

Effect of Load and Sliding Speed on Wear and Friction of Aluminum– Silicon Casting Alloy

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Abstract- The effect of load and speed on sliding friction coefficient and performance tribology of aluminum–silicon casting alloy was evaluated using a pin-on-disc with three different loads (10, 20, and 30 N) at three speeds (200, 300, and 400 r/min) and relative humidity of 70%. Factors and conditions that had significant effect were identified. Experiments showed that the load and the speed affect the coefficient of friction and wear rate of the alloy. The results showed that the wear rate increased with increasing load and decreased with increasing sliding distance, whereas the friction coefficient decreased with increasing sliding speed before a stable state was reached. The friction coefficient also decreased with increasing load.

Index Terms- friction coefficient, dry sliding, speed, load

I. INTRODUCTION

Tribology is the science of friction, lubrication, and wear and deals with a diverse array of man-made and natural systems of interacting bodies in relative motions [1]; it literally means the “science of rubbing.” Wear is the most recent important implication of this science, as it is the latest among the three pillars, and has carefully been considered at the present time. Its importance could be significant, and it can be defined as the result of full interaction between surfaces in relative motion [2].

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. Further, the type and amount of lubrication and surface cleanliness also affect wear, which can cause stoppage in operation [3]. The ideal term would be for the moving solids to reduce the coefficient of friction and the shear stresses at the interface when contact between surfaces is initiated [4]. The coefficient of friction effect can be readily known but is difficult to understand, although it has been used for a long time in engineering and scientific applications, because it is dependent on the type of grain, bulk density, and roughness of the wall surface [5]. The degree of wear is the result of several common factors applied in certain cases, particularly the relationship among the rate of corrosion and load, speed, coefficient of friction, and adhesion, as well as hardness and tensile strength. The factors that affect wear have been grouped under the following headings [6, 7]. The load greatly affects the

rate of wear, which is dependent on the direction of load application, either up or down [8].

Chowdhury et al. [9] researched the effect of normal load and sliding speed of friction and wear on the property of an aluminum disk against stainless steel pin. Results showed that the value of the coefficient of friction increased with increasing sliding speed in normal for aluminum. The wear rate was also found to increase with the increase in sliding speed and normal load. Ramachandra et al. [10] found that wear increased with increase in normal load and sliding velocity. Hardness increases with continuous or intermittent increase in SiC particles and is related to friction and adhesion. Thus, the wear rate for each metal is affected by heavy load conditions and is not associated with resistance to corrosion under less severe conditions. In sliding wear, the increased load and a long and unwritten sliding distance clearly affects the rate of wear. The parameters that affect wear are loads, speed, temperature, contact type, type of environment, and so on. Kumar et al. [11] researched the wear behavior of zinc–aluminum (ZA-27). The wear increased with increase of reinforcement in load and sliding speed. The wear resistant increased with increase in garnet content, considered one of the factors affecting the oxide layer. In some cases, it also affects the loading from the highest to the lowest, or vice versa. In addition, continuity or intermittence has a direct effect on the wear in the metal and is linked to the speed and other factors, such as lubrication, and the degree of heat generated by friction and environmental conditions surrounding the process. In a few cases, the effect of speed on the rate of wear is due to the circumstances mentioned and their connection to the velocity of these factors [12]. Wear is the loss of material and is expressed in terms of volume. Fig. 1 shows some of the common wear mechanisms, such as abrasion, adhesion, and erosion, as well as surface fatigue.

