INFLUENCE OF SURFACE TEXTURE ON FRICTION AND TRANSFER LAYER FORMATION IN Mg-8Al ALLOY/STEEL TRIBO-SYSTEM

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ABSTRACT
Surface texture influences friction and transfer layer formation during sliding. In the present investigation, various kinds of surface texture with varying roughness were produced on steel plates. Pins made of Mg-8Al alloy were then slid against the prepared steel plates using inclined pin-on-plate sliding tester to understand the role of surface texture of the harder surface and load on coefficient of friction and transfer layer formation under both dry and lubricated conditions. Normal loads were varied from 1 to 120 N during the tests. Scanning electron micrographs of the surfaces in contact for both the pins and plates were obtained to understand the morphology of the transfer layer. Surface roughness parameters of the steel plate were measured in the direction of the sliding on the bare surface away from the wear tracks using an optical profilometer. It was observed that the coefficient of friction and transfer layer formation are strongly dependent on surface texture and independent of surface roughness (Rₚ) of steel plate. Among the surface roughness parameters, the mean slope of the profile was found to explain the variations best. The plowing component of friction was highest for the surface that promotes plain strain conditions while it was lowest for the surface that promotes plane stress conditions near the surface.

Key Words: Friction, Surface Texture, Transfer Layer, Roughness Parameters

1. INTRODUCTION
Friction is the resistance to relative motion of two bodies that are in contact. It is described in terms of a coefficient i.e., coefficient of friction (μ), defined as the ratio of tangential force (T) to the normal force (N). The important factors that control friction are surface texture, normal load, sliding speed, environmental conditions such as temperature and lubricants and material properties [1]. Considerable work has been done to study the effect of these parameters on coefficient of friction using different experimental methods [2-10].

Among the many important factors, which affect friction, as pointed out earlier, the role of surface texture on friction is considered in the present study. A few attempts have earlier been made to study the influence of surface texture on friction especially of soft metals [11-13]. However, as the surface texture of deformable material cannot explain true friction values, it is hence important to have knowledge about the surface texture of harder material. Thus, the present study focuses on the effect of surface texture of harder materials on coefficient of friction. In the literature, considerable amount of work has also been done to study the effect of surface texture of harder material on coefficient of friction during sliding [14-17]. Lakshmipathy and Sagar [14] studied the effect of die surface topography on die work interfacial friction under lubricated conditions. They found that the friction factor, based on ring tests, were lower for a die surface that had criss–cross surface

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pattern compared to the uni-directionally ground pattern. Staph et al. [15] studied the effect of surface texture and surface roughness on scuffing using caterpillar disc tester. The authors [15] used steel discs of varying roughness and texture and concluded that both surface texture and surface roughness affect frictional behavior.

Magnesium alloys offer lightweight alternatives to conventional metallic alloys, and consequently are finding structural applications in the automotive and light truck industry. Magnesium alloys would normally not be candidates for bearings, sliding seals or gears. But there could be situations in which their surfaces could come into contact with other materials so as to make the study of their friction and wear behavior of interest. Despite the growing interest in magnesium alloys, very little data exist on their friction and wear behavior. Earlier, a few attempts were made to study the tribological properties of Mg alloys [18-21]. However, no attempts were made on Mg alloys to study the tribological performance in terms of surface texture and hence it is used in this study. Thus, in the present study, various kinds of surface textures with varying roughness were produced on the steel plate using various grits of emery papers or polishing powders. Inclined pin-onplate sliding tester was used to study the effect of surface texture of the prepared steel plates on coefficient of friction by sliding Mg-8Al alloy pins, owing to the importance in aerospace and automobile industries. In the following sections, present the experimental results along with the discussion on the nature and contribution of various components of friction are considered.

2. EXPERIMENTAL DETAILS

Materials used: Casting made of binary Mg-8 (wt. %) Al alloy was prepared in the laboratory using diecasting technique. Heat treatment of the casting was done using standard procedures to get the optimum mechanical properties. To confirm the chemical composition, the casting was analyzed using EDAX (Energy Dispersive X-Ray Analysis). The product was then machined to make pins of 10 mm long, 3 mm in diameter with a tip radius of 1.5 mm size. The pins were electro-polished to remove any work-hardened layer that might have formed during the machining. The counterpart, plate, was made of 080 M40 steel that had 28 mm x 20 mm x 10 mm (thickness) dimensions. Hardness measurements of the pins and plate were made at room temperature using a Vickers micro hardness tester with 100 gm load and 10-second dwell time. Average hardness numbers, obtained from 5 indentations, was found to be 68 and 208 for the pin and plate respectively.

