

Friction curve analysis of steel lubricated with jatropha oil

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ABSTRACT – Sliding friction has played a role in many mechanical components such as engines, clutch & brakes, bearings etc. Metal-to-metal contact in sliding motion could results in friction and wear to the metal surfaces. In order to avoid high friction, lubricants are commonly applied to the contacting surface. Although still need to be explored, explanation related to friction process via friction curve is seems to be forgotten. Analysis on the friction curve over the sliding time or sliding distance is important to understand any events during sliding friction. This work is subjected to analyze friction curve of steel lubricated with jatropha oil obtained from four ball-test and propose a sliding friction mechanism under this condition. The friction curve was obtained by four ball testing method under ASTM 4172 method. It is concluded that several friction transition taken place during the sliding friction can be related to the process occurs between the contact asperities.

1. INTRODUCTION

Sliding friction has played a role in many mechanical components such as engines, clutch & brakes, bearings etc. In some application high friction is required and in other application is try to be avoided. Metal-to-metal contact in sliding motion could results in friction and wear to the metal surfaces. In order to avoid high friction, lubricants are commonly applied to the contacting surface. However, there is a condition where the average oil film thickness is about in the same thickness or less than the composite surface roughness thus the contacted surface asperities come into direct contact with each other under relative motion. This condition known as boundary lubrication regime. Therefore, wear and surface damage typically occurs under boundary lubrication. Jatropha oil found to possess good boundary lubrication properties [1], therefore it is considered could

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to a friction curve transitions is affected not only by the materials involved but also by the applied load and other tribosystem characteristics [2]. Therefore, this study is subjected to analyse friction curve of steel lubricated with jatropha oil obtained from four ball-test so sliding friction process under this condition can be understood.

2. METHODOLOGY

Four AISI E-52100 steel balls with half inch of diameter and 62 ± 2 HRC of hardness were used as solid sample. Jatropha oil obtained from local market was used as lubricants.

Friction and wear preventive characteristics of the lube samples were characterized by four ball method using Ducom TR-701-M6 Multi Specimen Tester unit following ASTM D-4172 standard method. The test was carried out for 60 minutes under 40 kgf of loading. The temperature of oil sample was maintained at $75 \pm 3^\circ\text{C}$ and the sliding speed was 1200 rpm. A linear vertical displacement transducer was located between the top and bottom balls to record vertical displacement of both top and bottom steel ball samples. An optical microscope also used to evaluate wear features formed on the sliding surfaces.

3. RESULTS AND DISCUSSION

Friction characteristic of the steel bearing in the presence of jatropha oil as function of sliding time is shown in Figure 1. This figure also shows linear vertical displacement which represent linear wear during the sliding and possible events that were taken place during the sliding.

It is observed that friction of steel in the presence of jatropha oil show a slow increase of friction at the beginning of sliding to its maximum value then after reached the maximum value, the friction slowly decreased.

The behavior of friction show an increases and directly followed by a decreases at the beginning of sliding motion is known as “break-in” period, this behavior is typically followed by a steady friction [3]. This event was taken place for about 15 minute. At this

period, the friction raises were possibly caused by plastic deformation of the surface asperities as the result of loading and sliding. In four-ball testing, the contact is typically categorized as point contact. However the contact action is actually take place on a real area of contact and the load were actually withstand at several tips of asperities. The lubricant layer functioned as connection media which adsorbed to the bearing surface and carried out some part of the load in this situation. When the load was applied and high enough to squeeze the lubricant film, some tip of asperities typically experienced cold weld before the sliding started. The cold weld junction then broken due to shearing action (friction force) whenever the sliding motion started and provides adhesive component of the friction. This event also sequentially and frequently accompanied by engagement and collision of several other tips of asperities, which produce localized elastic and plastic deformation. The dissipation of energy due to these actions typically generate friction and heat [3]. In this event, the point contact has become area contact or it can be said that in microscale diameter of the real contact area were increased due to the cyclic process of friction and wear. Adhesive component from the cold weld action could adhere to other site on the surface and also could chemically react with the oil component to form a new layer so called “tribo-layer” [4,5]. The tribo-layer is a typical thin film that formed due to reaction between the metal surfaces to its surroundings caused by friction. Some deformed asperities may also plow across the surface of the mating surface resulting plastic deformation or elastic hysteresis which contributes to the rise of friction or it also could trapped between the sliding surfaces, abraded both of the mating surface thus give rise in the friction and wear as well. The loosen particle also capable to adhere and scratch other site of the surface and or its counterpart surface with continuation of sliding. The presence of the single hard debris could raise friction, as well as wear, by abrasion mechanism and the adhesion of the particles could increase the friction force by sticking action.

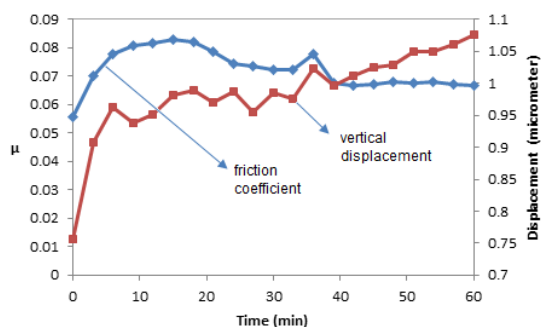


Figure 1 Friction characteristics and vertical displacement of steel in the presence of jatropha oil as function of time obtained by four ball testing.

Figure 2 shows wear scar images obtained by optical microscope. It can be seen scratch marks accompanied by smeared layer observed on the worn surface. This even also observed from the vertical displacement, where around 0.75 μm of the compound thickness already lost at the beginning of sliding and the

fluctuation on the displacement graph is considered related to formation and termination of the tribo-layer. After this event, the steady friction was took places from minutes of 40 to the end of sliding period. The steady friction state was achieved because of tribo-layer was already well maintained and strong enough to withstand the shear from sliding action.

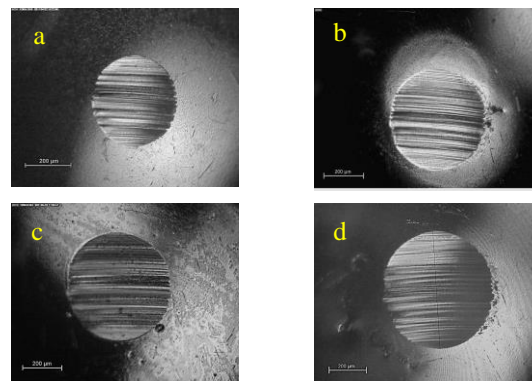


Figure 2 Wear scar feature of worn out bearing in the presence of jatropha at various sliding time; a. 15 minutes, b. 30 minutes, c. 45 minutes, and d. 60 minutes (F: 40 kgf, ω : 1200 rpm, T: 75°C, 100 \times mag.)

4. CONCLUSION

It is concluded that several friction transition taken place during the sliding friction can be related to process between contact asperities. Where the process is affected by formation tribo layer, deformation of contact asperities, and capability of the lubricant to flush out wear debris from contact area.

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