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Y, Aiman.
School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia

S, Syahrullail.
School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia

H, Hafishah.
School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia

Musa, M.N
School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia

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Friction Characteristic Study on Flat Surface Embedded With Micro Pit

Aiman. Y[1, *], Syahrullail. S[1], Hafishah. H[1], M.N Musa[1]
[1]School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

E-mail: wmaiman91@gmail.com, syahruls@mail.fkm.utm.my

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Abstract: Mechanical systems are always deal with wear and friction as the liability. The basic principle of the mechanical system is the surface interaction between surfaces which have a frictional force resulting in fatigue and damage to the mechanical components. Lubricant is used to minimize friction in order to solve the problem. A comparative friction characteristic analysis was then conducted to assess the coefficient of friction (COF) between Aluminum Alloy 5083 block and SKD 11 disk using two types of lubricant, that is SAE40 engine oil and RBD palm oil. The thickness of the oil film could be predicted in order to observe the influence of the different lubricants used. Pit pattern surface is required to research the function of the pit as a lubricant reservoir. The experiment was carried out in the laboratory according to the ASTM G99. Load is applied to experiments with loads of 1 kg, 5 kg and 10 kg, in order to find a COF correlation under different application condition. The rotational speed is held constant at 3m/s during the experiment. The results obtained revealed that when using RBD palm oil as a lubricant, the COF between block and disk is lower than when using SAE40 engine oil as a lubricant. The experimental result showed that RBD palm oil can minimize friction much lower than SAE40 engine oil. Based on the results of the comparison analysis on the flat surface and pit pattern surface, the finding revealed that the pit pattern may serve as a lubricant reservoir to retain and store the lubricant for longer than the flat surface that helps to reduce friction.

Keywords: Friction; palm olein. Pin on disk; tribology; fluid film

1. Introduction

Wear and friction are rivals of the mechanical system since they are capable of degrading the efficiency of the machine and the process. It can be difficult to avoid wear and friction, but it can be reduced by using a lubricant. Previous research was conducted on a factor of investigation that could exploit wear and friction such as, load [1)], speed [2)], lubricant [3)], temperature [4)], surface roughness [5)] and material [6)], that influences the production of wear and friction. However, this research focuses on the load, speed and lubricant that could aid in the study of friction characteristics.

Pin on disk is one of the tribotester machine that been widely used in order to study the tribology performance of lubricant sample. For the pin-on-disk wear test, two specimens are needed, which are a pin with a radius tip and a flat circular disk, which will have a circular sliding path as shown in Figure 1. The specimen pin is pressed against the disk at the required load and speed [7)]. Lubricant is applied to the disk at the initial stage of the experiment for the purpose of minimizing wear and friction. Most of the disk is designed to be groove, where the lubricant is been trapped on the disk surface to increase the efficiency of the test. Wear and friction data measurements could be collected and reported using a Linear Voltage Differential Transformer (LVDT) sensor.

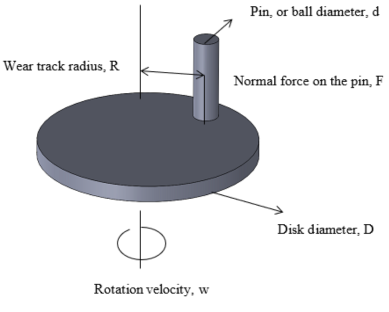

Figure. 1: Schematic of pin on disk wear test system

The stability of the coefficient of friction of palm olein has shown that palm olein has the ability to stabilize and reduce the coefficient of friction by creating a lubricating film that can be quickly sheared. This was demonstrated by M.I.Izhan [8)], which analyzed palm oil, hydraulic oil and paraffin mineral oil, and the results found that palm oil had the lowest friction coefficient, followed by hydraulic oil and paraffin mineral oil. Palm oil also produced lower wear on the surface of the pin at both low and high speeds. Palm olein also has the potential to minimize wear due to a higher proportion of long chain saturated fatty acids, resulting in lower cold flow behavior.