Surface texture preparation: Four types of surface textures were produced on steel plates. Type I, namely, uni-directional surface texture, were produced on the plates with varying roughness by dry grinding the plates against dry emery papers of 220, 400, 600, 800 or 1000 grit sizes. For the directional surface texture, care was taken so that the grinding marks were unidirectional in nature. Type II, namely, nondirectional surface texture, was generated on steel plates with varying roughness by moving the plate on dry emery papers of 220, 400, 600, 800 or 1000 grit size along a path with the shape of an “8” for about 500 times. Type III, namely, directional surface textures, similar to Type I was produced. But, here the grinding marks direction was perpendicular to that of Type I. Type IV, namely, random texture, with varying roughness was generated under wet grinding conditions using a polishing wheel with any one of the three abrasive media such as SiC powder (220, 600 and 1000 grit), Al2O3 powder (0.017 μm), and diamond paste (1-3 μm). Figures 1 (a), (b), (c) and (d) show the 2D and 3D profiles of plate surfaces along with its 3D roughness parameter, Ra, generated by Types I, II, III, and IV respectively. In figure 1, the surface textures, namely, Type I, II and III were generated using 1000 grit emery papers while the Type IV was produced using 1000 grit SiC powder. It was observed that the range of surface roughness values measured for different textured surfaces comparable to one another even though they were prepared using different techniques.

Experiments were conducted using an inclined pin-on-plate sliding tester, details of which were presented elsewhere [22]. The usefulness of this test is that from a single experiment, the effect of load on the coefficient of friction and transfer layer formation can be studied. Before each experiment, the pins and steel plates were thoroughly cleaned first in an aqueous soap solution and then with acetone in an ultrasonic cleaner. The steel plate was fixed horizontally in the vice of the pin-on-plate sliding tester and then the vice-setup was tilted so that surface of the plate makes an angle of 1° ± 0.05° with respect to horizontal base. Then pins were slid at a sliding speed of 2 mm/s against the prepared steel plates starting from lower end to the higher end of the inclined surface for a track length of 10 mm. Normal load was varied from 0 to 120 N during the test. The advantage of 1° inclination of the steel plate was that from a single experiment, the effect of normal load (up to the test limit of 120 N) on the coefficient of friction could be studied.
After the dry tests, the pin was removed and a new pin was mounted on the vertical slide to perform lubricated tests. For the lubricated tests, a drop (i.e., 0.05 ml) of commercially available engine oil lubricant ('Shell' make 2-stroke oil) was applied on the surface of the same steel plate and the tests were performed to obtain another five parallel wear tracks on the steel plate similar to the dry tests. The viscosity of lubricant oil was found to be 40 cSt at 40°C and had the extreme pressure additive ZDDP (Zinc Dialkyl Dithiophosphate). The presence of ZDDP was confirmed using Fourier Transform Infrared spectroscopy technique. Both the dry and lubricated tests were done on the same steel plate so that the results of the dry and lubricated experiments will exclude variations during preparation of the steel plates. The dry tests were conducted first followed by the lubricated ones, to avoid any additional cleaning of the steel plates. After the tests, the profiles and surface roughness parameters of the steel plates were measured in the direction of the sliding on the bare surface away from the wear tracks using an optical profilometer. Later, the pins and steel plates were observed using a scanning electron microscope (SEM) to study the surface morphology. In the following sections micrographs of the central regions of both the pins and steel plates are presented.

3. RESULTS & DISCUSSION

Figure 2 shows a typical variation in normal and traction force with sliding distance obtained in the inclined pin-on-plate experiments under dry sliding conditions. The recording is of the Mg-8Al alloy pin slid perpendicular to the unidirectional grinding marks (Type I surface texture) on the steel plate with a surface roughness of $R_a = 0.20 \mu m$ generated using 1000 grit emery paper under dry grinding conditions. It can be seen that the normal and traction forces increase continuously with sliding distance as the pin presses on the steel plate. A maximum normal load of ~120N could be achieved at a sliding distance of 10 mm.