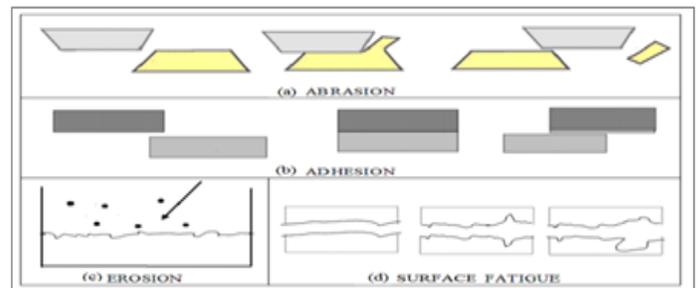


Fig. 1 Different types of wear mechanisms: (a) Abrasion, (b) Adhesion, (c) Erosion, (d) Surface fatigue

II. MATERIALS AND EXPERIMENT

Observation of surface roughness of aluminum–silicon alloy (A390) on the friction and wear of samples was made using the pin-on-disc type friction and wear tool, designed according to

ASTM specifications. The tool consists of the engine and a fixed pin. Micrographs showing before and after wear surface in Fig.2.

In addition, density, hardness, and tensile strength were studied due to their wide application in industry, particularly in pistons and cylinders. Result of the chemical analysis is given in Table 1, and testing of mechanical properties are presented in Table 2. The surface pattern was unidirectional.

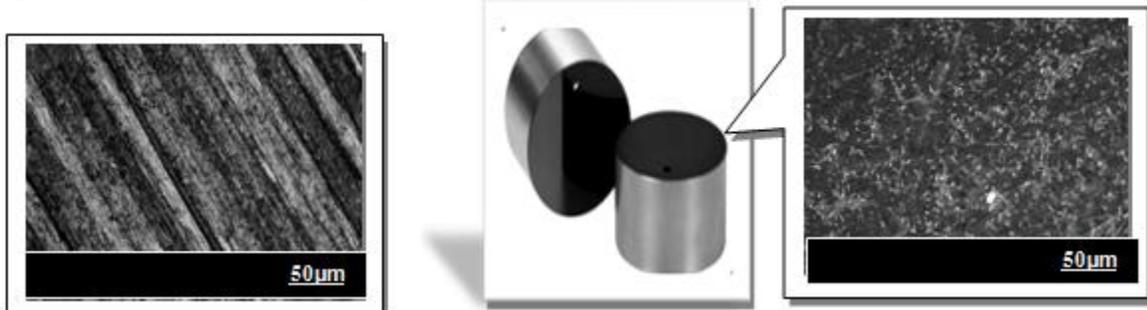


Fig. 2 Micrographs showing before and after wear surface load 10N& 400 rpm

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

| Si | Mg | Cu | Fe | Ni | Mn | Sn | Pb | Zn |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 16.69 | 1.176 | 1.304 | 1.130 | 1.224 | 0.024 | 0.012 | 0.026 | 0.012 |

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 |

To examine the microscopic structure and to know the composition of microscopic samples as shown in Fig. 3, we have used the following materials manifesting:

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

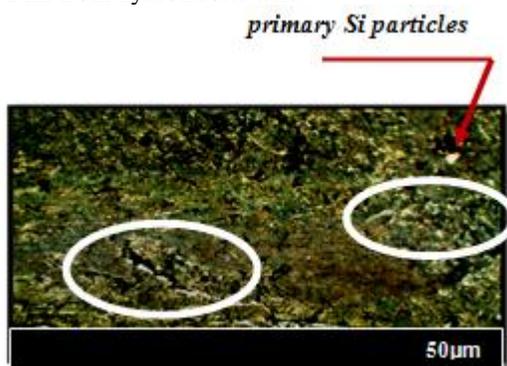


Fig. 3 Shows the process of preparing for installation of micro-alloy.

A. Wear Testing

A pin-on-disk tribological test rig was used for the investigation, as shown in Fig. 4. The upper specimen was a 10 mm-diameter Al-16Si casting alloy ($Ra = 2 \pm 0.05 \mu\text{m}$; $Hv = 112.65 \pm 12 \text{ kg/mm}^2$), and the disk was made of AISI 1045 steel ($Ra = 0.15 \pm 0.05 \mu\text{m}$; $Hv = 312 \pm 20 \text{ kg/mm}^2$). The applied loads were 10, 20, and 30 N, and the sliding speeds were 200, 300, and 400

r/min. The wear tests were run for 360 min. Before wear testing, the aluminum silicon disk sample was cleaned and dried using cotton and acetone, and the weight of the samples was measured using a digital balance. The values before and after the test were recorded, and the sliding distance was calculated. Wear rate was estimated by measuring the mass loss (ΔW) after each test. Cares have been given after each test to avoid entrapment of wear debris. It is calculated that ΔW to sliding distance ($S.D$) using:

