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THE TRIBOLOGICAL CHARACTERISTICS OF THE CACTUS AND MINERAL OIL BLENDS USING FOUR-BALL TRIBOTESTER

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Abstract

The oil derived from vegetables has been seen as an alternative to mineral oils for lubricants because of certain inherent technical properties, renewable source and their abilities to biodegrade. Vegetable oil is known to have a high viscosity index with a higher lubricity value compared to mineral oil. Despite its potentiality as a candidate alternative, vegetable oil has several limitations. It has a low wear resistance, and it is highly sensitive to temperatures with tribological characteristics. The majority of technical solutions, including additivation, chemical alterations, and blending, are being proposed as means of overcoming the listed limitations. This study seeks to investigate the characteristics of cactus oil with respect to its use as a bio-lubricant as well as the characteristics of environmentally friendly vegetable oil when they are mixed with mineral oils as alternative oil for petroleum, using the four-ball tribotester. The volumetric blending ratio was varied (20% to 80%) and these blends were performed at 1200 rpm, for one hour, with 40 kg of load at a temperature of 75°C (ASTM D4172-B) standard. According to the results, it was found that the lowest wear scar diameter was 431.23μm, which was identified in the blend of 20% cactus oil with 80% mineral oil which symbolized by (CC20%), compared to that of neat cactus oil at 669.16 μm and mineral oil at 546.46 μm.In addition, the result also indicates that a 80% addition of cactus oil, the coefficient of friction tends to decrease compared to the values of neat cactus oil. Finally, it is concluded, the blends of cactus oil with commercial lubricant oil have better performance compared to commercial lubricant oil or neat cactus oil.

Keywords: Cactus oil, volumetric blending ratio, wear scar diameter, coefficient of friction

1.0 INTRODUCTION

Lubricants play a critical role in reducing wear and friction in all industrial applications, such as automotive industry, food processing, cable car maintenance and others. In addition, lubricants are responsible for distributing heat and transporting foreign particles. Friction and wear are two major concerns that may disrupt all or parts of contact surface. Mineral oil is the main source of lubricant oil. Every year, more than 12 million tons of lubricant waste is released into the environment. Mineral oil-based lubricants can pollute the environment through open burning, as well as dispersing the oil and its pollutants into the air, drinking water and into the seas. Furthermore, sources of mineral oil are limited and will be depleted in the near future [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 substitute 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, There are two ways to use Vegetable oils are oils extracted from fruits and plants as a bio-lubricant, either use directly the neat vegetable oils without any additives or by use the blends with certain blending ratio of the vegetable oil with mineral lubricant [2-5]. 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].

Vegetable oils are easy to produce and form a renewable source of bio-lubricant. 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]. Tribological characteristics of Jatropha curcas oil were studied as additive to the mineral engine oil. In comparison to the mineral engine oil the blends shown lower value of friction coefficient. Moreover, when the pure Jatropha oil was applied, bigger scars of wear were observed [9]. This paper investigates the tribological characteristics, such as anti-wear, anti-friction, viscosity index and flash temperature parameter of cactus oil with mineral oil in different blending volume ratio by using a four-ball tribotester.

2.0 METHODOLOGY

2.1 Apparatus

For studying the features of the lubricant, a four-ball wears tester machine was used in this research. The tool had total 4 balls; three balls were placed at the base, whereas the fourth ball was placed on the top. The bottom balls were strongly held within a ball pot containing the lubricants to be examined and total system was pressed against the ball at the top. The top ball rotates at the speed desired and the three balls placed at the base are pressed against it. Before each of the tests was performed, acetone was used for cleaning the surfaces of all the components.

To measure the temperature of the oil, a thermocouple was embedded within the base of the ball pot. There is also a heating block under the ball pot that regulates the experiment temperature [10]. The wear study for these blends was performed at 1200 rpm, for one hour, with 40 kg of load (392.4 N) at a temperature of 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 cactus oil product that is liquid at room temperature. This oil was then blended with 20-80% by volume of SAE 10W-30 mineral engine oil. The results obtained from experiments using cactus oil in different blending volume ratio were compared with the results from the experiment which used commercial mineral engine oil (SAE 10W-30). Each trial tested 10 ml of the lubricant.

2.4 Kinematic Viscosity

Viscosity is normally used for the recognition of the properties of liquids and it is used to describe the internal resistance of liquid or gas for the flow. Viscosity has a direct impact on liquid thickness and on the wear rate of the sliding surface. Usually, the thick layer of lubricant between the contact parts can reduce friction and wear more than the thin layer when using the same lubricant. Viscosity index is unitized to measure the viscosity of liquid at various temperatures and is normally used in industrial applications, especially in the automotive industry .