![Graph showing variation of normal and traction forces](Image)

Fig. 2: Variation of normal and traction forces with sliding distance for Mg-8Al pin slid on steel plate ($R_a = 0.20 \mu m$) under dry conditions.
Figure 3 shows the variation in coefficient of friction with sliding distance, calculated from data in figure 2 using equation (1). It can be seen from the figure 3 that the coefficient of friction remains more or less constant with sliding distance within the load range in which the present tests were conducted. It can be noticed that the average coefficient of friction hovers around a value of 0.3 throughout the sliding distance of 10 mm.

![Graph showing variation of coefficient of friction with sliding distance](image)

**Fig. 3:** Variation of coefficient of friction with distance for Mg-8Al pin slid on steel plate (Rₐ = 0.20 μm) under dry conditions.

Experiments were done to study the effect of surface roughness generated using different grits of emery papers on coefficient of friction. Thus, figure 4 presents the variation of coefficient of friction with sliding distance for the pins slid perpendicular to the unidirectional grinding marks (Type I surface texture) on steel plates, with varying roughness under both dry and lubricated conditions. It can be seen from the figure that the coefficient of friction remains more or less constant with sliding distance under both dry and lubricated conditions. Roughness of the surface, measured in terms of Ra, does not seem to affect the average coefficient of friction significantly. It can be observed that, for the dry experiments, the average coefficient of friction crowds around a value of 0.28. Addition of lubricant at the interface decreases the average coefficient of friction from a value of 0.28 to 0.26.

![Graph showing variation of coefficient of friction with sliding distance for different Rₐ values](image)

**Fig. 4:** Variation of coefficient of friction with sliding distance for Mg-8Al pins slid on steel plate of different roughness (Ra in μm) under dry and lubricated conditions. Sliding direction is perpendicular to the unidirectional grinding marks.

Similar experiments, as described above, were also performed on Type II, III (here the sliding direction is parallel to the uni-directional grinding marks) and IV surface textures. For the Type II and Type IV surface textures, the direction of sliding was not important. Figures 5 (a) and (b) show the variation of average coefficient of friction with Ra for various surface textures under dry and lubricated conditions, respectively. For the Type I surface texture, the coefficient of friction data were taken from figure 4. The average coefficient of friction values was calculated for a sliding distance of 10 mm. It was observed that the coefficient of friction did not vary much under both sliding distance and normal loads. It can be seen from figures 5 (a) and (b) that no particular relation exists between surface roughness and coefficient of friction. In addition, it can be seen that for a given kind of texture, the coefficient of friction did not vary much with surface roughness. The roughness values presented here is the 2D surface roughness, Rₐ, values obtained by measuring along the sliding direction of the pin. It can be seen that the surface roughness (Rₐ) values for different textured surfaces are comparable with each other although they were ground against different grinding media. Previous results [2-4] have shown that coefficient of friction primarily depends on the surface texture. Thus, for example, even though surface textures and hence the 3D surface roughness parameters of Type I and Type III surfaces were the same, the coefficient of friction values were different and it was dependent on the direction of sliding. For this reason, 2D roughness parameters, along the sliding direction of the pin, were considered in this study.
Fig. 5: Variation of average coefficient of friction with surface roughness (Ra) for various surface textures under (a) dry and (b) lubricated conditions.

Now attempts to present the coefficient of friction values in terms of surface textures will be made. Thus, figure 6 shows the range about which the coefficient of friction values and the surface roughness values show a fall for each of the surfaces under both the dry and lubricated conditions. It can be seen that the range of surface roughness varies between 0.01 and 0.28 μm for different textured surfaces. From figure 6, it can be noticed that the coefficient of friction considerably depends on surface texture under both dry and lubricated conditions. In addition, it can be observed that the coefficient of friction is relatively high for the Type I surface texture, followed by Type II, Type III, and Type IV under both dry and lubricated conditions.

