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# The Influence of Roughness on the Wear and Friction Coefficient under dry and lubricated sliding

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**Abstract**— The aim of the present research was to the effect of surface roughness of aluminum-silicon casting alloy on the friction and wear is investigated. Various surface roughness average *(Ra)* of different degrees were verified via different grades of grinding, polishing and have been evaluated using a pin-on-disc as well as three different loads 10, 20 and 30 N, speeds 200, 300 and 400 rpm and relative humidity 70%. Different surface preparation techniques are resulted in different surface roughness of *(Ra)* = (4,6) μm .The monitor effects on the friction coefficient and wear are through the test dry and lubricated sliding. It was noted that the weighted and volumetric wear rate decreases as degree of roughness decreases, as well as coefficient of friction is considered as a function of the stability state. This paper attempts to bridge the gap between the damage mode, sliding conditions and surface roughness to provide an approach to evaluate the surface finishing as a factor in friction and wear damage processes.

**Index Terms** —Surface roughness, Lubrication, Dry sliding, Casting alloy, Coefficient of friction, Wear rate, Damage.

## 1. Introduction

Surface roughness is a major problem produced during the production process and greatly affect the quality of the product [1]. Can affect the surface roughness during the process of sliding through the contact between the surfaces at the Tops and this leads to cut and deformation these peaks during the slide and thus can cause economic damage so it is best to be a better understanding of the roughness[2] as well as affect the surface roughness coefficient of friction on the side by side with the frequencies and vibration incurred during sliding between the surfaces, and there are variables affecting the coefficient of friction when sliding[3][4]. is important to know the quality of the roughness of surfaces that require a process of coating and treatment to protect it from damage[5] That the installation and texture surface can increase the load hydrodynamic as well as increasing the thickness of film when the structure of surfaces of linear and moderate and thus increases the life of surfaces and reduce the cost [6]. of either rough surfaces usually lead to speed the process of wear and damage surfaces when working must take into account the mechanical properties and factors affecting when sliding between surfaces[7] .In these experiments we will notice the impact of this roughness is actually a coefficient of friction and wear rate between the surfaces sliding at the contact between the areas of nominal and actual handling of this effect by carrying out treatments on the surface of the coating, and other processes that help in smoothing the surface and the things that affect the advance on the surface is the manufacturing process of the basic surfaces and the surface termination phase[8]. Menezes et al. [9].have been studied the effects of roughness parameters on the friction of aluminum alloy under conditions of lubrication. They concluded that the coefficient of friction and wear are depending on the roughness It is important to know the quality of the surfaces roughness that requires a process of coating and treatment to protect it of damage [10]. Karpenko and Akay [11] have been studied the effect of roughness between two surfaces using an algorithm to calculate the coefficient of friction between them. They concluded that there is a flexible deformation and shearing resistance depend on external loads, mechanical properties and topography surfaces to give the approximate limits of influence. To increase the process of wear and damaged surfaces, we must take into consideration the mechanical properties affect the process [12]. . Chowdhury and Maksud [13] have been searched the effect of humidity on surface roughness and found that the friction is very high at low roughness and tends to be increased at high horizontal vibration. Wieleba [14] had been studied roughness and stiffness of composite materials against steel and showed its effect on the friction and wear. Al-Si alloys have been studied interestingly, but did not take into consideration the roughness study. Xing et al. [15] have been prepared the hypereutectic Al-17.5Si (wt pct) and Al-25Si (wt pct) alloys with various content of rare earth Er by conventional casting technique. They investigated the effect of Er on the microstructure and properties of hypereutectic Al-Si alloys using optical microscopy, scanning electron microscopy (SEM) as well as friction and wear tests and noticed an improvement of the anti-wear properties and the friction coefficient of the hypereutectic Al-Si alloys. Finally, Li et al. [16] have been prepared and fabricated hypereutectic Al-Si alloys by hot extrusion. They investigated the tensile fracture me-

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chanisms using SEM and proved an improvement of Al-Si alloy and wear resistance due to silicon particles refining.