2.5 Wear Scar Diameter (WSD)

Optical as well as high resolution scanning electron microscope was used to captured the wear scars area on the three ball bearings after the experiments were complete. The micrograph images captured through the microscopes were used to find out the diameter of the wear scars; and the average of the values was determined.

2.6 Friction Torque and Coefficient of Friction

The value of friction torque, T is needed for calculating μ, the coefficient of friction. The friction torque is used as a parameter to calculate the resistance of contact amongst metals. This data can be directly fed into the Winducom software from the four ball tribotester machine. The ratio of the force which maintains contact within the object and the force of friction which resists the speed of the object is represented by the coefficient of friction. This can be calculated by using the following equation:

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

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 center 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 [11]. The frictional torque data was recorded by the computer, which calculated the friction coefficient automatically.

2.7 Flash Temperature Parameter

FTP or the Flash Temperature Parameter is a unique number used for stating the critical temperatures when the emollients will fail to work under given conditions. The probability of degeneration of the lubricant films can be observed through the FTP [12, 13]. A high value of FTP demonstrates higher lubricant performance. The FTP is usually measured by using the equation (2):

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

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

3.0 RESULTS AND DISCUSSION

The effects of the cactus oil blended with lubricant was examined and also characterised.The Experiments results give a much better understanding of used areas of ball bearings with the cactus oil as being contaminants by using oil evaluation for example the wear scar diameter, friction performance and also the Flash temperature parameter. All these results were in comparison with commercial mineral engine oil (ENG100%).

3.1 Kinematic Viscosity

The kinematic viscosity values of cactus oil and mineral oil blends under various temperatures, of 40°C, 75°C, 100°C and 125°C, are illustrated in Figure 1, the CC(cubic centimetre) sample represents the volumetric blending of the cactus oil with mineral oil .This figure indicates that the kinematic viscosity of all blends of cactus oil with mineral oil decreased with the increase of the temperature[14-16].Furthermore, under high temperatures the viscosity quantities of oil samples were comparable to each other. The viscosity at 40°C for (CC20%) blend was 63.761 mm^2/s and was higher than the other test oils, compare with 31.828 mm^2/s for the neat cactus oil and 42.845 mm^2/s for the mineral engine oil(ENG100%). However, the lowest amount of viscosity was obtained for 125°C of the (CC20%) blend with 5.152 mm^2/s compare with the 9.157 mm^2/s for the mineral engine oil.

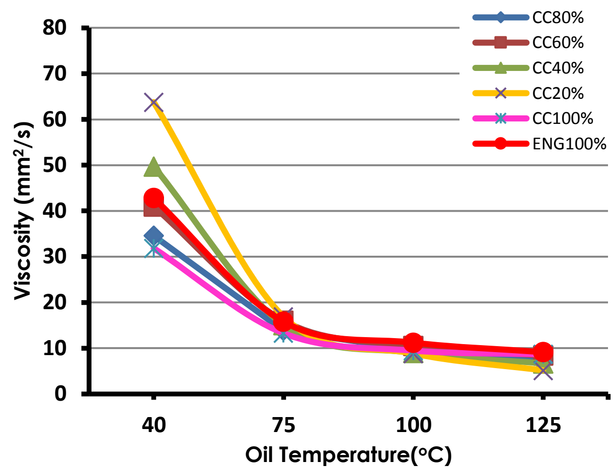

Figure 1 Kinematic viscosity for oil samples in different oil temperature

All samples of cactus with mineral oil blends show a good reliability with regard to viscosity grade requirements (ISO VG32),and blend (CC0%) has better performance of the viscosity test.The viscosity index values of blends for cactus oil alongside mineral oil are indicated in Figure 2. The value for neat cactus oil of 304.37 was higher compared to the mineral engine oil of 267.68 and another oil samples.

The lowest viscosity index quantities acquired for the CC20% blend stood at 111.94. Moreover, based on the illustration in Figure 2, the viscosity index values were reduced by the blending process, due to the increasing of the value of the kinematic viscosity at the high temperature of 100°C. Based on the result in Figure 2 can be seen also siginificant reduction in the CC20% and CC40% blends,that beacuse the blending procees led to high increment in the value of Kinematic viscosity of this two blends at 40°C compared to neat cactus oil CC100% which cause reduction in the viscosity index values. However, the values achieved the best required levels of the (ISO VG32) [17].

