Investigation of the Tribological Behavior of Eutectic Al-Si Casting Alloy

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ABSTRACT

The effect of roughness of Al-Si alloy on the wear is investigated. Roughness average (R_a) was verified via different polishing, also was using a pin–on-disc of different loads (5, 10, 15) N, different speeds (100, 200, 300) rpm and relative humidity 74%. Different values of R_a are obtained with (3, 5 and 7) µm. Worn surface were characterized using SEM / EDX. The results show that the wear rate of Al-Si eutectic alloys increases with the roughness increase. It was noticed that the specific and wear decreases as roughness decreases. Severe wear was observed at all loads.

التحقق من السلوك الترايبولوجي لسبائك الالمنيوم سليكون سهل الانصهار

الخلاصة

التحقق من تأثير خشونة السطح لسبائك الالمنيوم سليكون سهل الانصهار على معدل البليان باستخدام جهاز الدبوس على القرص مع مختلف الاحمال (5, 10, 15) نيوتن والسرع (100, 200, 300) دورة في الدقيقة وكانت الرطوبة النسبية 74% وخشونة السطح (7 and 3, 5) µm. السطوح البالية تم وصفها باستخدام SEM / EDX. واظهرت النتائج ان معدل البليان للسبائك يزداد مع زيادة خشونة السطح كما لوحظ ان معدل البليان الحجمي يتناقص مع تناقص خشونة السطح. بليان عميق حدث عند جميع الاحمال كما تم مناقشة جميع التشوهات التي حدثت تحت السطوح البالية.

1. INTRODUCTION

The properties of aluminum alloys can be constructed precisely to the requirements of particular applications by the automotive industry through the choice of alloy composition, heat treatment, and the manufacturing process. The main characteristics of Al-Si alloys used in vehicles are light weight, forming and fabrication, high strength to weight ratio, resistance to corrosion, recyclability, heat the conductivity and reflectance [1]. This has created the need to understand tribological properties of eutectic alloys Al-Si at low load conditions, mimicking the evolution during normal operation of conditions [2-4]. 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 [5-7]. Shivanath et al. [8] and Singla and Chawla [9] studied the wear of Al-Si alloys with silicon from 4 to 20% using a pin-on disc tester

against the steel disc. The authors have tested at a speed of 1 m/s to a load of 24kg and found that the amount of silicon had a noticeable impact on the transition from load MW to SW except of Al-11% Si, which showed discontinuity in the linear relation between load transient and silicon content. Also showed that within the oxidative wear rates were it independent of the silicon particle size.

Menezes et al. [10] in dry conditions, by sliding surfaces exist some mechanisms such as severe. Depreciation of these alloys is also classified based on the types of wear during sliding, ie oxidative deterioration or wear of the metal. Ku and Math [11], Kadirgama et al. [12] have been studied surface treatment termination and termination surface to reduce the influence of the roughness during sliding. This form of wear occurs when two smooth sliding body meet each other. The relative motion can be unidirectional or reciprocating motion. Karpenko and Akay [13], Takata [14] reported that effect of surface roughness between surfaces using an algorithm for calculating the friction between them. They came to the

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conclusion that there is a deformation and shear strength depends on the load, the topography of the surface to give the estimated effect of the border. To accelerate the process of deterioration and damaged surfaces. Wieleba [15] investigated hardness and roughness of the composite material, which shows its effect on the friction and wear. Chowdhury [16] studied the behavior of these alloys and mechanical properties (stiffness, toughness and flexibility), and micro (shape, composition) rate depends of temperature and environment. Xing et al.[17] show the wear resistance with silicon contents improved to only almost eutectic alloy composition was more than hypereutectic alloys. Pramila Bai and Biswas [18] studied the wear binary alloys with a silicone ranging from 4% - 24% in a wear tester against steel disc. The authors showed that the silicon content had no significant effect on the degree of wear. Finally, Li et al. [19] have been prepared for studying the effect of mechanical and tribological properties of piston alloy and suggested that thermal treatment has higher strength and wear resistance.

2. EXPERIMENTAL PROCESS

Tribological test experiments were performed using pin-on disc as shown in Fig. 1. The specimen was 10mm diameter. For Al-6.5Si alloy; R_a= 3, 5, 7± 0.05 μm, Hv=110.55 ± 12kg/mm² on disc of 1045 steel, and R_a=0.15±0.05μm, Hv=311±20 kg/mm². The applied load was (5,10,15N) and the sliding speed was (100,200,300rpm). The tracks observed by scanning electron microscopy.