It can be seen from figure 6 that the coefficient of friction significantly depends on surface texture. Thus, it is important to characterize the surface texture by means of surface roughness parameters. Many roughness parameters were investigated and these are available in the literature [23]. It is possible that two surface textures can have the same $R_a$, but their frictional characteristics could be different [2-4]. This fact can also be observed in figure 5 (a) and (b) where for a given $R_a$, the coefficient of friction varies considerably. Hence, it is important to study other roughness parameters of surface texture and to correlate with coefficient of friction. The roughness parameter changes during surface preparation, owing to texture and hence affects the coefficient of friction. Thus, efforts were made to correlate surface roughness parameters with coefficient of friction. For doing this, twenty-five surface roughness parameters were taken for consideration. The description of these roughness parameters are covered in Table 1. Figures 7 (a) and (b) show the results of the correlation analysis between surface roughness parameters and coefficient of friction under both dry and lubricated conditions, respectively. From the many ways of calculating fractal dimensions [24] such as (a) the power spectrum (b) the cover (c) the variation and (d) the rectangular cell counting, the variance method was chosen in the present study. Since, it was suggested that the variation method was substantially more accurate than the other methods as described briefly by Hasegawa et al. [25]. As anticipated, the correlation coefficient values varied over a wide range, from 0.03 to as high as 0.66, in absolute values, depending on the surface roughness parameter. The maximum correlation coefficient between coefficient of friction and surface roughness parameters was calculated to be 0.66 for dry conditions and 0.65 for lubricated conditions. These values were obtained for the correlation coefficient between the coefficient of friction and the mean slope of the profile 'Del a' [23].

Fig. 6: Variation of average coefficient of friction and surface roughness ($R_a$) with surface texture.
Now, coming to the scanning electron micrographic observation, figures 8 (a), (b), (c) and (d) show backscattered micrographs of the steel plate surfaces tested under dry conditions for the Type I with $R_g = 0.20 \mu m$, Type II with $R_g = 0.21 \mu m$, Type III with $R_g = 0.11 \mu m$, and Type IV with $R_g = 0.30 \mu m$ respectively. It can be observed that a certain amount of discontinuous transfer layer of Mg-Si alloy form on the steel plate under dry conditions. In addition, it was observed that the amount of transferred layer did not vary much with increasing normal load. At lower magnifications, it was observed that the amount of transfer layer formed on a steel plate surface was highest for the Type I surface texture, followed by Type II, Type III, and Type IV surface texture. Figures 8 (e), (f), (g) and (h) show the corresponding backscattered scanning electron micrographs of the steel plate surfaces under lubricated conditions. It was observed that the amount of transferred layer formed on the steel plates decreased with the application of lubricant. In addition, under conditions of lubrication, it was again observed that the amount of transfer layer formed on steel plate surface was much higher for the Type I followed by Type II, Type III and Type IV surface textures. It was also seen that for a given surface texture both under dry and lubricated conditions, the amount of the transferred layer formed on the steel plate did not vary much with the surface roughness.

<table>
<thead>
<tr>
<th>Roughness Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>$R_g$ ($\mu m$)</td>
<td>Root Mean Square (RMS) Roughness</td>
</tr>
<tr>
<td>$R_a$ ($\mu m$)</td>
<td>Average Roughness</td>
</tr>
<tr>
<td>$R_h$ ($\mu m$)</td>
<td>Maximum Height of the Profile</td>
</tr>
<tr>
<td>$R_p$ ($\mu m$)</td>
<td>Maximum Profile Peak Height</td>
</tr>
<tr>
<td>$R_v$ ($\mu m$)</td>
<td>Maximum Profile Valley Depth</td>
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<tr>
<td>$Rsk$</td>
<td>Skewness</td>
</tr>
<tr>
<td>$Rku$</td>
<td>Kurtosis</td>
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<tr>
<td>$R_z$ ($\mu m$)</td>
<td>Average Maximum Height of the Profile</td>
</tr>
<tr>
<td>$R_{max}$ ($\mu m$)</td>
<td>Maximum Roughness Depth</td>
</tr>
<tr>
<td>$R_{pm}$ ($\mu m$)</td>
<td>Average Maximum Profile Peak Height</td>
</tr>
<tr>
<td>$R_{vm}$ ($\mu m$)</td>
<td>Average Maximum Profile Valley Depth</td>
</tr>
<tr>
<td>Del a (mrad)</td>
<td>Average Slope of the Profile</td>
</tr>
<tr>
<td>Lam a ($\mu m$)</td>
<td>Average Wavelength of the Profile</td>
</tr>
<tr>
<td>Del q (mrad)</td>
<td>RMS Slope of the profile</td>
</tr>
<tr>
<td>Lam q ($\mu m$)</td>
<td>RMS Wavelength of the profile</td>
</tr>
<tr>
<td>Htp ($\mu m$)</td>
<td>Profile Section Height Difference</td>
</tr>
<tr>
<td>Rk ($\mu m$)</td>
<td>Core Roughness Depth</td>
</tr>
<tr>
<td>Rpk ($\mu m$)</td>
<td>Reduced Peak Height</td>
</tr>
<tr>
<td>Rvk ($\mu m$)</td>
<td>Reduced Valley Depth</td>
</tr>
<tr>
<td>Mr1 (%)</td>
<td>Peak Material Component</td>
</tr>
<tr>
<td>Mr2 (%)</td>
<td>Valley Material Component</td>
</tr>
<tr>
<td>$S$ ($\mu m$)</td>
<td>Mean Spacing of Local Peaks of the Profile</td>
</tr>
<tr>
<td>Sm ($\mu m$)</td>
<td>Surface Material Volume</td>
</tr>
<tr>
<td>Pc (/mm)</td>
<td>Peak Count</td>
</tr>
<tr>
<td>FD</td>
<td>Fractal Dimension</td>
</tr>
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Table 1: Description of surface roughness parameters.