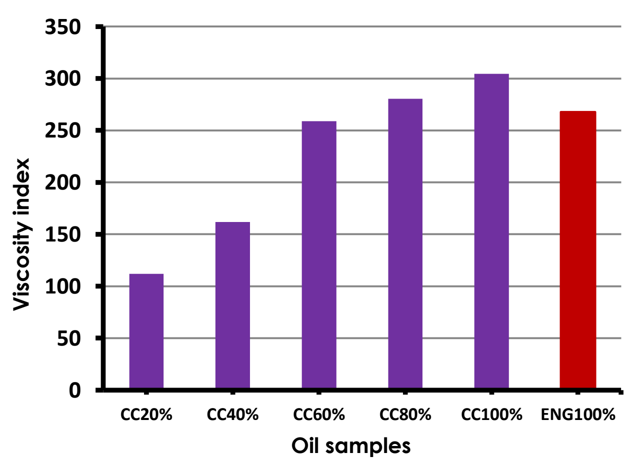

Figure 2 Viscosity index amount for oil samples

3.2 Wear Scar Diameter (WSD)

A comparison of the mean value of wear scar diameter (WSD) for the oil samples has been presented in Figure 3. Based on the result, can be indicated that the mineral and cactus oil blending reduces the WSD compared to the neat cactus and mineral oil, due to increase the value of the kinematic viscosity, furthermore, the fatty acid which might covered the rubbing contact surface fully [18]. However, it can be noted that the wear scar diameter was increased with increasing percentages of bio-lubricants.

The results also, indicated that above 20% addition of cactus oil, the WSD tends to increase. The lowest amount of the diameter of the wear scar was 431.23 µm, which was identified for CC20, compared to 669.16 µm for neat cactus oil and 546.46 µm for mineral engine oil. Volumetric blending ratio (CC60) yielded a higher wear scar diameter of 552.1 µm compared to other blending ratios and mineral oil, this result indicates that 60% addition of cactus oil adversely affects the quality of the lubricant, that meain the oil sample has ahighest possibility for its lubricating film breaking down.

3.3 Friction Torque

The results of the friction torque (FT) that resulting from the four-ball tribotester with the use of a computer system were offered graphically as indicated in Figure 4. The figure compares the friction torque quantities of neat cactus oil, blends of cactus with mineral oil, and mineral oil.

Based on the figure, it was found that the friction torque values were increased by the blending process compared to neat cactus oil. However, the values of friction torque for blends of cactus oil were still lower than that for mineral oil .The lowest friction torque value of 0.09710 Nm was identified in CC80% in respect to 0.11221 Nm for clean cactus oil and 0.14423 Nm for mineral oil, The results from the Figure 4 can be attributed to the fact that the bio-lubricants particularly, CC80 has strong affinity to act as a friction reducing additives as well as ability to retain its property. Based on the result in the Figure can be seen also,when blend less than 80% of the cactus oil as a volumetrice blending ratio with mineral oil, the friction torque tends to increase.

