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INVESTIGATION THE TRIBOLOGICAL CHARACTERISTICS OF CASTOR OIL WITH MINERAL OIL BLENDS

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ABSTRACT

Vegetable oil can be a possible substitute for petroleum-based products for many applications and is the focus of research in this study. Besides being a renewable energy resources with instant and perpetual availability, vegetable oil based products can also have the potential for reducing carbon dioxide and hydrocarbon emission, when used in such applications as lubricant in internal combustion engines and in industrial processes. In this paper, the impact of mixing mineral oil at certain proportions with vegetable oil is discussed its use as commercial lubrication oil is also outlined, The tribological attributes are investigated through the well known four ball tribotester method. In the experiments, castor oil is blended at volumetric ratio ranging from 20 to 80 % with commercial mineral oil, where the setup is consictent with ASTM D4172. Results indicate that a mix of castor oil with commercial lubrication oil rather than mineral oil, can bring down the diameter of wear scar. The mix exhibits a decrease in the coefficient of friction when compared with lubrication oil. A belend of castor oil with some commercial lubricant oil has shown a better tribological performance as compared to neat castor oil.

KEY WORDS: *Castor oil, blending, lubrication, coefficient of friction, tribological*

INTRODUCTION

In the mid nineteenth century, researchers had proposed various methods and techniques for the utilization and generation of petroleum based products. A by-product of such efforts had led to environmental issues as greenhouse effect, global warming and so on. Consequently, the impacts of petroleum products on the environment are now being universally understood. Moreover, there are many petroleum products, which have some contaminations, and efforts are being made to minimize their effects by using biodegradable products. A survey found that almost twelve million tons of lubricant and its by-products are consistently added and retained as a part natural environment (Delgado *et al.*, 2010). As a result, biodegradable oil items might become the ultimate substitute to the petroleum based products. Animal fats and vegetable oils are suggested as an alternative to mineral-based oil such as grease. It is to be mentioned that the use of oil from vegetables as lubricants is nothing contemporary. Studies have also suggested that in ancient Egypt, vegetable oils have been utilized for the construction of monuments (Nosonovsky, 2000).

The advantages of vegetable oils over mineral resources are that they are biodegradable and are less toxic. Vegetable oils can be utilized as bio-ointments in two ways: one by straight forwardly utilizing the perfect vegetable oils without mixing, and other is by utilizing certain mixing proportion of vegetable oils alongside the commercial lubricants. In addition, the investigation on the tribological performance for sliding metals by using biodegradable oil as lubricant has demonstrated that the vegetable oils provides a better greasy performance when compared to other mineral oils. The reason of this effective lubrication is that they contain a numerous unsaturated and polar ester bunch segment that perfectly affects the conditions during the reactant to sliding movement (Kalin *et al.,* 2006). Oil of good greasing quality is usually obtained from vegetable oil in order to attain minimum frictional coefficient. On the other hand, various scholars have also reported that most vegetable oils have lower coefficient of friction but have a higher wear rate. In another study on the chemical reaction on the surfaces of metal, where fatty acids were present in the vegetable oils, it was found that during sliding the metallic soap films were washed away and produced the non-reactive detergent, which increased the wear (Golshokouh *et al.,* 2014).

Many researchers have tried palm oil for engineering practice, which incorporates unrefined palm oil in diesel engines (Bari *et al.,* 2002), due to its capability as water driven liquid (Wan-Nik *et al.*, 2005a , Wan-Nik *et al.,*

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2005b, Wan-Nik *et al.*, 2007) and as a metal shaping grease (Syahrullail *et al.*, 2005 , Syahrullail *et al.*, 2011). The study of palm oil as grease can be classified into 3 main groups, which include, i) using pure palm oil as a trial lubricant (Ing *et al.,* 2012 , Maleque *et al.,* 1997), ii) using palm oil a mixture of two immiscible fluids (Hayati *et al.*, 2009) and iii) using additives (substances that upgrade the quality of lubricants) with palm oil (Jabal *et al.,* 2014, Maleque *et al.*, 2000, Shanhua *et al.*, 2016, Bongfa *et al.*, 2015). Results from these studies show that palm oil can be utilized broadly as a part of engineering exercises, with possible side effects of vegetable oil oxidation. According to Maleque *et al.,* (1997), the trans-esterification also enhanced the thermal stability of the palm oil. This study investigates the friction coefficient and wear execution of castor oil blends with mineral oil in different blending volume ratio using a four ball tribotester.