Scanning electron micrograph of the pins (which developed the features on the flat counterface shown earlier in figure 8), revealed strong surface shearing and plowing marks on their surfaces under dry conditions. Under lubricated conditions, it was observed that the intensity of surface shearing was reduced in comparison with that occurring under dry conditions.

The coefficient of friction is controlled by two different friction components (a) an adhesive force acting at real area of contact and (b) a deformation force acting during the plowing of harder tool surface asperities in the softer metal surface. Consequently, the coefficient of friction can be written as follows:

$$\mu = \mu_a + \mu_p$$

where the first term, $\mu_a$, is the adhesive component, which is material related and the second one, $\mu_p$, is the deformation or plowing component, which is related to the surface texture of the tribo-surfaces in contact.

Fig. 7: Correlation coefficient between coefficient of friction and roughness parameters under (a) dry and (b) lubricated conditions. White and black bars represent positive and negative correlations, respectively.
In the present experimental conditions, the steel plate surface is harder than the Mg-8Al pin surface, and hence, any surface irregularities of the former surface may result in plowing in the latter, thus increasing the friction force. The importance of the adhesion between two solids in sliding contact has been emphasized by Bowden and Tabor [26]. The adhesive friction component is also dependent on the chemistry of the tribo-surfaces at the sliding interface.

The contribution of the adhesion component can be reduced by introducing a lubricant at the interface. This is practically significant in the case of a lubricant with an "extreme pressure additive" in it. The lubricant used in the present case is a commercially available engine oil which has an extreme pressure additive such as ZDDP.

The magnitude of friction between two surfaces considerably changes with lubrication regime as explained by the Striebeck curve [27]. To gain insight into the physical nature of friction between the pin and plate, it is important to establish the lubrication regime for which experiments were conducted. This can be accomplished utilizing the minimum film thickness equations developed by Hamrock and Dowson [28]. The method and details of calculating both minimum film thickness and lubrication regime were explained in earlier paper [29]. Based on such an approach, it was confirmed, that the present experiments were conducted under boundary lubrication regime. Thus, it can be assumed that the coefficient of friction recorded for the lubricated experiments (figure 6) indicates sliding in the boundary lubrication regime and basically represents plowing friction.

In the present investigation, considering the suggestion of Bowden and Tabor [26], the results were explained based on different components of friction. Figure 9 presents the variation of different components of coefficient of friction in terms of test conditions i.e. dry conditions representing both adhesion and plowing components, lubricated conditions representing only plowing component. Adhesion component of friction was obtained by subtracting friction values at lubricated conditions from that at dry conditions. The average coefficient of friction data were taken from figure 6. From the figure 9, it can be observed that the plowing component of friction is highest for Type I surface texture and reduces for Type II, Type III, and Type IV surface textures. Figure 9 also clearly exhibits that the dependency of adhesion component of friction on surface texture is minimum while plowing component of friction varies considerably with surface texture. Thus, from figure 9, it can be seen that the contribution of plowing component to the total coefficient of friction was predominant. From this it can be inferred that the effect of surface texture on coefficient of friction was influenced by the variation of plowing component.

Fig. 8: Backscattered SEM of steel plates for various surface textures after sliding tests under dry (a, b, c, d) and lubricated conditions (e, f, g, h) with (a, e) surface roughness of \( R_s = 0.20 \) \( \mu m \) (Type I), (b, f) \( R_s = 0.21 \) \( \mu m \) (Type II), (c, g) \( R_s = 0.11 \) \( \mu m \) (Type III), and (d, h) \( R_s = 0.30 \) \( \mu m \) (Type IV). The arrows indicate the sliding direction of the pin relative to the plate.