N.Sapawee 9) supported the findings obtained from A.K. Mohamed Rafiq 10) and M. I.Izhan 8) when tested on palm olein, hydraulic olein and paraffin mineral oil and found that palm olein has improved anti-friction properties compare to other lubricants. However, palm olein has shown the highest wear compared to other lubricants due to the high temperature produced at the interface, which also influences the wear dominated by the pin. Besides that, H.H Masjuki 5) also has shown that palm oil has better wear efficiency relative to the coefficient of friction. This is due to the concept of palm oil contains fatty acids that typically have thicker molecular layers. In general, this properties has gain an benefit as this thick layer may reduce the rate of wear.

Palm olein is use as to promoting the use of bio lubricant to replace commercial mineral oil 11, 22). Besides that, from the previous study, palm olein also has the potential to be use as a commercial lubricant. Due to that, this research paper is aimed to the coefficient of friction between the sliding body of an AA5083 Aluminium alloy block 30 × 10 mm and SKD 11 disk at different loads applied, to predict film thickness based on worn surface and to observe effect of friction on flat and pit pattern surfaces.

2. Methodology

2.1 Materials and Lubricants

There are two categories of surfaces used in this analysis that are flat surface and pit pattern surfaces as shown in Figure 2. Flat surface is a surface that was originally used from a specimen without any adjustment made on the surface, while for the pit pattern surface, pit markings were made on the flat surface to allow the lubrication to be maintained throughout the experiment. Materials used are block surface for stationary flat surface and disk for rotating disk. Flat surface material is a 5083 aluminum alloy and the disk used is an SKD11 material. Table 1 shows the lubricant sample and its physicochemical properties.

Table 1: Lubricant kinematic viscosity and density

Sample	Kinematic Viscosity (mm^2/s) @40℃	Density
Palm olein	35.36	0.91
SAE40 Engine oil	128.8	0.8971

2.2 Experimental parameters and procedures

Tribology tester machines are used according to ASTM-G99 for this research. Table 2 shows the controlled variable test parameter for this analysis. In order to study the performance of the sample lubricant, 3 low variable load is been used (10N, 50N and 100N) as to observe of the sample surface under different application.

Table 2. Experimental parameters

Surface	Lubricant	Load (N)
Plain surface	SAE40 (Engine oil)	10
		50
		100
	Palm Oil	10
		50
		100
Pit pattern surface	SAE40 (Engine oil)	10
		50
		100
	Palm Oil	10
		50
		100

Pin on disk machine is a laboratory device used to measure friction and wear properties. The pin on the disk tester consists of a spinning disk of the materials to be measured against a stationary pin. Figure 3 shows the schematic diagram for the pin on disc machine. The two surfaces of the specimen, which are flat surfaces and pit pattern surfaces, which have been produced using a marking machine in the hope that it can serve as a lubricant reservoir, are used. Measure the specimen (both the plain and pit pattern surface) weight prior to the experiment. The machine is continuously set for a period of 60 minutes at a speed of 919 rpm = 3 m/s (constant variable).

Figure. 2: Specimen used for the study.

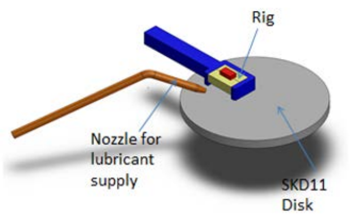

Figure. 3: Schematic diagram of pin on disk mechanism system.

3. Result and Discussion

3.1 Coefficient of Friction (COF) Analysis

As illustrated in Figure 4, SAE40 engine oil as lubricant showed decreasing trend of COF between specimen and disk over increasing load, while the RBD palm olein as luncricant showing the opposite trend. For flat surface, results showed that COF when using RBD palm olein is 63% lower than the SAE40 engine oil for 1 kg load. The percentage difference is getting decrease as the load increase, as 5 kg load has recorded about 49% and 10 kg load is about 26% of COF when using RBD palm olein is lower than using the SAE40 engine oil as lubricant. The differences between lubricant used for pit pattern surface is illustrated as in Figure 4.