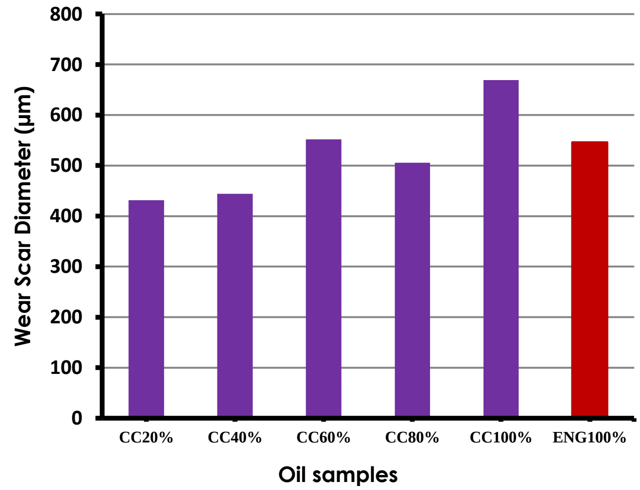

Figure 3 Wear Scar Diameter for oil samples

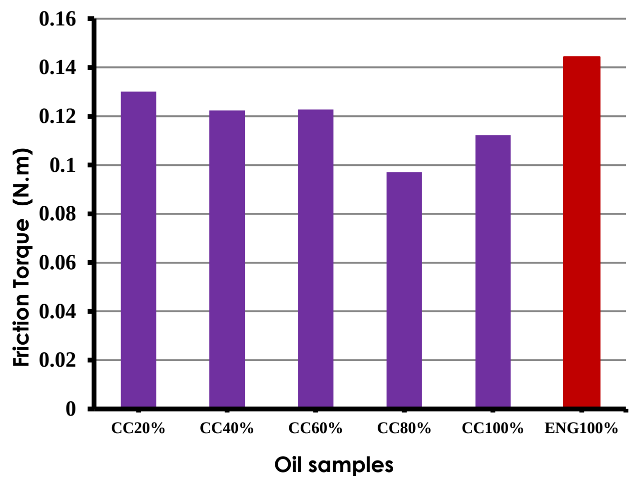

Figure 4 Friction torque values for oil samples

3.4 Coefficient of Friction

Coefficient of friction (COF) quantity for cactus oil mixed with mineral oil is outlined in Figure 5. Based on the figure, in general the process of blending cactus oil and mineral oil increased the friction coefficient higher than neat cactus oil. However, the friction coefficient values for cactus oil blends contained a low value in comparison to the mineral engine oil, because of the long chain fatty acid and the esters of the bio-lubricants that are known as surface active materials. The lowest friction coefficient value is 0.05538 for the CC80 compared to 0.06378 for neat cactus oil and 0.08149 for mineral engine oil. An 80% addition of cactus oil in base lubricant showed the best performance in terms of reducing the coefficient of friction and less 80% addition of cactus oil the COF tends to increase, this behaviour due to effect of the fatty acid which acting as an active surface material which cause reduction in the value of COF. Another important fact is that less 80% addition of the bio-lubricant adversely affects the quality of the lubricant.

3.5 Flash Temperature Parameter

The flash temperature parameter (FTP) for the neat cactus oil, blends of mineral with cactus oil, and mineral oil are illustrated in Figure 6. The figure shows that mineral and cactus oil blended increased the FTP values more than the mineral oil and neat cactus oil, which can be attributed to the fact that the FTP depends on the applied load and WSD. Since the applied load is constant, thus lower the wear scar diameter increases the FTP .

The results implied that CC20 has the better lubricating performance with stability of the its lubricating film enduring without breaking down at FTP value 128.85 in comparison to 70.19 for the neat cactus oil and 93.21 for mineral engine oil.

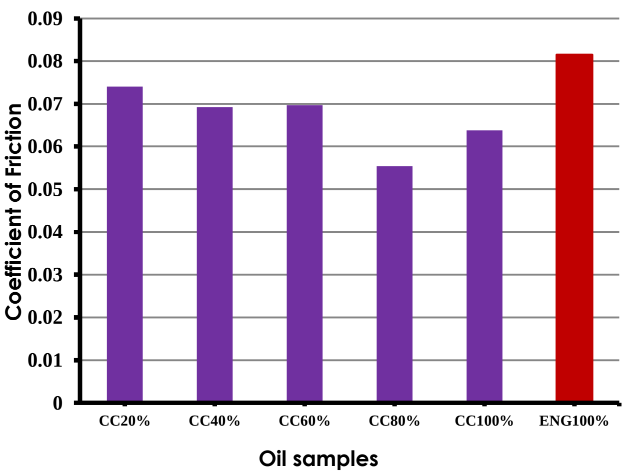

Figure 5 Coefficient of Friction values for oil samples

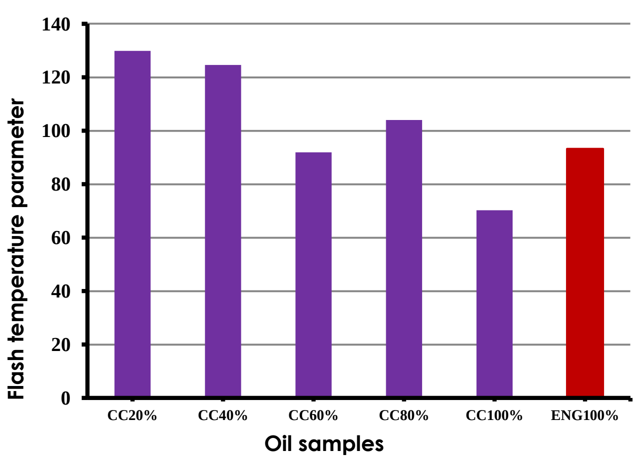

Figure 6 Flash temperature parameter for oil samples

4.0 CONCLUSIONS

Based on the overall experiments, there are several conclusions can be explained as below:

I. The 80% of cactus oil blends lubricant improves the lubricants performances based on the lower COF and lower Value of Friction Torque as comparing with the 100% commercial lubricant and pure cactus oil (CC100%).

II. The WSD for cactus oil blend lubricant shows that 20% cactus oil blend has lower WSD than 100% commercial lubricants and it has a good decrement of about 26.72 %. This means that the blend of cactus oil in lubricant has the potentialities for acting as anti-wear lubricant.

III. The overall analysis suggests that, the cactus oil has the potential in becoming a partial alternative bio-lubricant because the blends did not give any bad effect on the wear phenomena and lubricating performance.

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