Fig. 9: Variation in the average coefficient of friction with the texture of surfaces.
When a surface is ground uni-directionally (Type I surface texture), it will have a "wave" like texture (figure 1(a)) and if randomly polished (Type IV surface texture) a "hill-and-valley" texture (figure 1(d)). When a soft material like Mg-8Al pin is pressed and slid on a harder material (steel plate) with a particular texture, the softer pin material will deform and flow along the contours of the asperities. In the experiments, where the pins were slid perpendicularly to the uni-directional grinding marks (Type I surface texture), the softer material needs to flow over the asperities. This induces a higher level of stresses under more pronounced plane strain condition, leading to severe shear failure and higher material transfer. As higher shear stresses are to be expected for Type I surface texture, the plowing component of friction would be large. In the case of pins slid parallel to the un-directional grinding marks (Type III surface texture) the softer material need not flow over the asperities, and instead it flows along the valleys of the steel plate, which requires less energy for the deformation. Thus, the level of stresses and the plowing component generated in Type III surfaces were lower than those in the Type I surface textures. For the case of Type II surface texture, softer pin meets the asperities of the steel plate that are aligned in many orientations, thus one can expect generation of moderate shear stresses, and corresponding reduction in the plowing component of friction. For the Type IV surface texture, the softer material can flow around the asperities and the number of asperities opposing the direction of sliding is lower and causes lower stresses and a stress state that is more plane stress near the surface. This will lead to a much lower shear stresses and lower material transfer. Similar observations were made in publications of Kailas and Menezes [3], and Faulkner and Amell [30] using finite element technique when aluminium slides over hard cylindrical and spherical asperity. They reported [3, 30], that the shear forces and hence, the coefficient of friction was more for aluminium sliding over cylindrical asperity than spherical asperity. As high coefficient of friction results in larger constraint to flow due to higher interfacial friction at the interface, the shear stress in the pin material is expected to increase which situation means the stresses generated for the dry experiments are expected to be higher ahead of the asperities. This would lead to collection of transfer layer ahead of the asperities. Thus, the plowing component of the coefficient of friction under lubricated conditions would be higher for Type I surface texture, and lower for Type IV surface texture. For the Type II and Type III surface texture, the plowing component would hence, be expected to fall in between the Type I and Type IV surface texture in the present model. The result shown in figure 9, based on experiments, confirms this analysis.

The results obtained thus far, provide a basis for controlling the coefficient of friction across various locations along the interface between die and sheet metal in metal forming process. These results may be employed to obtain a particular die surface finish in a particular area of the die so as to obtain the desired coefficient of friction. The coefficient of friction maybe controlled in the following ways: Type I surface texture maybe machined on the die surface to obtain a high coefficient of friction. Type IV surface texture maybe generated when a low coefficient of friction is required.

The usefulness of this approach lies in the fact that during simulation, a variable value of coefficient of friction, depending on the surface finish, maybe assigned. At present the coefficient of friction given is either constant or, at best, different in different location of the die. [31-34] the value of which is based either on experience or standard experimental data.

4. CONCLUSIONS

In the present study an inclined pin-on-plate sliding tester was used to study the effect of surface texture on coefficient of friction, and the transfer layer formation while sliding Mg-8Al alloy pin on 080 M40 steel plate.

The conclusions based on the experimental results are as follows

- The normal load up to the test limit of 120N does not have major effect on the coefficient of friction. The coefficient of friction is broadly constant within the present test range of load.
- The coefficient of friction predominantly depends on surface texture of harder counter surface.
- The plowing component of friction and thus the coefficient of friction varies with surface texture whereas adhesive component of friction was independent of surface texture.
- The coefficient of friction does not vary much with surface roughness (as given by $R_s$) in the present test range and instead found to depend predominantly on surface texture.
- Under lubricated conditions, the coefficient of friction is highest for the Type I surface texture and is lowest for the Type IV surface texture. For the Type II and Type III surface textures, the coefficient of friction falls in between the above two extremes.
- The transfer layer depends on coefficient of friction which in-turn depends on the texture of surfaces.
- Among the surface roughness parameters, which influence the plowing component, the average or the mean slope of the profile, i.e., 'Del a', was found to explain the variations best.
- The stress state near the surface is an important factor in determining coefficient of friction and transfer layer formation.
5. REFERENCES


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