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THE TRIBOLOGICAL CHARACTERISTICS OF RUBBER SEED OIL WITH MINERAL OIL BLENDS

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Abstract

Malaysia, in the early years, was known as the main producers of natural rubber that involved large cultivation of rubber trees. The milky latex produces many types of rubber products such as tyres, balloons, boots, gloves and others, its seeds contain oil that can be used in making paints and soaps. In this study, the rubber seed oil was investigated to study its lubricant characteristics. There are two ways for using plant oils as bio-lubricants, either use directly as neat plant oils or using certain blending ratio of the plant oils along with the commercial lubricants. In this paper, the influences of the blending ratio of mineral oil with rubber seeds oil were investigated on the tribological characteristics and compared with commercial lubricant using the four ball tribotester. Rubber seeds oil was blended at volumetric ratio ranging from 20 to 80% with commercial mineral oil SAE 30. All experimental works conformed to ASTM D4172-B. The results show that the some blends of rubber seeds oil with commercial mineral oil have lower coefficient of friction and friction torque compared to commercial mineral oil. In conclusion, the rubber seeds oil blends show a better anti-friction performance compared to mineral oil. Therefore, rubber seeds oil has the potential to be used as lubricant of mating components.

Keywords: Rubber seeds oil; Blending ratio; Blending ratio; Coefficient of friction

1.0 INTRODUCTION

Hevea brasiliensis, an indigenous species to Brazil was cultivated and harvested in Malaysia, Indonesia, Thailand and Vietnam, forming the largest producers of the world natural rubber. The latex of Heveabrasiliensis is the raw material for making of natural rubber. The latex is a renewable resource that can be sustainably obtained from the tapping of the tree stem. The rubber is a water-resistant and durable and most importantly, is highly elastic that having the useful properties in the manufacturing of rubber products. Beside the rubber products, an investigation was done on the seeds of the rubber trees for the purposes of bio-lubricant.Bio-lubricants, also known as bio-based lubricants are made from a variety of edible oils such as rapeseed, canola, sunflower, soybean, palm and coconut oils and the non-edible oils from jatropha, jojoba oils. The usage of bio-lubricants from non-edible oils can overcome the problems of food verse fuels, lubricants, environmental and economic issues related to edible vegetable. Non-edible oils are not suitable for human food due to the presence of some toxic components in the oils. The selection of non-edible oils as lubricants requires extensive characterisation studies. Moreover, non-edible seed crops are expected to use lands that are largely unproductive and those that are located in poverty-stricken areas and degraded forests. They can also be planted at field boundaries, fallow lands, and in public land such as along railways, roads and irrigation canals. A survey was conducted on the environment against pollution caused by the mineral-based lubricants which found out that the lubricant wastes of almost 12 million tons were deposited into the environment every year [1].

The advantages of choosing vegetable oils rather than mineral lubricants sources are the fact that they are biodegradable and are less toxic as compared to petroleum-based oil. They are easy to produce from renewable source. In addition, during an investigation on the tribological behaviour of two contact sliding metals between one another using biodegradable oil as lubricant, they showed that the vegetable oils possess even a better lubricating ability compared to mineral or synthetic oils. This is because they contain a large amount of unsaturated and polar ester groups components that favourably affected the conditions during the reciprocating sliding motion [2], [3]. Moreover, the long chain fatty acids in vegetable oils have better intrinsic boundary lubricant properties. Vegetable oils reveal good lubricating abilities because they produce low coefficients of frictions. On the other hand, other scholars have reported that most vegetable oils having a lower coefficient of the frictions, but has higher wears rate. A study on fatty acids which were present in the vegetable oils causing the metallic soap films being washed away during sliding and form a non-reactive detergent which increases the wear [4].

There is an increase interest in the research and development on the uses of bio-lubrication in metal forming industries and reciprocating machines, which uses palm oil as a fuel in diesel engines [5], [6], as hydraulic fluid [7], [8] and as a metal forming lubricant [9], [10]. The studies of vegetable oils as a potential substitute for mineral base oils can be categorized into four major groups, where studies that was focused on the tribological attributes of neat vegetable oils [11], [12], vegetable oil emulsion [13], vegetable oil with additives [14], [15] and studies that was focused on the tribological characteristics of vegetable oil as an additive [16]. In their studies, it show that the vegetable oil exhibited satisfactory results, could be further improved and has a potential to be used in many engineering applications. In the previous studies, researchers used various vegetableoil-based lubricants and additives, but there are very limited references that use rubber seeds oil as a base lubricant. This study investigates the anti-frictions and anti-wear performance of rubber seed blends with mineral oil in different volumetric blending ratio using a four-ball tribotester.

