STUDIES ON FRICTION AND TRANSFER LAYER USING INCLINED EN8 FLAT AND SUPER PURE ALUMINIUM PIN

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ABSTRACT

Friction influences the nature of transfer layer formed at the interface between tool and metal during sliding. In the present investigation, basic studies were conducted using "Inclined Scratch Test" to understand the mechanism of transfer layer formation during sliding of super pure aluminium pins on EN8 steel flats of different surface roughness under both dry and lubricated conditions. The coefficient of friction, which has two components – the adhesion component and the plowing component, is controlled by the "nature of surface". It is seen that on surfaces that promotes plan strain conditions near the surface the transfer of material takes place due to the plowing action of the asperities. But, on a surface that promotes plane stress conditions the transfer layer is more due to the adhesion component of friction. It is seen that the adhesion component increases for surfaces that are random in nature but is constant for the other surfaces. The plowing component of friction is highest for the surface that promotes plane strain conditions near the surface.

INTRODUCTION

Friction plays an important role during sliding and it depends on local contact conditions, such as surface roughness, contact stress, lubrication, and relative speed of the contacting surfaces [1-2]. The understanding of friction is crucial in metal forming operations and is also an important input in simulations [3-7]. Inclined scratch tests have been used to understand the effect of normal load on the failure point of lubricants [8]. The advantage of this test is that the failure load could be obtained from a single experiment. In the present studies inclined scratch is used to study the effect of normal load on the friction force and transfer layer formation during the sliding aluminium alloy pin over EN8 flats. The effect of the surface morphology and lubrication of the EN8 flats on the coefficient of friction and transfer layer formation is studied and the results of these studies are presented in this paper.

EXPERIMENTAL DETAILS

Experiments were conducted using an inclined scratch-testing machine. Super pure Al (99.997% Al) was used as pin and EN8 steel flats were used as counter part. The pins were first machined, and then were electro-polished to remove any work-hardened layer that might have formed during machining. The EN8 steel flat was ground against emery papers of grit size 220, 400, 600, 800 and 1000 to generate 3 kinds of surfaces with varying roughness. For the first surface, care was taken so that the grinding marks were more or less unidirectional in nature. 8-ground surfaces were generated by moving the EN8 steel flat on the emery papers in path having profile of "8" for about 500 times. Third kind of surfaces with random grinding marks were generated using a polishing wheel with abrasive medium as SiC powder (600 and 1000 grit), Al_2O_3 powder (0.017 microns), and diamond paste (1-3 microns). Before every experiment, the pins and EN8 steel flats were thoroughly cleaned in a soap solution and then in an ultrasonic cleaner with acetone. The angle of the EN8 steel flat was kept within $0.3^o \pm 0.05^o$. Then pins were scratched at a sliding speed of 2 mm/sec against the prepared EN8 steel flats so that a scratch length of 10 mm could be obtained.

The pins were slid at parallel and perpendicular to the uni-directional grinding marks on EN8 steel flat. For the 8-ground and randomly ground surface, the direction of sliding was not important. The experiments were conducted under both dry and lubricated conditions (using commercially available engine lubricant). The profiles and roughness parameters of the EN8 steel flat were measured with a standard contact-type profilometer in the direction of the sliding on the bare surface away from the scratches. Later, the pins and EN8 flats were observed using a scanning electron microscope (SEM) to study the surface morphology.

RESULTS & DISCUSSION

Figure 1 shows the variation of coefficient of friction, surface roughness (R_a), and fractal dimension with nature of surfaces for super pure Al pins slid on EN8 flats with varying roughness under both dry and lubricated conditions. Here U-PD and U-PL represents scratch direction perpendicular and parallel to the uni-directional grinding marks respectively. The bar indicates the maximum and minimum values of coefficient of friction, surface roughness, and fractal dimensions where as the connecting line indicates the average coefficient of friction. Here it was observed that the coefficient of friction varies considerably with nature of surfaces under both dry and lubricated conditions. It was observed that, for a given kind of surface, the coefficient of friction remains more or less constant with sliding distance (or increasing normal load). In addition, the roughness of the surface does not seem to affect the coefficient of friction drastically.