In this work, to best of our knowledge, there is not available in the literature investigation of roughness on the wear rate with sliding distance and velocity of Al-Si casting alloy, on the volumetric wear rate and friction coefficient with normal load. It was attempted to bridge the gap between the damages resulting from the sliding surfaces and surface roughness effect on the friction and wear to provide an approach for evaluation the surface finishing operations. All of these are divided into the followings: Section 2 displays the experimental process, while results and discussion are given in section 3. Finally, section 4 concluded the obtained results.

## 2. Experimental Procedure

For the purpose of this investigation, aimed at investigating influence of surface preparation on roughness parameters and correlation between roughness parameters and friction and wear, A pin-on-disk tribological test rig was used for the investigation shown in Fig. 1 The upper specimen was a fixed (10 mm) diameter Al-16Si casting alloy Ra = (4,6 ) ± 0.03 μm, Hv= 112.65 ±12kg/mm²), on disc, made of AISI 1045 steel (Ra = 0.15±0.05μm, Hv= 312±20kg/mm²), ,were tested. The applied load was (10,20,30) N and the sliding speed, (200,300,400) rpm (1.32,1.885.3) m/s. before the start of effective wear samples of aluminum silicon disc was cleaned and dried using cotton and acetone as the weight of the samples was measured using a digital balance and recording the values before and after the test in each test is calculated sliding distance. The wear tracks were observed by scanning electron microscopy (SEM) combined with energy dispersive X-ray spectroscopy (EDX).Surface roughness was also measured by a stylus surface analyzer, with the effective measure length 0.350 mm and the cutoff length,0.05mm. The work hardening of contact surfaces due to the friction shear was identified by their hardness increase as determined by micro-Vickers indentation test.


Fig. 1 Pin-on-Disc wear testing machine

Chemical analysis was conducted for the aluminum-silicon casting alloy, also density, hardness and tensile strength are studied due to its widely used in industry, particularly in pistons as well as the cylinders, the resulted chemical analysis is given in the Table 1, and testing of mechanical properties are cleared in Table 2. while the surface roughness parameters ($R_a$) are calculated in Table 3.

**Table 1:** Compositional analysis of Al-Si casting alloy.

| Si | Mg | Cu | Fe | Ni | Mn | Sn | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| 16.69 | 1.176 | 1.30 | 1.13 | 1.22 | 0.02 | 0.012 | 0.026 | 0.01 |

**Table 2:** Investigated hardness, density and tensile strength of Al-Si casting alloy.

| | |
|---|---|
| **Hardness** | 112.65 VHN |
| **Density** | 2.72 gm/cc |
| **Tensile strength** | 250 MPa |

**Table 3:** The calculated surface roughness average ($R_a$) of Al-Si casting alloy.

| **Reference surface Sample area** | **$R_a$ (μm)** |
|---|---|
| Sample 1 | 4 |
| Sample 2 | 6 |

The microscopic structure and the composition of microscopic samples are examined and shown in Fig. 2. It is shown that Si particles are distributed uniformly, while the Si seems a bulk, we have used the following materials manifesting:

- 190 ml of water distil
- 3 ml from hydrochloric
- 2 ml from hydrofluoric acid

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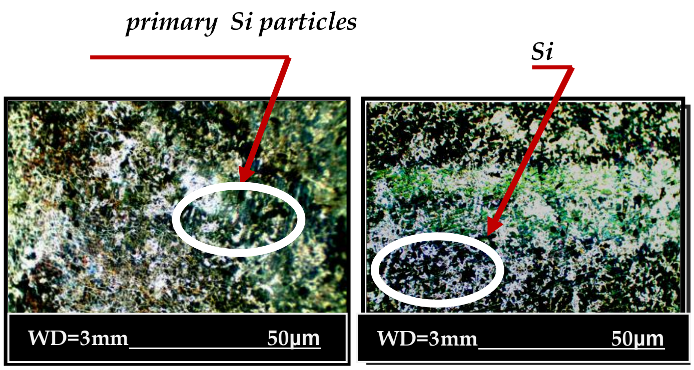


Fig. 2 The SEM images of microscopic structures of Al-Si casting alloy.

