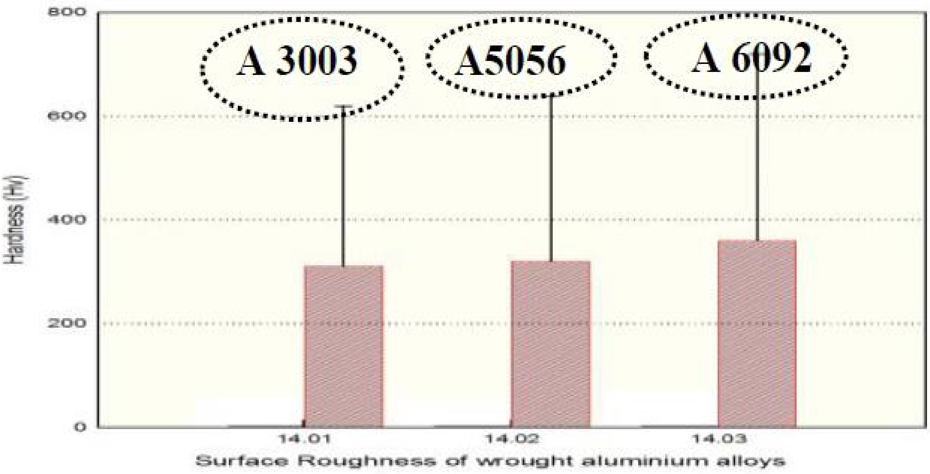

Figure 4. Hardness vs. Surface Roughness of A 6092, A5056 and A3003 alloys.

Worn Surface Morphology and Wear Mechanisms

The structures of the worn surfaces are greatly dependent on sliding speed and applied load conditions. Worn surface of A 6092 (a), A5056 (b) and A 3003 (c) alloys at 5, 10 and15N loads, respectively. The difference between the worn surfaces of the alloys was also difficult to quantify, often with greater variability observed within a single sample than from sample to sample. All alloys exhibited plastic grooving, the surface of alloys grooves formed in the sliding direction, and the width and depth of these grooves were lower in the A 6092 alloy. With increase in applied load although the amount of cavitations appears to be low but deep cracks and grooves are clearly visible in the A5056 (b) and A 3003 (c) alloys. Thus, particle destruction took place, and the fragmented particles acted as abrasives, causing the formation of multiple slotsin the A5056 (b) and A 3003 (c); the high surface roughness has also been associated with the formation of a few comments grooves. Another was the change of surface roughness compared to the initial roughness. Changes in surface roughness were also observed in the respective mating surfaces, and increase the surface roughness in all cases [14]. However, the roughness of the mating surface after wear test is always higher than the worn surfaces by abrasion mating surfaces **(Figure 5)**.