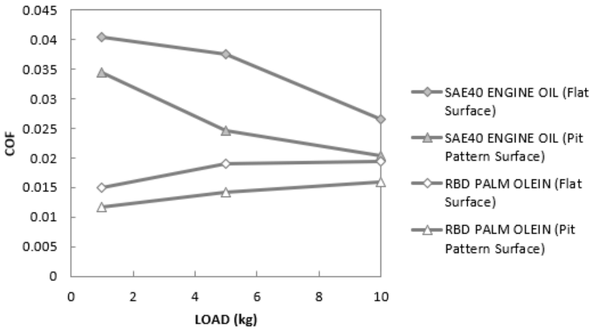

Figure. 4: COF versus load for two different surfaces and lubricants.

It is apparent that SAE40 engine oil as a lubricant displayed a higher COF compare to RBD palm olein. The maximum COF of the specimen and disk when using SAE40 engine oil was approximately 0.035, whereas only around 0.010 was reported for the same variable RBD palm olein test. The percentage difference for the COF value decreases as the load increases, continuing the flat surface pattern. As an overview, COF when using RBD palm oil is lower than COF when using SAE40 engine oil at around 66 % for 1 kg load, followed by 42 % for 5 kg load and 22 %for 10 kg load.

Flat surface has a higher COF value compared to the pit pattern surface. The reasons for this finding may be explained by the tendency of the pit to maintain the lubricant for a longer period of time relative to the flat surface that quickly sheared the lubricant. For SAE40 engine oil sample, we can see that the COF is decreasing, as the load is increase. The reason for this is that the additives used in the engine oil are capable of reducing COF even when the load is growing [13,23]. This proves that SAE40 engine oil is suitable for higher loads where less friction occurs relative to higher loads.

The connection between the declining trend of SAE40 engine oil and the rising trend of RBD palm olein overload is interesting because it reflects the Stribeck curve. This study shows that SAE40 engine oil is estimated on elastohydrodynamic lubrication and mixed lubrication as its oil film thickness is approached evenly with the surface roughness. In the other hand, RBD palm olein is in hydrodynamic lubrication as its increasing pattern is the same and the explanation is that the oil film thickness of RBD palm olein is greater than the surface roughness between the specimen and the disk. This is verified by the N. Sapawee research, which shows that palm olein can stabilize and reduce the coefficient of friction by creating a lubricating film that can be quickly sheared [9].

Pit pattern surface has often had a lower COF as compared with a flat surface due to the ability to contain lubricant. For the RBD palm olein we can see that, as load increase, COF also increased. Asadauskas [11] has shown that although vegetable-based lubricant is a possible lubricant, its main drawback is its limited range of available viscosities. In addition, RBD palm olein used in the study is with no additives at all, compared to the SAE40 engine oil that already have been processed with the additives in order to enhance the stability of the lubricant. The increase in COF in RBD palm oil is therefore due to oxidation caused by the fatty acids present in vegetable oils which cause a high chemical reaction on the metal surface and therefore oxidize the lube oil [14, 15]. Masjuki [12] clarified that the rise in COF is due to the contribution of corrosive wear, because the vegetable palm oil contains palmitic and free fatty acids in its structure, which could induce corrosion of the mating surfaces. He also reveals that another possible interpretation is due to lower boundary effect and/or breakdown of boundary lubrication due to the lower viscosity of palm oil [12, 16].

3.2 Surface Roughness Profile and CCD images

From Figure 5, as the load increases, the surface roughness of the specimen using SAE40 engine oil as a lubricant is lower, this may due to SAE40 engine oil has smaller film thickness compared to the RBD palm olein. At early stage, when using RBD palm olein as a lubricant, the surface roughness is lower compared to SAE40 engine oil as a lubricant. As the load is increasing to 10kg, both flat and pit pattern surface showed that SAE40 engine oil has the lesser roughness of the specimen than the RBD palm olein.

