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The Tribological Characteristic of the Blends of Rbd Palm Olein with Mineral Oil Using Four-ball Tribotester

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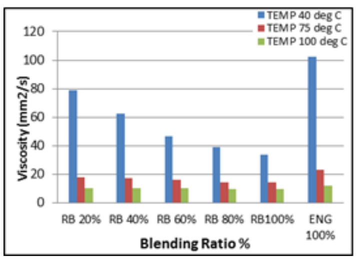
Graphical abstract



Abstract

Vegetable oils are sustainable fluids which have been promoted to replace petroleum-based oils due to its environment friendly characteristics; it is being a very important supply of biolubricant. The excellent advantage of vegetable oil is the fact it is really which can be used environment friendly supplier. In addition, vegetable oil based lubricant clearly show the possibility to minimize carbon monoxide also hydrocarbon emissions when used in IC engines. There are basically two different ways to using vegetable oil to be a bio-lubricant, either one by directly use the pure vegetable oil with additives or use certain blending ratio of vegetable oil with mineral lubricant. In this paper, the influences of the blending ratio of mineral oil with RBD palm olein on the tribological characteristics were investigated and compared with commercial lubricant oil by using the four ball tribotester. The blending ratio was varied from neat with interval of 20% by volume. All experimental works were conforming to ASTM D4172. The results exhibited that the blend of RBD palm olein with commercial lubricant oil has lower the wear scar of ball bearings and coefficient of friction compared to commercial lubricant oil. As a conclusion, the blending of RBD palm olein with commercial lubricant oil has better performance compared to commercial lubricant oil or pure RBD palm olein.

Keywords: RBD palm olein; blending ratio; wear scar diameter; coefficient of friction; flash temperature parameter

■1.0 INTRODUCTION

1.1 Oil Palm Biomass

Starting in the early 19th century, engineers and researchers found an effective solution to increase the production of petroleum. This has led to the production of low-priced petroleum-based lubricants, which brought into society the greenhouse effect and the issue of global warming. The increase of worldwide concerns about health, the environment and limited petroleum resources has promoted the use of biodegradable products. Special attention has been paid to protecting the environment against pollution caused by the petroleum-based lubricants. A survey was conducted, which found out that nearly 12 million tons of lubricant wastes were deposited into the environment every year [1]. As a result of increasing awareness of ecological pollution, biodegradable oil products are becoming an important alternative to conventional lubricants. Animal fat and vegetable oil are considered as substitutes for mineral-based oil as a lubricant. In recent decades, researches were undertaken on vegetable oils such as palm oil, sunflower oil, soybean oil and castor oil to make hydraulic liquid and lubricant oils [2-5]. Nosonovsky, M. (2000) found out that vegetable oils were used in the construction of monuments in ancient Egypt [6]. Based on this statement, the usage of vegetable oil as a lubricant in the industrial sector is not an impossible work. The advantages of choosing vegetable oils rather than lubricants from other sources are the fact that they are biodegradable and are less toxic when compared to petroleum-based oil [6]. They are easy to produce and form a renewable source. In addition, when investigated the tribological behaviour of the two moving metals using biodegradable oil compared to mineral oil, they showed that the vegetable oils possess even a better lubricating ability than the current mineral or synthetic oils because they contain a large amount of un-saturated and polar ester groups components that favourably affected the conditions during reciprocating sliding [7]. Furthermore, the long-chain fatty acids found in vegetable oil have much better intrinsic boundary lubricant characteristics. Vegetable oils present high-quality lubricating abilities because they give rise to the lower coefficients of friction. However, a large number of researchers study that even when the coefficient of friction is lower with vegetable oil as the boundary lubricant, the wear amount is higher. Golshokouh, *et al*. investigated the chemical attack on the surface by the fatty acid contained in the vegetable oil [8]. This paper investigates the tribological properties, such as anti-wear, anti-friction, viscosity index and flash parameter point of RBD palm olein with mineral oil in different blending volume ratio by using a four-ball tribotester.