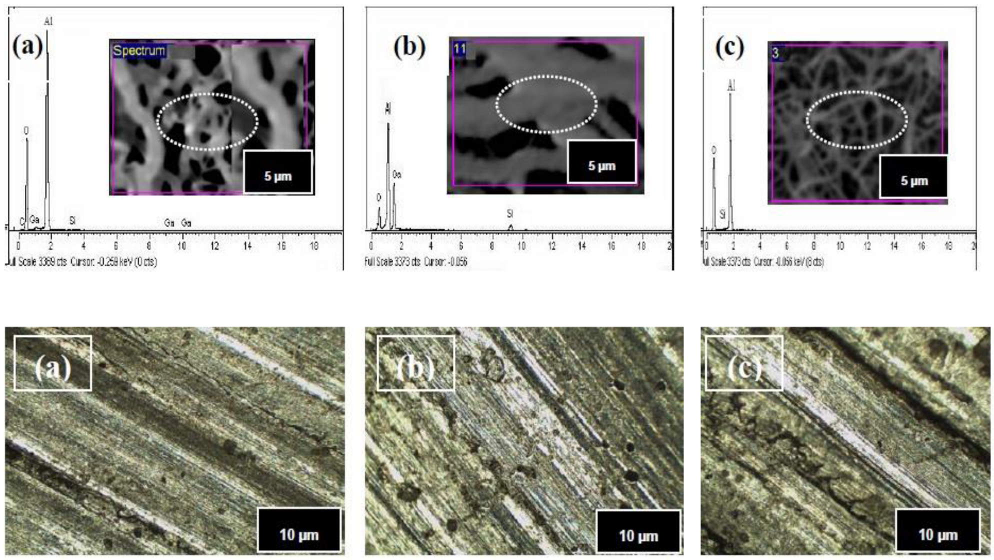

Figure 5. SEM and EDS of (a) A 6092, (b) A5056 and (c) A 3003 alloys. Corresponding SEM-EDS, at 10N & 200 rpm.

Comparison of the Alloys

Figure 6 to facilitate comparison, the comparison of samples, depending on the degree of wear. *Ra* parameter shows a low wear in A6092 alloys for all sliding speeds, although they have the same average roughness. However, the difference decreases

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with increasing sliding speed, and it decreases surface topography. In dry contact, initial topography was changed due to abrasive wear, so the correlation between roughness parameters and tribological behavior is strong. Worn surface morphology was observed in the AFM in contact mode on a 5 x 5 μm^2 area and analyzed with increasing temperature and contact pressure, the silicon particles were completely immersed in the matrix. The data show that the average surface roughness (*Ra*) increases with time of sliding [15]. Hence, it can support the adhesion improvement under dry sliding conditions that the tests were carried.