2.0 EXPERIMENTAL

Raw rubber seeds were collected from rubber plantation and were manually de-hulled to separate the kernels from the shells. After cleaning the rubber seed kernels, it was ground to smaller particles and was placed on a tray. It was dried in the oven at 105°C for 4 hours. After the drying process, the rubber seed particles were placed in the airtight container for the extraction process.

Oil Extraction Process

The extraction of rubber seeds oil from the rubber seed kernel particles was done using Soxhlet extractor. An amount of rubber seed particles was placed into the paper thimble in the Soxhlet extractor. N-hexane was used as the solvent is pour into the round bottom flask. The Soxhlet extractor was heated to temperatures of 70°C, which is above the boiling temperature of n-hexane. The vapours of n-hexane evaporate from the round bottom flask and flow into the Soxhlet chamber where it was condensed by the cooling temperature of the condenser. The condensed n-hexane liquid was drop into rubber seed particles and extracts the rubber seeds oil and flow back into round bottom flask with the rubber seeds oil.

After the extraction process of rubber seeds oil has been done, the separation the n-hexane from the rubber seeds oil need to be separated. Rotary evaporator was used to separate the n-hexane from the rubber seeds oil.

Tribotester Apparatus

A four-ball wear tester machine was used under ASTM D4172-B conditions. The machine uses four balls, one ball on the top and three balls at the bottom of the ball pot wherein the lubricant are being placed. The top ball pessed the three-bottom ball which is being held strongly in the ball pot. The top ball is being held and made to rotate at the desired speed, while the bottom three balls are pressed against the top ball. The four-ball tribotester machine comprised of the oil cup assembly, collet, and the ball bearings. Before conducting each test, the surfaces of the components were cleaned with acetone. A thermocouple was embedded at the bottom of the ball pot to measure the oil temperature. A heating block is located at the bottom of the ball pot which controls the temperature of theexperiments. For these wear tests, a load of 392.4 N, speed of 1200 rpm and time of 1 hour were used at lubricant temperatures of 75°C.

The standard balls used for each test, are made from AISI E-52100 chrome alloy steel, with the following specifications: diameters 12.7 mm; extra polish (EP) grade 25; hardness 64-66 HRC (Rockwell C Hardness).

Tribotester Apparatus

The lubricants used for this experimental study wastherubber seeds oil. This oil was blended with 20-80% by volume of SAE10W-30 mineral engine oil. The results obtained from experiments using rubber seeds oil (RS100) in different volumetric blending ratios were compared with the results from commercial mineral oil (E100). Each trial test uses 10 ml of the lubricant.Table 1 shows the kinematic viscosity and density in detail.

Table 1. Kinematic Viscosity and Density of the Oil Samples

	Rubber seed oil	Mineral engine oil SAE 10w-30
Code	(RS100)	(E100)
kinematic viscosity at 40°C (mm²/s)	39.10	42.84
Density at 25°C (g/cm³)	0.90	0.86

3.0 TEST PROCEDURES

Before setting up the tribotester, the ball pot and the steel balls were thoroughly cleansed using acetone and wiped dry using fresh lint free industrial wipe. No trace of solvent should have been left when the lubricants were introduced and the parts were placed together. The steel balls were placed into the ball pot assembly and the assembly was tightened using a torque wrench in order to prevent the bottom steel ball from moving during the experiments. The top, spinning ball was locked inside the collet and tightened onto the spindles, then the test lubricants were introduced into the ball pot assembly. The assembled ball pot components were installed onto the non-frictions disc in the four-ball machine and the test load was applied slowly to avoid the shock loadings. Thereafter, the lubricant was heated to 75°C by the tribotester built-in heater. When the set temperature was reached, the motor was switch on to drive the top balls at a desirable speed. After one hour, the heater was turned off and the oil cups assembly was removed from the machine. The test oil was drained off from the oil cup and the ball bearings were wiped using fresh lint free industrial wipe.

Wear Scar Diameter

The three bottom test balls were used to calculate the average of the wear scar diameter. They were initially cleaned with acetone and wiped until dry using fresh lint free industrial wipe. A suitable magnification lens was chosen and the image of the wear scar was focused until a clear picture was shown on the computer screen. The image was captured, saved and by using available software, the wear scar diameter was measured and calculated. The increase in wear scar diameter is related to the increase of friction and load.