2.0 EXPERIMENTAL METHOD

2.1 Apparatus

The research for this study used a four-ball wear tester. The four-ball wear machine was described by Golshokouh, *et al.* (2013) has already having acquired the status of an established institution in the fundamental investigation of characteristics of the lubricants [9]. This machine works by using four balls, three balls at the bottom and one ball at the top. The three-bottom balls are held firmly in a ball pot including the lubricant being examined and pressed against the top ball. The top ball is designed to rotate at the desired speed while the bottom three balls are pushed against it. The surfaces of the components were cleaned with acetone before conducting each test. Within this paper, wear evaluation was performed at 40 kg loading and also at 1200 rpm for 60 minutes at temperature of lubricant 75°C.

2.2 Materials

The standard balls used in this experiment are made from AISI E-52100 chrome alloy steel, with the following specifications: diameter 12.7 mm; extra polish (EP) grade 25; hardness 64–66 HRC (Rockwell C Hardness). Four new balls were used for each test. Each time before starting a new test, the balls were cleaned with acetone and wiped dry using a fresh lint-free industrial wipe.

2.3 Lubricants

The lubricants used for this experiment was RBD palm olein is a refined palm oil product that is liquid at room temperature. This oil was then blended with 20-80% by volume of PETRONAS/SAE 40 engine oil. The results obtained from experiments using RBD palm olein in different blending volume ratio were compared with the results from the experiment which used commercial mineral oil (SAE 40). Each trial tested 10 ml of the lubricant.

2.4 Wear Scar Diameter

The wear scar diameter of each of the three bottom test balls was measured to determine the lubricity performance of the test lubricant. In general, the larger the wear scar diameter, the more severe the wear. The wear scar was evaluated by a computer running optical and scanning electronic microscope (high resolution) software and from the captured photomicrograph. Using this process, the wear scar diameter was determined for each of the three fixed balls.

2.5 Friction torque and Coefficient of Friction

From the four-ball tribotester machine, the friction torque was recorded using specific data acquisition system. The friction torque for all test lubricants increased rapidly at the beginning of the test after 5–10 min, the friction torque data became a steady-state condition. The average of friction torque at the steady state condition was recorded and the friction coefficient, as calculated according to IP-239, is expressed as follows:

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

where μ is the friction coefficient, T is the frictional torque in kg mm, W is the applied load in kg and r is the distance from the centre of the contact surface on the lower balls to the axis of rotation, which was determined to be 3.67 mm. The same calculation method was used by Thorp [10]. The frictional torque data was recorded by the computer, which calculated the friction coefficient automatically.

2.6 Flash Temperature Parameter

The flash temperature parameter (FTP) is a single number that is used to express the critical flash temperature at which a lubricant will fail under given conditions. The FTP refers less possibility of lubricant film to breakdown [11]. High value of FTP means excellent performance of the lubricant. The FTP is usually measured by using the Equation (2) [12]:

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

Where W is the applied load in kg and WSD is the wear scar diameter in μm.

3.0 RESULT AND DISCUSSION

The impacts of RBD palm olein blended with lubricant was examined and also characterised. The test results give a much better understanding of used areas of ball bearings with RBD palm olein as being contaminants by using oil evaluation for example the kinematic viscosity analysis, WSD, COF and also FTP. All these results were in comparison with 100% mineral engine lubricant.

3.1 Density and Kinematic Viscosity

The density of fluids is considered as the unit of mass per volume. A laboratory experiment had been performed to determine the density of the mixture samples of RBD palm olein and commercial mineral oil using a hydrometer. Kinematic viscosity is a measure of the resistance of a fluid which is deformed by either the shear stress or the tensile stress of the fluids. It is also known as the internal friction of the fluids. A viscometer was used to measure the viscosity for both lubricants to evaluate fluidity. The viscometer has a spindle that rotates with a certain speed. After inserting the spindle into the lubricant, the speed of the spindle resisted the fluidity or viscosity of the lubricant and the viscosity are obtained as shown in Table 1.