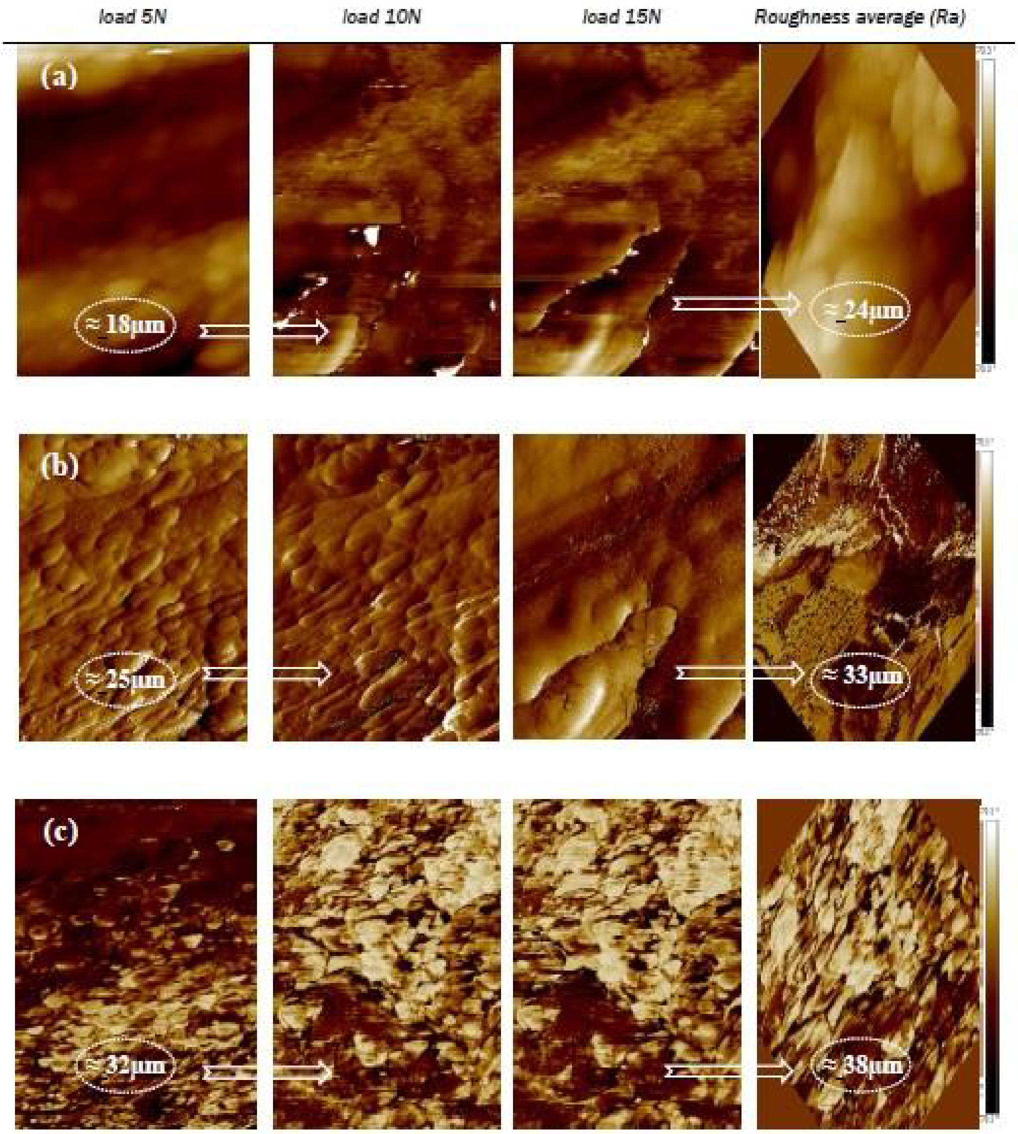

Figure 6. 2D Optical image AFM of (a) A 6092, (b) A5056 and (c) A 3003 alloys at (5, 10, 15) N loads.

However, the surface damage of the A5056 and A 3003 alloy was larger compared with the A6092 alloy and the reason is attributed to the presence of larger proportion of silicon in the A 6092 alloy.

Figure 6 show the change in the length of the surface roughness testing materials to 200 rpm of the A 6092 alloy was increases the surface roughness from 14 ± 0.05 to 24 ± 0.05 µm; While in the A5056 and A 3003 alloy increased from 14 ± 0.05 to 33 ± 0.05 µm, and 38 ± 0.05 µm, , respectively at a load of 15 N. The tests illustrate by the microscope atomic force microscopy (AFM) of the surface roughness *(Ra).*

Figure 7 shows the depth profiles, which was adopted in various regions of the wear tracks after 60 min, a load of 5, 10 and 15 N and dry contact at 200 rpm, A 6092 alloy comparison with A5056 and A3003 alloys. However, there is an improved wear resistance, generally accepted mechanism for the wear of A6092, A5056 and A3003 alloys. Usually, the relationship between them is a little complicated, but the severity of damage on the sample surface at high loads as known in terms of contact with the steel in the conditions of this study. In some cases, debris control transfers from the sample surface on the disc surface due to a difference in hardness.

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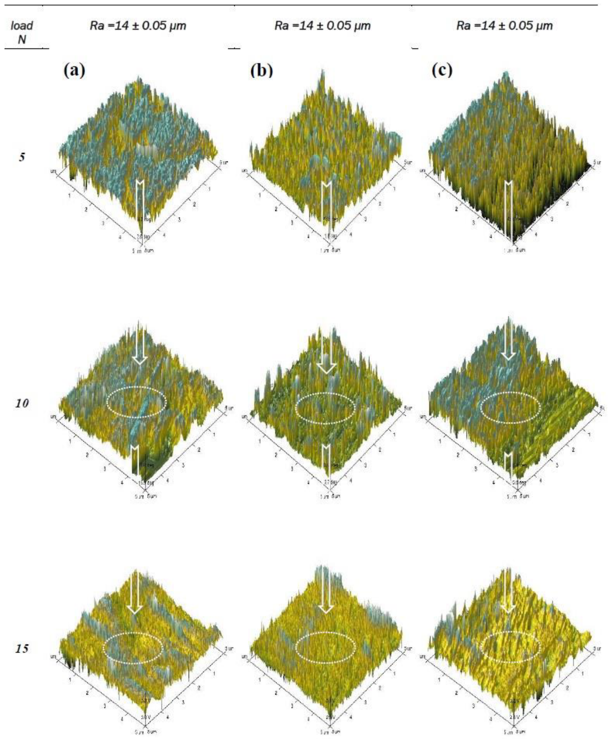

Figure 7. 3D Optical image AFM of (a) A 6092, (b) A5056 and (c) A 3003 alloys at (5–15) N loads.