Scanning Electron Microscopy showed that the amount of transferred layer formed on the surface depends on coefficient of friction. The amount of transferred layer formed on the EN8 steel flat was comparatively higher under dry conditions than that of under lubricated conditions. Under both dry and lubricated conditions, damage to the pin surface was severe when aluminium pin slid parallel to the uni-directional grinding marks on EN8 steel. In addition, damage to the pin surface was severe under dry conditions than under lubricated conditions.

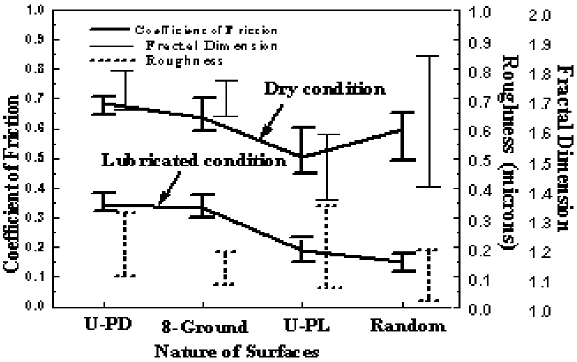

Figure 1: Variation of friction with nature of surfaces

The adhesion component of friction can be minimized if not eliminated, by the addition of a lubricant between the contacting surfaces. This would be true in case of a lubricant with "extreme pressure additive" added to it. The lubricant used in the present case is commercially available engine oil that is expected to have an extreme pressure additive such as ZDDP. Further, the speed of the present set of experiments, which is 2mm/sec, would ensure that hydrodynamic lubrication is absent. Thus one can say that the coefficient of friction recorded for the lubricated experiments would be in the boundary lubrication region and is basically the plowing component of friction. It can be seen that the plowing component of friction is highest for the scratch made perpendicular to the uni-directionally ground flats and reduces monotonically for the 8 ground, uni-directional parallel scratches and the randomly ground EN8 surface. The figure also clearly shows that the adhesion component of friction, which is the difference between the coefficient of friction for the dry experiments and the lubricated experiments, to be highest for the randomly ground specimens.

The higher coefficient of friction for the uni-directionally ground EN8 steel flat with scratch direction perpendicular to unidirectional grinding marks is attributed to the constrained nature of flow of the soft material. This constrained flow of the soft material induces a higher degree of plane strain conditions near the surface, which promotes shear failure of the pin. This also increases the amount of transferred layer on the EN8 steel flat. For the uni-directionally ground EN8 steel flats with scratch direction parallel to unidirectional grinding marks, the coefficient of friction is lower as the flow is unconstrained. This unconstrained flow of the soft material induces a plane stress conditions near the surface. This reduces the shear failure of the pin and thus the amount of transferred material. For the 8-ground EN8 steel flats the coefficient of friction is lower than uni-directionally ground EN8 steel flats with scratch direction perpendicular to unidirectional grinding marks, and higher than uni-directionally ground EN8 steel flats with scratch direction parallel to unidirectional grinding marks as the flow is not fully constrained because on the orientation of harder asperities. For the randomly polished EN8 steel flat the coefficient of friction is lower as the flow is unconstrained. This promotes a stress condition closer to plane stress near the surface. This reduces the shear failure of the pin and thus the amount of transferred material.

CONCLUSIONS

The conclusions based on the experimental results are as follows:

- The normal load does not have any effect on the coefficient of friction.
- The plowing component of friction and adhesion component of friction varies with nature of surfaces.
- The high coefficient of friction during sliding with scratch direction perpendicular to unidirectional grinding marks is due to the larger plowing component of friction.
- The coefficient of friction is found to be independent of surface roughness (as given by R_a) in the present test range and depends predominately on the nature of surfaces.
- Lubrication reduces the adhesion component of friction, but not the amount of material transferred on the EN8 steel flats, since the amount of transfer layer is dictated primarily by the plowing component of friction.

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