Al-Si casting alloy. Was cleaned then starting an actual test of wear process and the hard substance acetone with cotton and dry well was registered height and weight of samples accurately to provide a very precise and digital recording of all data using a stopwatch to set a time slip and post-test .

Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss, *(ΔW)* in the specimen was obtained. Cares have been taken after each test to avoid entrapment of wear debris in the specimen. It is calculated to the mass loss to sliding distance *(S.D)* using:

$W.R = \Delta W / S.D$ (1)

The volumetric wear rate $Wv$ of the composite is related to density (ρ) and the abrading time ($t$), using:

$Wv = \Delta W / \rho t$ (2)

The friction force was measured for each pass and then averaged over the total number of passes for each wear test. The average value of coefficient of friction, $\mu$ of composite was calculated from

$\mu = Ff / Fn$ (3)

where $Ff$ is the average friction force and $Fn$ is the applied load with an assumption that the temperature is constant at 31 °C.

$Ws = Wv / S.S\ Fn$ (4)

where S.S is the sliding velocity.

## 3. Results and discussion

The results of tests conducted on different surface roughness of *(Ra)* = (4,6) μm under dry sliding speed and conditions of (1.32, 1.885, 3 ) m/sec within the range of different loads; (10, 20 and 30) N,and note in Figure 3.(a) that the value of surface roughness *(Ra)* = 6 μm gave highest percentage in the rate of wear weighted $W.R = 0.1473 \times 10^{-6}$ (N/m), at the speed of low compared with the amount of roughness to the surface of the *(Ra)* = 4 μm , the other Ra=4 μm gives $W.R = 0.1262 \times 10^{-6}$ (N/m) and goes down with the passage of time sliding the amount of roughness *(Ra)* = 4 μm had given the rate of wear is less compared with the surface of the former reason is attributed to increase the surface roughness reduces the area of contact real are concentration load only in the areas of contact between the surfaces and gets broken layer oxide and cause an adhesion metal is strong and therefore, the force required to cut notches related to higher than the force required to cut the bonds of atomic alloy, This effect continued for all the loads used in the test In Figure 3. (b) When comparing these results between the dry test with the test Note the presence of lubrication to reduce all the values where we got on the rate of wear weighted $W.R = 0.1052 \times 10^{-6}$ (N/m), $0.0842 \times 10^{-6}$ (N/m) respectively.