Figure 8 shows that the depth of each curve represents the profiles taken in different areas of wear track after 60 min, load 10 N at 200 rpm for A 6092 alloy and A5056 and A 3003 alloy, at dry sliding and the effect of depth of A 6092 alloy was (5) μm little more compared with A5056 and A3003 alloy which was (6) μm and (9) μm respectively. Optical profilometer surface wear of aluminum matrix surrounding the silicon particles is defined in the 3D profiles. It is the accumulation of positive results in the formation of the asymmetry in the distribution of aluminum a convergent effect of ultra-mild [14]. As a result, microtopography, contact between two moving surfaces is an important basis for the development of basic concepts. Modern technologies and the size and the availability of digital computers have allowed us to describe and measure the surface shape [15].

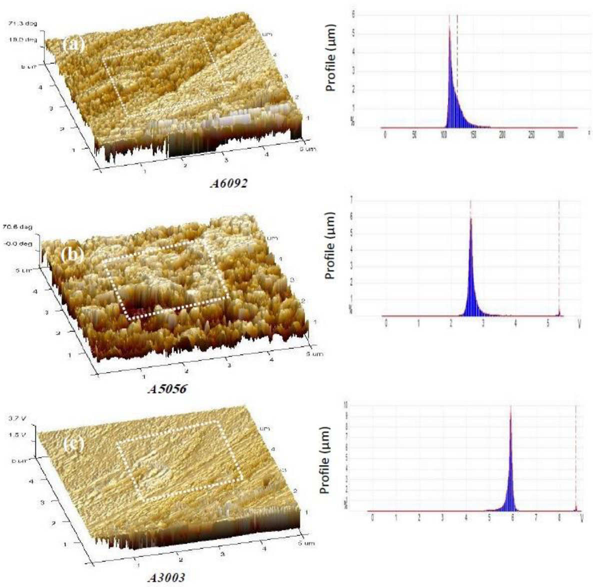

Figure 8. 3D Optical image AFM and depth profiles of (a) A 6092, (b) A5056 and (c) A 3003 alloys at 10 N load.

The difference in the wear of these modes may be more than two orders of light wear small (<4 μm), characterized by the formation of a particle mode and are mainly composed of aluminum oxide. Thus, generated soft modes of wear, oxidation, wear

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mechanism of wear particles of strict regime of large (>8 μm), some of the wear on the surface of metal fatigue (split) to be formed are different, but its load also depends on the speed sliding, changes in behavior that occur at high temperature and high speed sliding [15,16].

CONCLUSION

In this research, for the contact between of surface roughness of wrought aluminium alloys on the surface of steel , in order to understand and comparison of the effects surface roughness of wrought aluminium A 6092, A5056 and A 3003 alloys. Were adopted to perform friction and wear tests. The effect of dimple patterns was investigated in different load- conditions and damage mechanisms were analyzed, the following results are observed:

At a light load of 5 N, surface roughness of wrought aluminium A6092, A5056 and A 3003 alloys, both of them obviously reduce friction and wear. When dimples are on the surface of steel, in the A 6092 alloy was wear reduction is 10% comparison with A5056 and A 3003 alloys in this research.

- At a load of 10 and 15 N, performs a better effect of wear resistance of A 6092 alloy and was wear reduction is 18% comparison with A5056 and A 3003 alloys and reduce friction.
- The depth of each curve represents the profiles (AFM), the maximum reduction rate of the average wear depth is 20% of A 6092 alloy while in A5056 and A 3003 alloys was reduce 29% and 40% respectively.
- The result of differences in hardness and strongly depends on the alloy composition elements present in the Al alloy. The effect was observed even at low concentrations in the wear rate was a strong function of the surface roughness. This comprised severely work hardened aluminium alloy. The morphology of the layer depended on alloy composition, was a function of the alloy composition. Severe wear was observed at all loads.
- This is believed to be the result with the linear dependence between the wear rate and sliding distance of A6092 observed for A3003, A5056 was relatively to the surface roughness.

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e-ISSN: 2321-6212
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