Palm Olein with Jatropha Curcas Oil Blend as a Renewable Bio-Fluid

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Abstract. Many bio-fluids have been introduced to replace petroleum-based products one of which is vegetable oil which has characteristics that are friendly to the environment. Based on its characteristics, it is turning into a significant bio fluid source. Vegetable oil has a great advantage over other forms of bio-oils which is its wild availability as a renewable source. Furthermore, when used in engines, vegetable oil based lubricants have the ability to decrease hydrocarbon emissions as well as carbon dioxide. Using the pure vegetable oil with no additions and using certain blending ratios are the two methods of using vegetable oil as a bio-fluid. This paper focuses on conducting an investigation on the influence of using the normal load on the performance characteristics for the blending of two types of vegetable fluid, and making a comparison between this and a commercial mineral fluid using the four ball tribotester, palm olein with Jatropha curcas oil which were mixed in (RB60/J40) ratio. All conducted experiments were conformed to ASTM D4172. It has been noticed from the obtained results that RBD palm olein and Jatropha curcas oil Blend has the ball bearings wear scar and friction coefficient less than the commercial fluid. Based on that, it is concluded that the RB60/J40 blend is more efficient than neat RBD palm olein and commercial mineral fluid as well.

Keywords: RBD palm olein, jatropha curcas, applied normal load, anti-wear, anti-friction, parameter of flash temperature.

1. Introduction

An efficient method to boost petroleum production has been found by engineers and scientists since the beginning of the 19th century which led to cheap petroleum based lubricants.
productions. These cheap lubricants caused the effect of greenhouse and global warming issue. The need for biodegradable products has increased due to the increased health awareness and restricted resources of petroleum. A lot of efforts were put to fight pollution especially that produced by petroleum-based lubricants. It has been found that every year the environment was polluted by dumping about 12 million tons of lubricant wastes [1]. Oil products of biodegradable have become an effective substitute to regular lubricants due to the pollution of ecological. Furthermore, other bio-oils such as animal fat and vegetable oil are being used as alternatives to mineral-based oil. It has been discovered that ancient Egyptians had used vegetable oils in making their monuments [2]. This makes it safe to say that using vegetable oil in the industry is applicable. Promoting vegetable oil as a lubricant is based on its features which are first, it is biodegradable and second, it is less toxic than other petroleum based oil. Additionally, vegetable oil is an easy renewable source to produce and work with. Also, an investigation has found that vegetable oils have better lubricating ability compared to the synthetic oils and mineral oil when used between two moving metals. This lubricating ability is due to that fact that vegetable oil has a huge quantity of unsaturated and polar ester elements which influence the sliding movement of the two metals [3]. On top of that, vegetable oil has a long of fatty acids that have superior fundamental limits lubricant properties.

Several researchers have reported that the wear rate is still high even in the case of low friction coefficient associated with using vegetable oils due to their ability to increase friction coefficients. This makes vegetable oils have quality lubricating abilities. An investigation was conducted to monitor the chemical attack of the vegetable oil fatty acid on the surface [4]. It has been found that during sliding movements, the metallic soap film is wiped away. Palm oil has been tested by many researchers for applications that are engineering related such as using it as a diesel engine fuel [5, 6]. Palm oil was studied as a hydraulic fluid [8]. Also, palm oil characteristics were investigated as a metal forming lubricant by Syahrullail and his co-workers [7, 8]. Studying the pure palm oil as a bio-fluid can be divided to many categories. The first category includes using one hundred percent palm oil as a test lubricant [9, 10]. The second category includes suing emulsion of palm oil [11, 12]. The third category includes using additive mixed with palm oil [13, 14]. The forth category includes using palm oil as an additive [15]. The obtained results were promising and showed great potential which can utilized in engineering applications. Though, the oxidation of vegetable oil among other factors has to be taken into account. This paper aims to explore the RBD palm olein friction coefficient and wear performance and Jatropha curcas oil friction coefficient and wear performance blending with various normal loads using four ball tribotester.