Table 1 Viscosity (mm^2/sec) of the blend samples of RBD palm olein and commercial mineral oil

Temp(°C)	RB 20%	RB 40%	RB 60%	RB 80%	RB 100%	ENG 100%
40	79.0	62.1	46.6	39.0	33.8	102
75	18.1	17.2	15.8	14.4	14.2	23.2
100	10.3	10.4	10.3	9.8	9.8	12

Viscosity is considered the most important feature for lubricating oil. At 100°C, the blended lubricant's viscosity was with about 9.857 mm^2/sec to 10.440 mm^2/sec, whereas at 40°C, the blended lubricant's viscosity was within the range of 39.035 mm^2/sec to 79.014 mm^2/sec. Figure 1 shows the viscosity of RBD palm olein oil blended lubricant at 40, 75 and 100°C before the four-ball experiment was conducted. It is normally identified that the viscosity of RBD palm olein mixed lubricant was less than the viscosity of 100% mineral lubricant but it higher than use the pure RBD palm olein oil highest viscosity of RBD palm olein oil blended lubricant at 40, 75 and 100°C was at 20% RBD palm olein oil added lubricant. From the Figure 1, the results show that there is a convergence in the values of the viscosity of the bio-oils blended with mineral oils, particularly when the values of high-temperature.

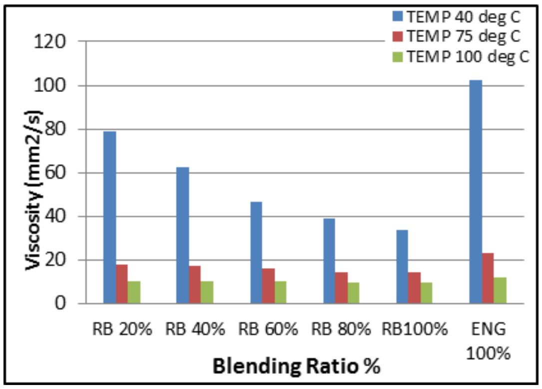


Figure 1 Effect of bio-lubricant blends on viscosity at 40, 75 and 100°C before four ball test

3.2 Wear Scar Diameter

The results for wear scar diameters of the three bottom ball bearings were measured using a special microscope and the mean values were calculated. Figure 2 shows the mean value of the Wear Scar Diameter (WSD) for each RBD palm olein oil blended lubricant.

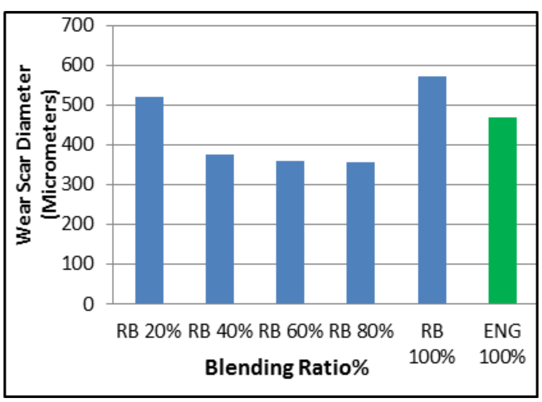


Figure 2 Wear Scar Diameter, WSD (µm) vs. Blending ratio (%)

From these values, we can conclude that the WSD of RBD palm olein oil blended lubricant was lower than WSD of pure RBD palm olein oil and the WSD OF 100% commercial lubricant. From the figure, we can observe that the minimum wear occurred at 40% RBD palm olein oil blend (375.3 µm). But at 20% RBD palm olein oil blending the maximum wear occurred (520.233 µm). Therefore, the RBD palm olein oil worked as an anti-wear additive by reducing the WSD. This is due to the formation of a protective layer to improve wear property.

3.3 Friction Torque

To study the friction performance of RBD palm olein contamination under normal load (392.4 N), experiments were keeping the rotational speed at 1200 rpm and the bulk oil temperature at 75°C for one hour. The results of the friction torque tests were plotted and are illustrated in Figure 5. The lowest FT occurred at 60% (0.0932786 Nm) compared to all percentages of blending as shown in Figure 3. Therefore, RBD palm olein oil blended lubricant has better lubricity ability in terms of friction compared to the 100% commercial lubricant because the RBD palm olein contains fatty acids that help the lubricant molecules to stick on the ball bearing surface very well and maintain the lubricant layer.