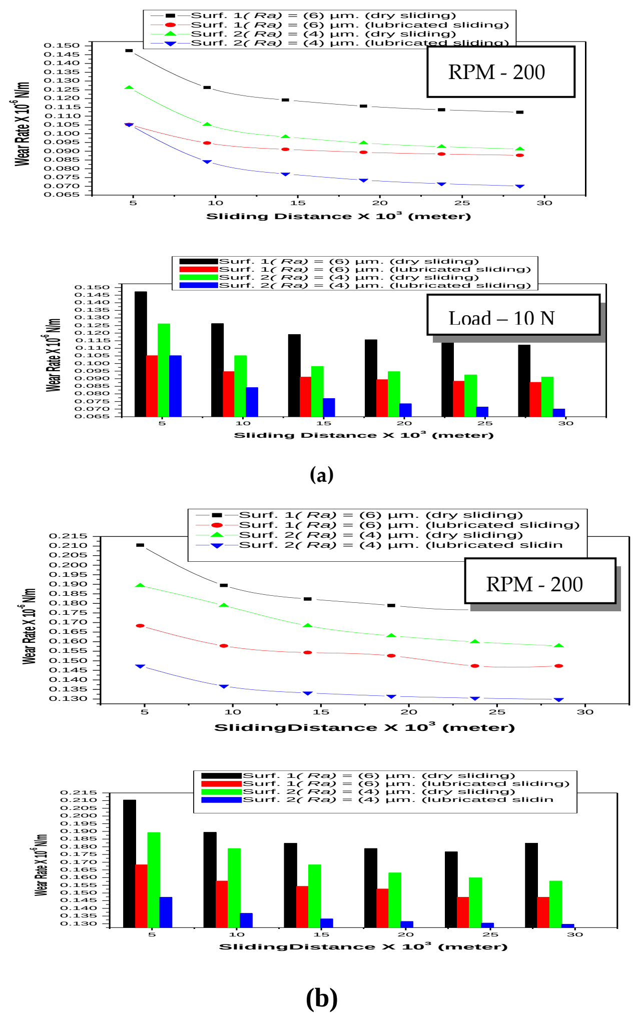


**Fig. 3** Variation of surface roughness $R_a$ = 4 and 6 μm and wear rate with sliding distance of 200 rpm at (a) 10 N, (b) 20 N. under dry and lubricated Conditions

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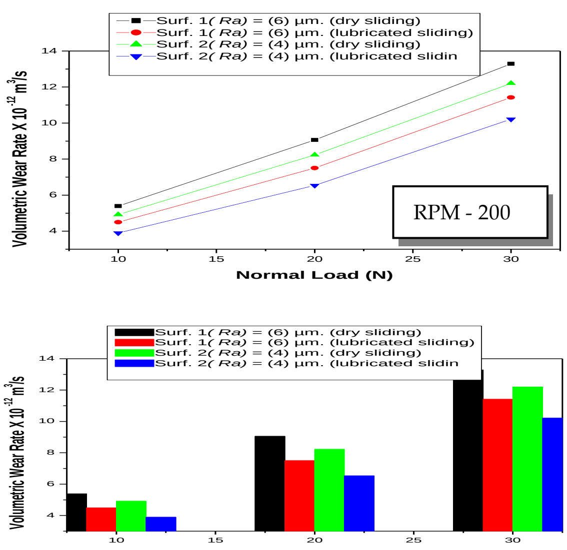
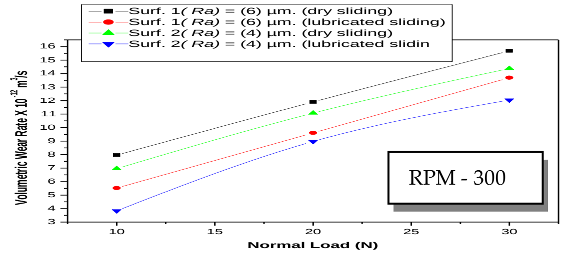
In Figure 4. (a),(b)and (c) we note the low rate of volumetric wear with a low surface roughness, where it decreased *from* $Wv = 5.393 \ X\ 10^{-12}\ (m^3/sec)$ to $4.918X10^{-12}(m^3/sec$ respectively and these values are also lower when compared with the test lubrication, where the presence of oil reached is due to the formation of a film led to lower the temperature and reduce the contact between the surfaces and thus reducing the friction, which reduced the loss of the metal weighted, as well as note that the amount of load significantly affect the specific of wear and this is clear ,where the shed loads low during the slide will lead to the formation of film protector reduces the contact between the surfaces and this is the force required to cut the interdependence between the bumps less than the force required cut the ties of atomic alloy and therefore less wear specific is the qualitative increase of load showed the results of the surface at *Ra*= 6μm has amount of specific wear equals to $Ws = 3.410\ \ X\ 10^{-13}\ (m^3/N\text{-}m)$. and fell to the amount slightly at high speed compared with the amount of roughness (*Ra*) = 4 μm , shows that the amount of loss of quality depends on the roughness of the surface as well as increases with roughness and less signal decreases, as well as can be seen that the reason for lack of wear resistance at the beginning of the test is to be a thin layer of material corroded between bumps the disk surface and settle over time and that the continuation of the process of sliding lead to emotional to the surface of the sample and the low rate of wear of the qualitative and by roughness of the surface.