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

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

$$W_v = \Delta W / \rho t \quad (2)$$

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 friction coefficient, (μ) of composite was calculated from

$$\mu = F_f / F_n \quad (3)$$

where F_f is the average friction force and F_n is the applied load with an assumption that the temperature is constant at 31 °C

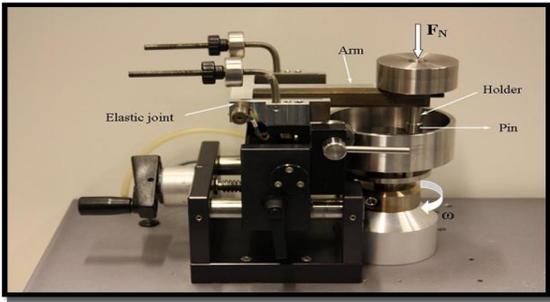


Fig.4. Pin-on-Disc wear testing machine

III. RESULT AND DISCUSSION

Fig. 5 shows the variation in wear rate with the variation of the normal load and the duration of rubbing at different sliding speeds for the aluminum–silicon casting alloy. The curve shows the result for speeds of 200, 300, and 400 r/min. All curves show similar trends. Other parameters, such as normal load (10, 20, and 30 N), surface roughness (2 μm), and relative humidity (70%) are identical for these three curves. The sliding movement occurs in very small areas at the peaks and over time. The ruptures or breaks at the peaks increase the contact area and results in rise in temperature. The increase in the load causes rise in friction. These findings are in agreement with the findings of Chowdhury and Khalil [13] for aluminum, in general for surface comprising (i) moisture, (ii) oxide of metals, and so on. Aluminum–silicon casting alloy readily oxidizes in air in the initial duration of rubbing. An increase in the load leads to increased wear and loss of the metal. The initial rubbing duration breaks the surface layers, which cleans and smoothens the surfaces and increases the strength of the connections and contact between the surfaces. The friction force due to the tillage effect between the surfaces increases the temperature between them. This effect results in adhesion and increases the deformation at the surface layers, leading to further loss of the metal. This result is consistent with the results obtained by Miroslav and Slobodan [14].

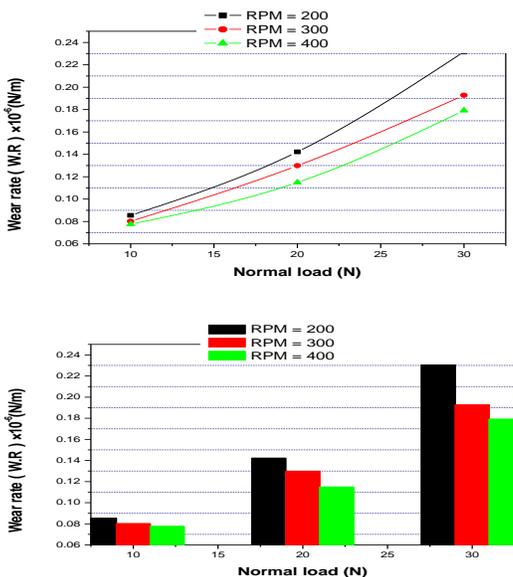


Fig. 5 Variation of wear rate with the variation of normal load (Relative humidity =70%, Sliding Speed =200,300,400 rpm).

The curve in Fig. 6 shows that the low coefficient of friction results from increasing load and sliding speed due to the change in shear rate. This event affects the mechanical properties of materials and in turn increases the destruction and wear of the surfaces, reduces the contact area, and breaks the oxide layer, thereby causing adhesion. The wear from one stage to another depends on the test conditions, and the slide speed leads to the formation of membrane protector that reduces the contact between the surfaces, consistent with the findings of Alias and Hague [15].