2. Experimental Method

2.1. Equipment

A four-ball wear tester was utilized for this research. This tester was initial defined by [16] already having attained the standing of a long-time establishment within the elementary investigation of lubricants characteristics. This device utilizes four balls, one ball on the highest and 3 balls at rock bottom. The 3 balls are placed inflexibly in a sphere pot comprising the lubricant subjected to the test and pushed against the highest ball. The highest ball is created to rotate at the wanted speed whereas rock bottom balls force the highest ball to stay in place. The up described tester is shown in Figure 1, while the necessary parts such as the ball bearings, collect, and the oil cup assembly are shown in Figure 2. Acetone was used to clean components surfaces prior to executing each experiment. (100,200 to 600 Newton) normal loads were applied under (1200 rpm) as a rotary velocity for a time period of 60 minutes and 75°C lubricant temperature in this investigation.
2.2. Materials

In the study, the four balls are made of AISI E-52100 chrome alloy steel. The specifications of the ball are as followed: a 12.7 mm diameter; extra polish grade 25; hardness 64–66 HRC (Rockwell C Hardness). For each experiment, a new cleaned with acetone and dried with a fresh lint-free industrial wipe set of balls were used.

2.3. Lubricants

RBD palm olein and jatropha curcas were used in this study as lubricants. The two oils were mixed in 60% of RBD palm olein and 40% of Jatropha curcas oil. The obtained results from each experiment were compared to the results obtained from conducting the same experiment using commercial mineral fluid (SAE 40). The experiment was designed to test 10 ml of fluid each time.

2.4. Test procedures

In order to prop the steel balls, all components including the four balls and the sphere pot were completely cleaned by acetone and dried utilizing a fresh lint-free industrial wipe to assure no residuals of any solvent are remained before putting together the parts and pouring the lubricant into the pot. To fix the three bottom ball in position, a torque wrench was used to tighten the ball bearings. After that, the highest ball placed and fixed in the collector and bounded onto the spindle. Finally, the fluid being tested was poured into the assembled pot. The oil level was observed to fill all the gaps within the cup assembly. A non-friction disc in the four ball machine was used a platform to fix the pot component on. Then, the load was slowly applied to dodge any shock loading. After that, the tribotester created in heater was used to heat up the lubricant to 75 °C. After this temperature was
achieved, the drive motor was started to rotate the highest ball at the wanted speed. After 60 minutes, the heating was stopped and the pot was removed from the machine.

2.5. Wear scar diameter

Commonly known, the greater the diameter of the wear scar, the worse the wear. Therefore, measuring the diameter of wear scar of the three ball of each test was performed to examine and find out the lubricity performance of each tested lubricant. To evaluate and determine the wear scar for all the three balls individually, high resolution computer software using the obtained photomicrograph was used.

2.6. Torque of friction and coefficient of friction

A specific data acquisition was used to recode the friction torque which was observed to increase fast at first then after 5 to 10 min, it became a steady-state condition. Also, in the steady state case, the torque of friction average was recorded and the coefficient of friction was determined according to (IP-239) which is shown in the Equation below.

$$\mu = \frac{T\sqrt{6}}{3W} \quad (1)$$

where $\mu = \text{friction coefficient}$.
$T = \text{the frictional torque in kg mm}$.
$W = \text{the applied load in kg}$.
$r = 3.67$ (the distance from the centre of the contact surface on the lower balls to the axis of rotation).

This method was used by [17-19] and [9]. A computer was used to record and calculate the frictional torque and the coefficient of friction automatically.

2.7. Flash temperature parameter

a particular number known as the flash temperature parameter (FTP) which is used to determine the critical flash temperature. At this temperature and at given conditions, a lubricant would fail. The FTP can be determined by Equation (2). The FTP shows low breaking dawn possibility of lubricant film [18]. High value of FTP expresses high lubricant performance.

$$FTP = \frac{W}{(WSD)^{1.4}} \quad (2)$$

Where:
$W = \text{the applied load in kg}$
$WSD = \text{the wear scar diameter in mm}$.
3. Result and discussions

An investigation and a characterization of the Jatropha curcas oil with refined, bleached & deodorised palm olein (RBD) mixing effects under various loads. The obtained results which were also compared with 100% commercial lubricant give a deeper understanding of ball bearings worn surfaces utilizing oil analysis for example WSD, COF and FTP.

3.1. Density and kinematic viscosity

The unit of mass per volume is the fluid density. To determine the density of the lubricants specified earlier in this paper, an experiment has been conducted. The fluid resistance defined as kinematic viscosity. Shear stress or the tensile stress can deform the fluids also known as the fluid internal friction. To determine viscosity and fluidity, a viscometer was used which has a rotating spindle a specific speed. The rotation speed of the spindle encounters the viscosity or fluidity after dipping the spindle into the lubricant could be measured. Table 1 shows that as the lubricant temperature raises, the viscosity declines but the fluidity increases. It is easier for particles to move in lubricants with more fluid. Therefore, the fluids viscosity is influenced by the fluids temperature.