**(a)**

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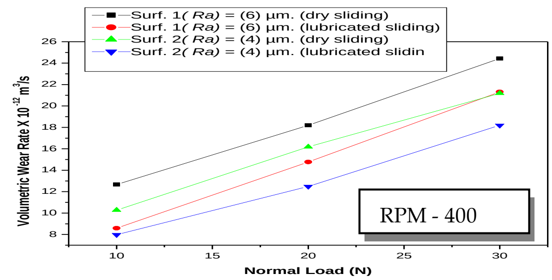


**( C )**

Fig. 4. Variation of surface roughness $R_a$ = 4 and 6 μm and volumetric wear rate with normal load of 10,20 and 30 N at (a) 200 rpm, (b) 300 rpm and (c) 400 rpm. under dry and lubricated Conditions.

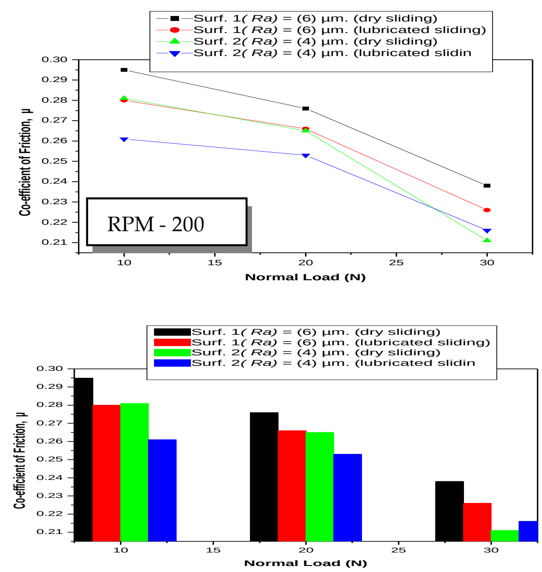


Fig. 5 Variation of surface roughness $R_a$ = 4 and 6 μm and coefficient of friction with normal load of 200 rpm at (10) N. under dry and lubricated Conditions

Figure 5. that the surface roughness increases the friction coefficient and for all the loads that the coefficient of friction represents the percentage of friction force to the load hanging and that the increase in load lead to the flow of plastic the protrusions surfaces slippery and then an increase in the area of contact of real and this increases the area of connections and therefore we need to force cut is bigger than lead to increased friction force over time

increase the temperature of the surfaces and increase the flow of plastic to the protrusions, leading to flattening gradually protrusions become surfaces smooth and for the case become surfaces smooth and obtain steady-state and that higher speed leads to high temperature instant during the slide, leading to softer bumps, which reduces the shear force required to cut the connections and this leads to reduce the friction coefficient and when the test with a lubricant and all forms of the results were better and dropped all values for the wear rate and volumetric and weighted as well as specific addition to the coefficient of friction and be because they are to the layer of film between the surfaces reduces the contact between them, leading to lower the temperature.while Low coefficient of friction with increasing load and sliding speed of the lubrication situation, compared with the dry state When test conditions similar. The micrographs wear surface increases with increasing load as shown in Fig. 6. It is observed for the same velocity, the wear rate on the surface is increased as load increases.