The surface roughness can be described as follows:
• Surface roughness (R_a) is the absolute values of the roughness.

$$R_a = \frac{1}{l}\int_0^1 |Z(x)|dx \tag{1}$$

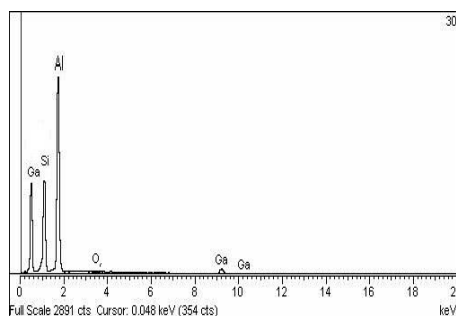where Z(x) is the mean of roughness depths and 1 is traversing length, (R_q) is the root square average [20,21].

$$R_q = \sqrt{\frac{1}{l}\int_0^1 |Z(x)|dx} \tag{2}$$

In Table 1, the chemical analysis. Mechanical properties and hardness in Table 2, while the roughness parameters (R_a) are calculated in Table 3.

The SEM images of the structure and composition of samples as shown in Fig. 2. The Micro-Topography and SEM images of micrographs as in Fig. 3.

Fig. **1.** Testing machine of wear.

Table 2
Details of alloy of Al-Si alloy.

Hardness	110.55 VHN
Density	2.72 gm/cc
Tensile strength	250 MPa

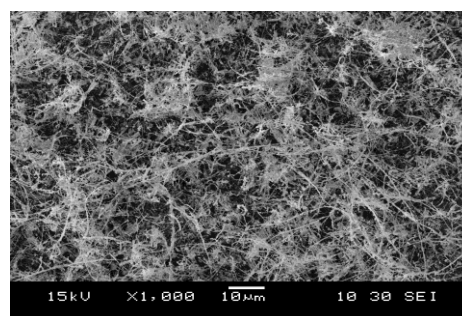Weight loss for each sample, wear volume loss was calculated by:

$$W_r = \frac{\Delta W}{S.D} \tag{3}$$

where Wv is the volumetric wear, ρ density and t Time, using:

Table 3
Surface roughness average (R_a) of Al-Si alloy.

Reference surface	
Sample area	R_a **(μm)**
Sample 1	7
Sample 2	5
Sample 3	3

Table 1
Chemical compositions of Al-Si alloy (Wt%).

Si	Mg	Cu	Fe	Ni	Mn	Sn	Ti	Zn
6.5	0.1	3-4	1.0	0.35	0.5	0.026	0.25	1.0

Fig. 2. The SEM of Al-Si alloy.

$$W_v = \frac{\Delta W}{\rho t} \qquad (4)$$

The friction coefficient, (μ) was calculated:

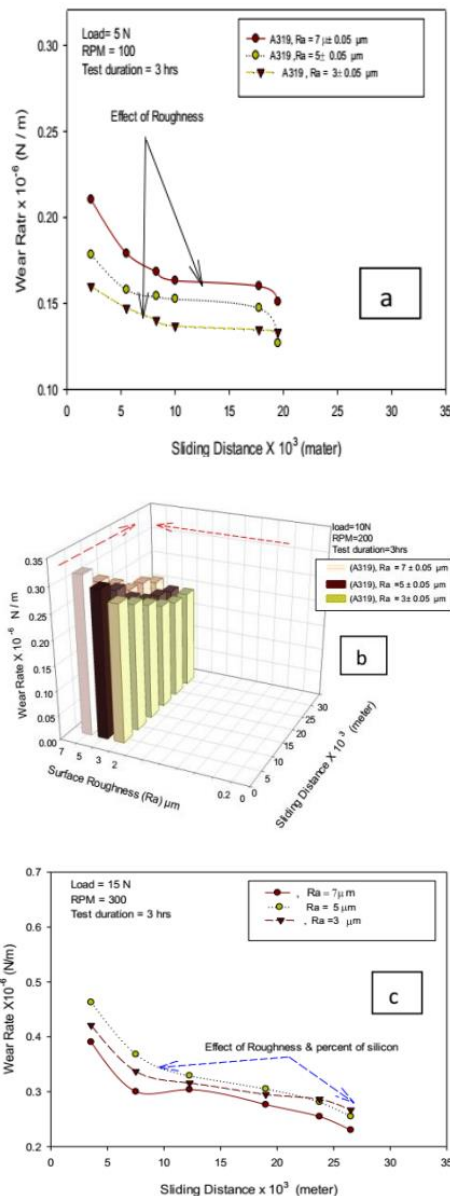$$\mu = \frac{F_f}{F_n} \qquad (5)$$

where F_f is the friction force and F_n is the applied load temperature is constant at 30 $^{\circ}$C.
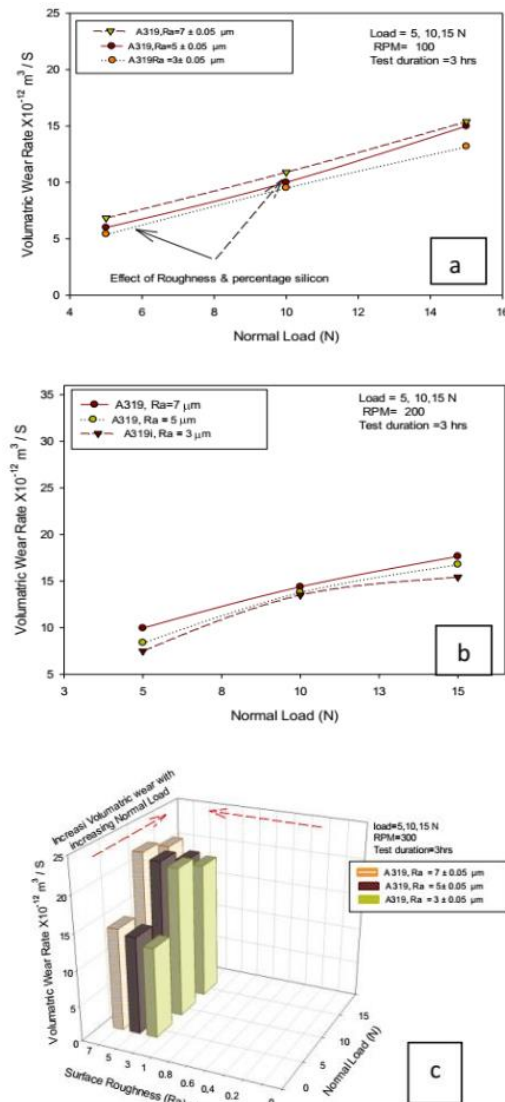
3. RESULTS AND DISCUSSION

The alloy that used in this study which is a eutectic diversity. Different roughness average (R_a); 3, 5 and 7μm within different loads; 5, 10 and 15N for both samples, Fig. 4. For 10N with R_a equal 7μm gives the wear equals to 0.2087x10⁻⁶N/m, for R_a equal 5 and 3μm gives 0.17771x10⁻⁶N/m and 0.16159x10⁻⁶ N/m, Input is considered normal weight load on sample. When load increases it, the friction between two moving surfaces to increase. Due to friction and over the actual surface area in

contact with more solid material, it will grind the softer material at a higher speed. It was observed in Fig. 4(b) and (c) load will increase the strain hardening of materials, they are in contact. This will increase the resistance to undermine, thereby reducing the rate of wear. Perhaps this reason that at a higher load, the real surface area, the wear rate is slowed. Little wear rate at 10 N of the surface at R_a=7 μm has an amount of volumetric wear value to Wv= 10.8312 x 10⁻¹² (m³/s), higher slightly than with R_a=5 and 3 μm as shown in Fig. 5 (a). The wear damage has improved. At the same time observations have shown that the wear rate was more pronounced. Volumetric and specific wear it increased with increasing rotational speed, however, the increase in the sliding distance is showed a trend towards reduction.
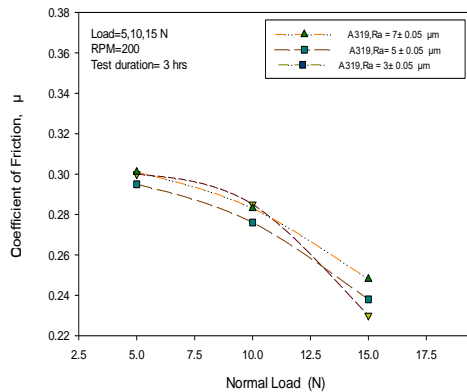

Fig. 5. Surface roughness R_a = 3,5 and 7 μm and volumetric wear with load of 5,10 and 15 N at (a) 100 rpm, (b) 200 rpm and (c) 300 rpm.

It notice that the volumetric wear with load in Fig. 5 at 200rpm is positively and the volumetric wear at R_a equal 7μm is Wv= 7.00677 X 10⁻¹²m³/sec at increases as load increases to 10 and 15N. Increasing of Wv values due to the same reason of increasing of roughness, while the Wv decreases with the decreases of roughness Ra as shown in Fig. 5.

Fig. 4. Variation of roughness R_a = 3,5 and 7 μm and wear of 200 rpm at (a) 5 N (b) 10 N (c) 15 N.

In Fig. 6 the coefficient of friction decreases in all cases with increasing normal load. This decline is probably the result of particles standing above production of sample surface contact area at least.

Fig. 6. Surface roughness R_a = 3, 5 and 7μm and friction coefficient with load of 200rpm at (5,10,15) N.

4. CONCLUSIONS

1- For dry contact, the friction losses increase as the surface roughness increases.
2- The roughness parameter of Al-Si casting alloy attributes to the shape of asperities of R_a and has it the greatest influence on the wear rate.
3- The wear rate increases as the load and roughness average increase, while it correlates inversely with sliding distance.
4- Volumetric wear increases with increasing the rotation speed, and the overall wear damage for sample was found to be increasing.
5- Contacting surfaces of materials are sliding with a higher load, which leads to a slow rate of wear.
6- The coefficient of friction decreases as the load increases.

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