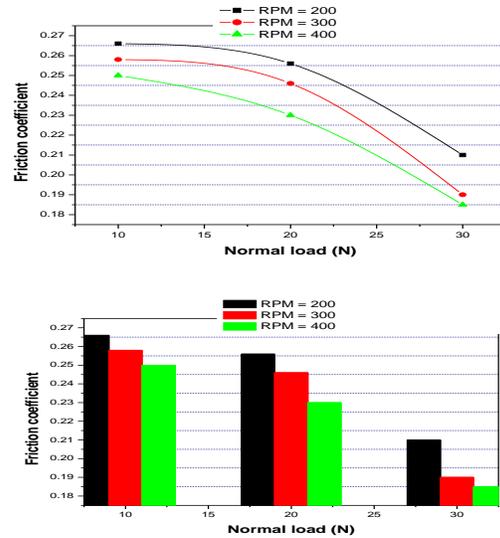


Fig. 6 Variation of friction coefficient with the variation of normal load (Relative humidity =70%, Sliding Speed = 200,300,400 rpm).

Fig. 7 shows the increase in volumetric wear with the increase in normal load within the observed range. Increased surface roughness and a large quantity of wear debris are believed to be responsible for the decrease in friction with the increase in normal load. Several experiments were conducted to investigate the effect of normal load and sliding speed on the wear rate of the aluminum–silicon casting alloy.

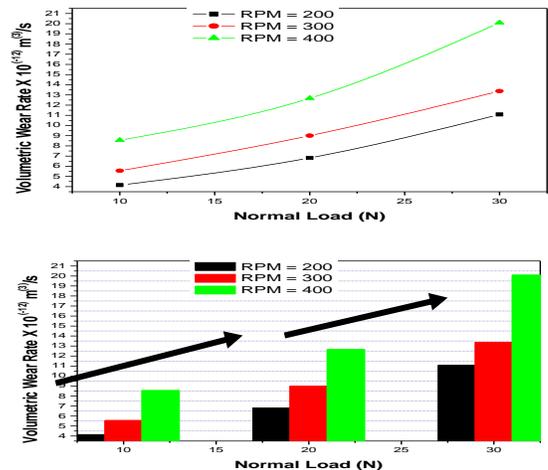


Fig. 7 Variation of wear rate with the variation of normal load (Relative humidity =70%, Sliding Speed =200,300,400 rpm).

The wear adhesion mechanism draws the high precision of tribology behavior in addition to many influencing factors. An increase in load was noted to lead to increased wear and loss of the metal. The rubbing duration results in the initial surface layers to become clean and increases the strength of connections, the friction force due to the tillage effect between the surfaces, the temperature, the adhesion, and the surface layer deformation, which lead to increase in the loss of metal. Therefore, the findings confirm that the increase in wear rate is due to heavy load and sliding speed. In addition, sliding over long distances causes hardening of the surface layer composition of the waste debris and reduces wear. The increase in volumetric wear and wear rate, as well as the roughness surface, is due to the increasing load throughout the tests. These findings are in agreement with the findings of Singla and Singh [16] that shows that plastic flow along the sliding surfaces increases the real area of contact, causing an increase in space connections and increased friction force. The increase in surface temperature leads to gradual flattening of the protrusions, resulting in steady state and higher slide speed at high temperature, which reduce the shear force, reduce the coefficient of friction, and attain low roughness. As the normal load increases, frictional heat is generated at the contact surface, hence the decrease in the strength of materials.

IV. CONCLUSION

The load and the sliding speed affect the amount of friction force. The wear rate significantly increases when the load increases. On the other hand, small coefficient of friction values, together with increase in sliding speed, loading, and sliding over long distances, reduce wear rate. Thus, maintaining appropriate sliding speed and normal load levels can reduce frictional force and wear and improve the mechanical processes.

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