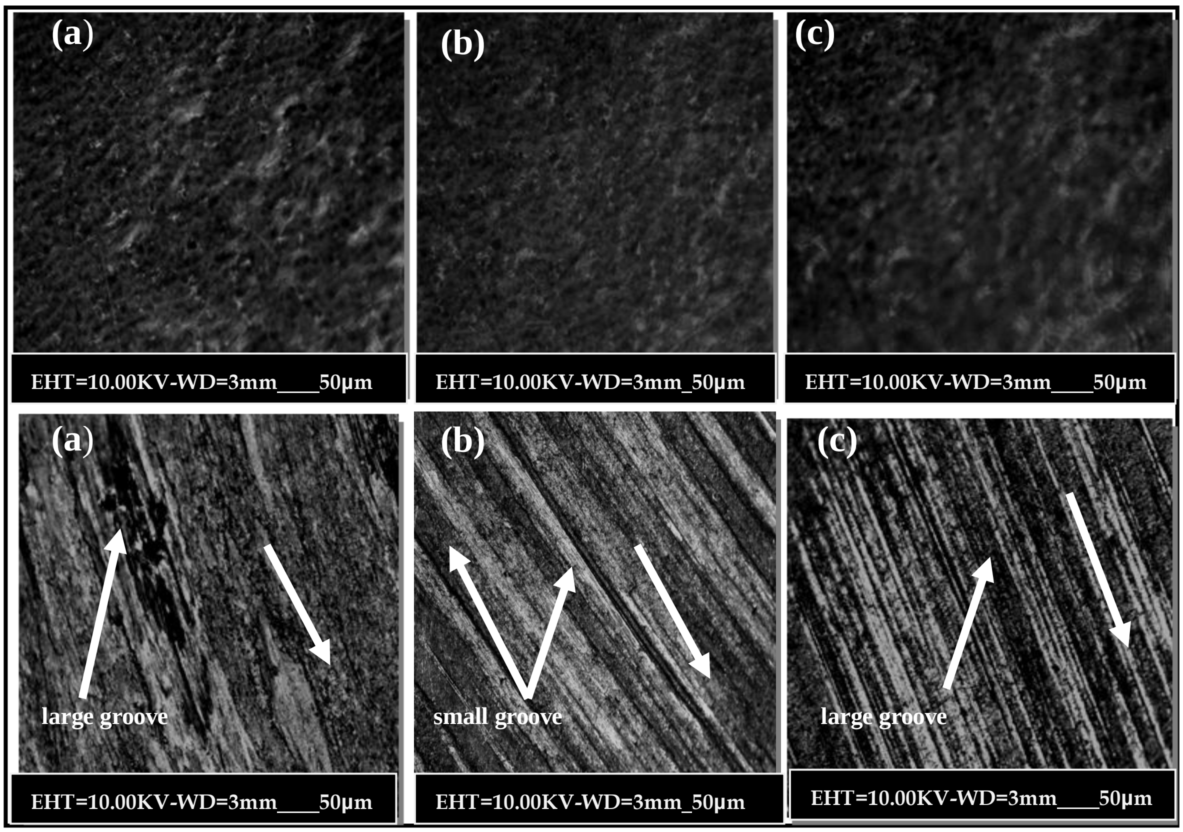


Fig. 6. The SEM images of micrographs before and after wear surface of 400 rpm and load (a) 10 N, (b) 20 N and (c) 30 N. under lubricated Conditions.

## 4 Conclusion

In summary, using the investigated results, we concluded the followings:

- The use of lubrication has led to lower wear rate the weighted and volumetric and specific, compared with dry sliding tests With low surface roughness.
- For dry contact, the friction conditions increase as the surface roughness increases. and low status of lubrication at the same test conditions.
- The roughness parameter of Al-Si casting alloy attributes to the shape of asperities of *R*a and has the strongest influence on the wear rate.
- The wear rate increases as load and roughness aver age increase, while it correlates inversely with slid ing distance.
- The specific wear rate decreases as load increases, it correlates inversely with sliding velocity, which is attributed to thin film of material eroded between bumps of the disk surface.
- The smoothness of surface as well as sliding distance reduces the volumetric wear rate due to lacking wear resistance of material thin film.

- The friction increases as the surface roughness increases, it correlates inversely with load.
- The higher value of friction is attributed to the higher value of *R*a.

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