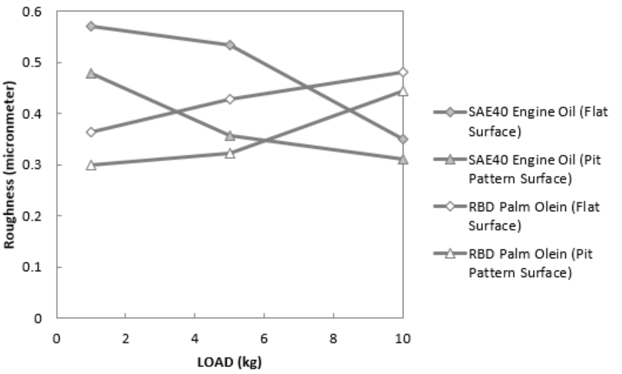

Figure. 5: Roughness measurement for two different surfaces and lubricants.

Friction is a direct influence of roughness, since when we describe friction, it is simply explained that friction is the force applied as contact surface moves in a particular direction that could affect surfaces. But, RBD palm olein lubricant has shown that the roughness of the specimen increases as the load increases. This is may due to the larger film thickness characteristic that carried by RBD palm olein [17, 18]. Figure 6 shows the specimen observation of flat and pit specimen after test.


SAE40 Engine Oil (Flat Surface), 1kg load
SAE40 Engine Oil (Flat Surface), 5kg load
SAE40 Engine Oil (Flat Surface), 10kg load
SAE40 Engine Oil (Pit Pattern Surface), 1kg load
SAE40 Engine Oil (Pit Pattern Surface), 5kg load
SAE40 Engine Oil (Pit Pattern Surface), 10kg load
RBD Palm Olein (Flat Surface), 1kg load
RBD Palm Olein (Flat Surface), 5kg load
RBD Palm Olein (Flat Surface), 10kg load
RBD Palm Olein (Pit Pattern Surface), 1kg load
RBD Palm Olein (Pit Pattern Surface), 5kg load
RBD Palm Olein (Pit Pattern Surface), 10kg load

Figure. 6. Low specification images

On the other hand, the second reason that may be discussed is the additional additive, where, SAE40 engine oil is a lubricant that has undergone a treatment procedure that is applied to the durable output additives [19, 20]. That is the reason, when compared to the RBD palm olein, which is naturally raw form the palm tree with no additives added, the results showed that the roughness different between the lubricants could be impressed for RBD palm olein [21]. RBD palm oil could not be sustained for higher loads as well as SAE40 engine oil, although this could be reduced by using an additive to achieve improved properties [22-25].

Conclusion

The friction characteristic was studied in order to calculate the COF between Aluminum Alloy block and SKD11 disk using SAE40 engine oil and RBD palm olein as lubricants at various loads and constant rotational speed. The results showed that the COF between the specimen and the disk was always lower when RBD palm olein is being used as a lubricant than when SAE40 engine oil. However, when it came to the impacts of load on COF, SAE40 engine oil still showed a decreasing trending of COF between surfaces as load increased, while RBD palm olein showed the opposite trend. According to the COF outcome, the COF between SKD11 rotating disk and Aluminum Alloy 5083 block specimen with the assistance of palm oil as lubricant was 64.5% lower for 1 kg load. SAE40 engine oil, 45.5% lower than SAE40 engine oil for 5 kg load and 24% lower than SAE40 engine oil for 10 kg load, but when more than 6 kg of load is applied in the experiment, the performance of the RBD palm olein degrades. In other words, for low load (1 to 6 kg), RBD palm olein with no additive is the best lubricant to use, while for loads greater than 6kg, SAE40 engine oil may be preferable. Following the completion of the experiment, the film thickness for each lubricant was determined. Based on COF trending findings, a firm conclusion has been reached: the film thickness for RBD palm olein has always been larger than that of SAE40 engine oil. At the end of the research, the effect of friction on micro pit has been found. SAE40 engine oil is in the region of elastohydrodynamic lubrication and mixed lubrication, while RBD palm olein is in the region of hydrodynamic lubrication. Since pit patterns may carry lubricant and act as reservoirs, they may help in friction reduction.

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Nomenclature

$ASTM$	American Society for Testing and Materials
$LVDT$	linear voltage differential transformer

COF	Coefficient of Friction
RBD	Refine Bleached and deodorized
SAE	Society of Automotive Engineers

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