Friction Torque and Coefficient of Friction

The friction torque was recorded using specific data acquisition system from the four-ball tribotester machine. The frictions torque initially increased rapidly, but after 10 min, it became stable and at steady-state condition. The average friction torque was recorded and the friction coefficient, was calculated according to IP-239, as shown in equation (1):

$$M = (T\sqrt{6})/3Wr \quad (1)$$

where μ is the friction coefficient, T is the frictional torque in kg mm, W is the apply loads in kg and r is the distance from the center of the contact surfaces of the lower balls to the axis of rotation, which was set as standard 3.67 mm for the specific ball diameter. The same calculation method was used by Golshokouh et al., [17].

Flash Temperature Parameter

Flash temperature parameter (FTP) is a single number for a lubricant that fail under certain given condition showing the possibilities of lubricant films for breaking down [18]. The flash temperature parameter will decrease when wear scar diameter is increasing with load. The FTP with high value shows high performances of the lubricants and the following equation (2) was used,

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

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

4.0 RESULT AND DISCUSSIONS

The results of rubber seeds oil and mineral lubricant blends of WSD, COF, FT and FTP were analysed. Its provide an insight to a clearer understanding of the worn metal surface bearings using rubber seeds oil and commercial mineral lubricant blends.

Wear Scars Diameters

The result for wear scars diameters of the three bottoms steel balls were measured using a special microscope and the mean values of three were calculated. Figure1shows the comparison of WSD between the rubber seeds oil blends, neat rubber seeds oil and commercial lubricant. From thefigure, it could be concluded that the WSD of the neat rubber seeds oil was lowerthanthevaluesof another oil samples. For the rubber seeds blends,the lower wear occurred at E20/RS80 with 711.6μm compared with 484.4 μm for the neat rubber seeds oil and 546.4 μm for mineral oil. Therefore, the neat rubber seeds oil shown better anti-wear performance compared with other oil samples.

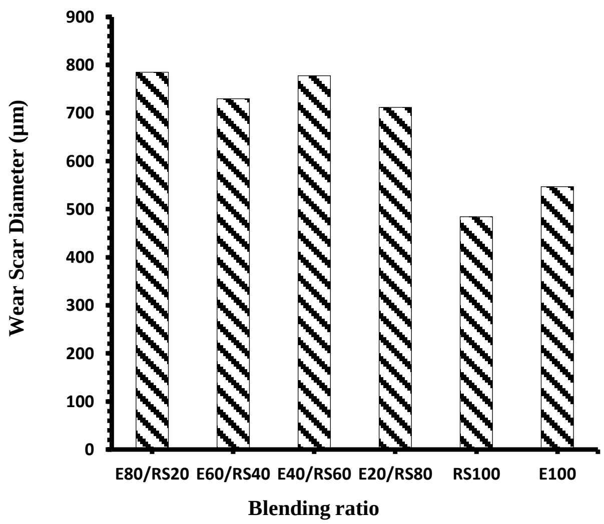

Fig. 1. Wear scar diameter for different blending ratio (%)

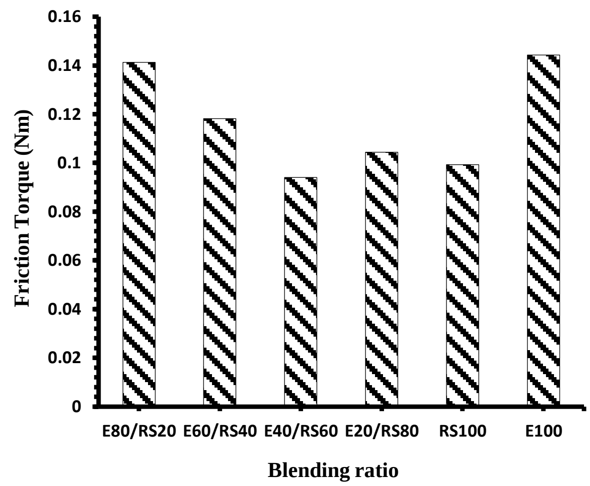

Fig. 2. Friction torque values for different blends

Friction Torque

The friction torque of the rubber seeds blends were studied under normal load of 392.4 N, at the rotational speed of 1200 rpm and the bulk oil temperature at 75°C for one hour. Figure 2, illustrated the graphs of the friction torque tests for the various rubber seeds oil blends. The friction torques results of the rubber seeds oil blends were compared with the mineral engine oil (E100) and neat rubber seeds oil (RS100). The lowest friction torque was at E40/RS60 with0.094 Nm as compared with 0.0992 Nm for neat rubber seeds oil (RS100) and 0.1442 Nm for mineral engine oil (E100). Therefore, the rubber seeds oil blended lubricants has good lubricity abilities in terms of the frictions compared with the mineral engine oil because the rubber seeds oil contain fatty acids that help the lubricant molecules to stick on the steel ball surface very well and maintain the lubricant layer. The presence of the thin lubricant films between the steel ball surfaces minimized the material transfer and adhesion of the two surfaces.