Table 1: fluid samples viscosity (mm$^2$/sec)

| Temp(°C) | RB60/J40 | RB 100% | ENG 100% |
|----------|----------|---------|---------|
| 40       | 28.02    | 33.85   | 102.50  |
| 75       | 9.26     | 14.25   | 23.22   |
| 100      | 5.54     | 9.85    | 12.07   |

For lubricating oil, viscosity is the most significant property. The lubricant's viscosity is between 5.54 and 12.07 mm$^2$/sec at 100°C. Whereas, it is between 28.02 and 102.50 mm$^2$/sec at 40°C. Prior to conducting the test, comparison between the viscosity of the of RBD palm olein and the blend of RBD palm olein and Jatropha curcas oil (RB60/J40) and the commercial mineral oil at 40, 75 and 100°C is present in Figure 3. The neat RBD palm olein viscosity is higher than blend of Jatropha curcas oil with refined, bleached & deodorised palm olein (RB60/J40) viscosity. However, at all temperature tests, it is less than viscosity of 100% commercial lubricant.

Figure 3: Oil samples viscosity at 40, 75 and 100°C.
3.2. Wear scar diameter

By a personal computer operating optical & scanning electron microscope, the diameter of wear area on the three ball bearings was monitored and determined. Figure 4 shows the wear scar diameter average values. The data of all lubricant samples presented in this figure indicates that wear scar diameter (WSD) increases with the increment of the normal loads. Thus, by reducing the WSD, the blend of RBD palm olein (RB60/J40) and Jatropha curcas oil operated as an anti-wear additive.

![Figure 4: Wear Scar Diameter (µm) vs. Normal load (N)](image)

3.3. Friction Torque

The mixture of refined, bleached & deodorised palm olein with Jatropha curcas oil (RB60/J40) friction performance was evaluated under 100 to 600 normal loads, 1200 rpm rotational speed, and 75°C, oil temperature for 60 min. The obtained friction torque results are shown in Figure 5 which shows that the friction torques of all oil mixtures used in this research increase in a similar pattern as normal load raises. The torque of friction was quickly raised in the starting phase of the tests and became a steady-state while heading to the last phase of the experiments. The steady-state condition of the friction torque indicates that the film of lubricant between ball bearings was unchanging with no lubricant layer breaking down. Nevertheless, at 600N, the friction torque increased along the process because of the breakdown of the lubricant film causing great friction at the metal to metal contact area.
3.4. Coefficient of friction

The friction coefficients for all tested lubricants under the specified conditions were determined and plotted as illustrated in Figure 6. An analysis of the plotted results concludes that for all specified samples, the friction coefficients are less than those for 100% commercial lubricant. Also, at 100N normal load for the pure refined, bleached & deodorised palm olein, the least friction coefficient is (0.025126) also, for the mixture of the Jatropha curcas oil with RBD palm olein is (0.051319). Upon that it is concluded that 60% of refined, bleached & deodorised palm olein blended with 40% of Jatropha curcas oil gives the highest lubricating ability in comparison to the other tested lubricants.
3.5. **Flash temperature parameter**

Figure 7 shows the results obtained from calculating and plotting the flash temperature parameter for the three tested lubricants using various normal loads.

As shown in Figure 7, the greatest FTP For the neat refined, bleached & deodorised palm olein which is (65.458) happened at 600N normal load and (85.46) for palm olein (RB60/J40) at 500N. Thus, it can be concluded that when blending 60% refined, bleached & deodorised palm olein oil with 40% of Jatropha curcas oil, it boosts the lubricity performance and also reduces breakdown of lubricant film comparing to pure RBD palm olein lubricant.

4. **CONCLUSIONS**

A four ball tribotester was used to execute the tribological evaluation of the RBD palm olein and Jatropha curcas oil (RB60/J40). The experiment time was set to 60 min and the rotating speed of the top ball was 1200 rpm. A set of normal loads was used which are 100, 200, 300,400,500 and 600N. The collected data illustrated that (RB60/J40) had less friction coefficient in comparison to the other two tested lubricants. It also had less wear scar diameter under all normal loads. However, the RBD PS had a tendency to create larger wear scar due to the production of non-reactive detergent. From the observation on the surface topography of the worn surface, the rough surface (deep valley of asperities) that formed helped to create an oil reservoir of the RBD PS, and prevented metal-to-metal contact.
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