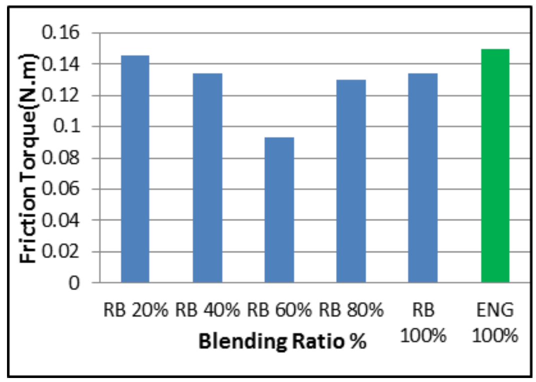


Figure 3 Friction torque vs. Blending ratio (%)

3.4 Coefficient of Friction

The coefficients of friction for RBD palm olein blends, the pure RBD palm olein oil and the 100% commercial lubricant were conducted. For each experimental condition, the coefficients of friction were determined and the results were shown in Figure 4.

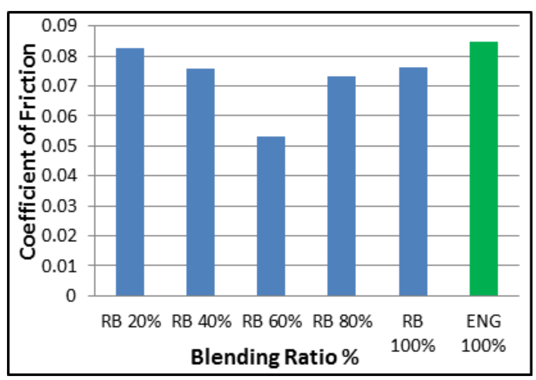


Figure 4 Coefficient of Friction vs. Blending ratio (%)

For the RBD palm olein and engine oil blends, the lowest Coefficient of Friction occurred at 60% (0.053044) as compared to other percentage of blending ratios and the highest was obtained at pure engine mineral oil. Therefore, RBD palm olein blends lubricant has a good lubricity ability in terms of friction compared to the pure RBD palm olein oil and the 100% mineral lubricant.

3.5 Flash Temperature Parameter

Flash temperature parameter is determined and then tabulated for RBD palm olein oil blended. Test results are |show in Figure 5. For the RBD palm olein oil contamination. The largest FTP happened at 80% (169.28) in comparison to all of the percentages of blending as shown in Figure 5. Therefore, when 80% RBD palm olein oil was additional into the lubricant, it will lesser the probability for lubricant film to breakdown and raise the lubricity overall performance compared to 100% mineral lubricant.

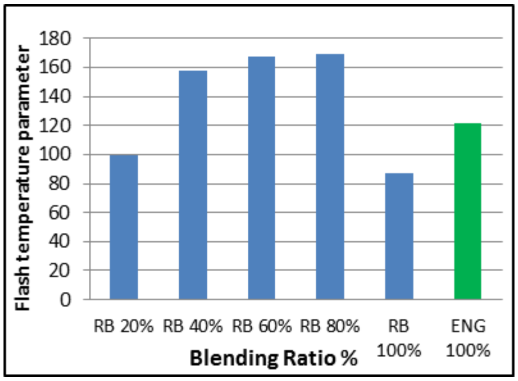


Figure 5 Flash temperature parameter vs. blending ratio (%)

■4.0 CONCLUSSION

It can be concluded that the 60% of RBD palm olein blended lubricant increases the lubricant effectiveness depending on the lower COF with lower value of Friction Torque as compared with 100% mineral lubricant. In addition, the WSD for RBD palm olein blended lubricant shows that only 60% RBD palm olein contamination has got lessen WSD compared to 100% mineral lubricant so it is a very good decrement of around 23%.This means the contamination of palm oil in lubricant which have the potential to work as anti-wear lubricant additive. Therefore, the overall analysis suggests that, the RBD palm olein has the potential in becoming a partial substitute bio-lubricant because the contamination of it did not give any negative impact on the wear phenomena and lubricating effectiveness.

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