Coefficients of Frictions

The coefficients of friction for the rubber seeds blends, neat rubber seeds oil (RS100) and commercial lubricant (E100) were investigated. For each experimental condition, the COF were calculated, tabulated and the outputs were shown in Figure 3. For the rubber seeds blends, the lowest COF occurred at E40/RS60 (0.0533) compared with 0.0563 for the neat rubber seeds oil (RS100) and 0.0815 for the mineral engine oil (E100). Therefore, when 60% of rubber seeds oil blended with 40% of mineral oil and used as lubricant, it will shows a better lubrication performances as compared to the neat rubber seeds oil and commercial mineral lubricant.

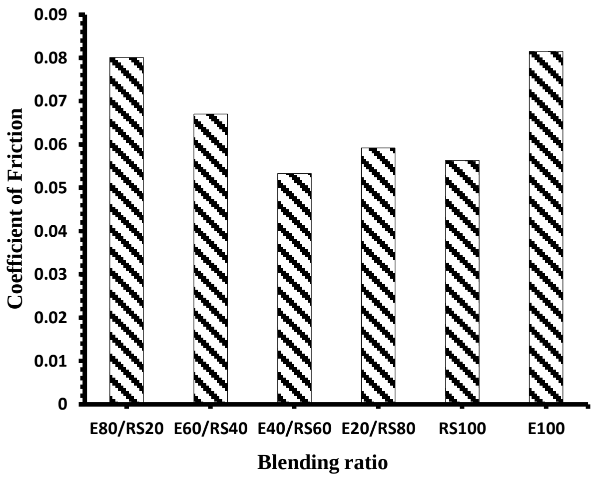

Fig. 3. CoF values for different blends

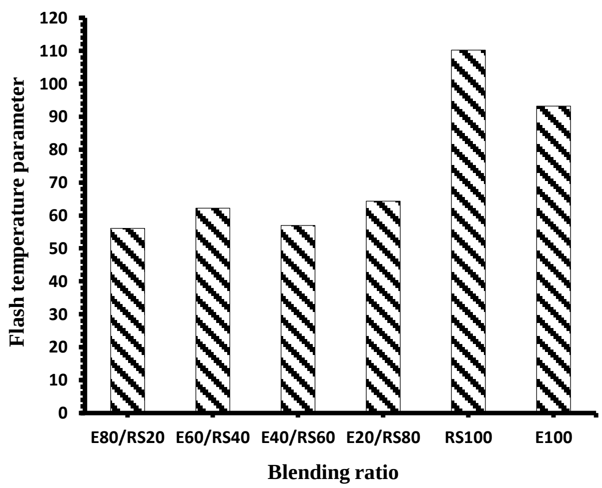

Fig. 4. Flash temperature parameter for different blends

Flash Temperature Parameter

The flash temperature parameter was calculated and tabulated for theneat rubber seeds oil, blendsof rubber seeds oil with commercial mineral lubricant and neat mineral lubricant. The results are shown in Figure4. From this figure, it could be observed that, the highest value of FTP occurred for the neat rubber seeds oil at 110.2 compared with the 93.21 for the mineral oil. For the rubber seeds blends, the higher value occurs at (E60/RS40) with 62.18 as compared with another blends samples. Therefore, when the neat rubber seeds oil was used as lubricant, it will lower the possibility for lubricants film to breakingdown and increasing the lubricity performance compared to other oil samples.

5.0 RESULT AND DISCUSSIONS

There are conclusions given below based on this study:

i. Rubber seeds blend (E40/RS60) showed lower friction coefficients compared to the commercial mineral oil.

ii. Steel ball lubricated with rubber seeds blendsshowed larger wear scar diameter thanthose lubricated with the commercial mineral oil.

iii. Steel ball llubricated with neat rubber seeds oil showed smaller wear scar diameter thanthose lubricated with other oil samples.

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

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