MATERIALS AND METHOD

This study essentially utilized a four-ball analyzer machine, which is described by Boerlage, (1933) for investigation of attributes for a lubricant. One ball is at the top, while three balls are used at the base of the setup. The three baseballs are unequivocally grasped in a pot with lubricants and were analyzed and clasped as opposed to the top. Each segments of the four-ball tribo-tester machine constitute the oil cup assemblage, the collet, and the ball bearings. Before starting each test, CH3-CO is used to clean the surface of all parts. To gauge the oil temperature, a thermocouple was attached at the ball pot base. A warming piece was located at the base of the ball pot, which controlled the temperature. In this research, the wear test was performed at 40 kg loads for one hour at a lubricant temperature of 75^{o}C and at 1200 revolution per minute (RPM).

Ball bearings wereused as a part of this study and were manufactured using a AISI E-52100 chrome and (alloy) steelcombination with the following important parameters: dia 12.7 mm; extra polish (EP) grade 25; hardness 64–66 HRC (Rockwell C Hardness).For every test 4new balls were used. In a trial study, castor oil was used as lubricant. This oil was blended with 20-80% by volume of PETRONAS/SAE40 engine oil. The experimental results using castor oil in different volumetric blending ratios were compared with results from commercial mineral oil (ENG100%). The ball pot and the steel balls were thoroughly cleansed using wiped dry fresh lint industrial wipe and acetone. It was ensured that no trace of solvent was left when lubricants were added, and the parts set together. The steel balls were set into the ball pot gathering and the test setup was fixed by utilizing a torque wrench to avoid the base steel ball from collapsing into the tests. The turning ball at the top was bolted in the inner side of the collet and fixed onto the spindles, and then the test oils were brought into the ball pot. When the temperature reached the set point of 75°C the motor was switched on to run the balls at the top to a desirable speed. The test oil was drained off from the oil cup and fresh lint free industrial wipe were applied for ball bearing cleaning.The lubricity of test lubricants and three balls were measured along with their wear scar diameter. The assessment of wear scar was done by a computer optical program, and checking by electronic magnifying instrument and from photomicrograph. By following the procedure discussed, the distance of wear scar was obtained for each of three altered balls. It shows that increased wear scar diameter resulted in extreme wear scar. Utilizing information procurement framework, the friction torque was recorded with the help ofthe four ball tribotester apparatus. The friction torque for all test lubricants expanded quickly towards the start of the test from 5 to 10 min, then became steady and achieved steady state after 10 min.

The mean frictional torque was noted for the steady t condition and the coefficient of friction was determined according to IP-239, as shown in Equation (1):

$$\mu = \frac{T\sqrt{6}}{3Wr} \tag{1}$$

where μ = friction coefficient, T = frictional torque in kg mm, W = applied load in kg and r = the distance from the center of the contact surfaces on the lower balls to the axis of rotation, which was set as standard 3.67 mm for the specific ball diameter. Using the procedure of Golshokhou *et al.,* (2013) the turning effect of friction was noted by the computer, which then automatically estimated the coefficient of friction. FTP (flash temperature parameter) is a solitary numeric value which is widely used for communicating the censorious flash temperatures, when the lubricants flop under certain condition. The FTP specifies minimum potential results of lubricant films for separation as discussed in (Masjuki *et al.,* 1997). High estimation of FTP shows superior performance of the greases.

The FTP is defined as:

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

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

RESULTS AND DISCUSSIONS

This study examined the blending of castor oil and the results gave a better understanding of the worn surface of ball bearings. Ingredients utilized in the study include castor oil and blends. Testing for oil analysis included kinematic viscosity analysis, *WSD*, *COF* and *FTP*. Final analysis includes results comparison with 100% commercial mineral lubricant. The density of fluid is explained as the units of the mass per unit volume. Experiments were performed for estimating the density of the blend samples of castor oil and commercial mineral oil using a hydrometer. Kinematic viscosity was measured as the resistances of a fluid that is deformed by either the shear stresses or the tensile stresses. It is also defined as internal frictions of the fluid. For measuring the viscosity of both lubricants and for assessing the fluidity, a viscometer was utilized. The viscometer works with a spindle circles with a definite speed.

Table 1: Viscosity (mm^2/sec) of the blend samples of castor oil with commercial mineral oil.

Temp (°C)	CA	CA	CA	CA	CA	ENG
	20%	40%	60%	80%	100%	100%
40	161.8	594.7	472.9	249.2	333	102.5
75	33.79	67.81	70.77	37.94	38.75	23.22
100	12.12	12.55	20.68	17.87	16.93	12.07

In Table 1 above, it can be seen that the viscosity of all lubricant samples reduces with the increase in temperature. One of the most significant effects of lubricating oil at 100°C is its viscosity. The blend lubrication viscosities were in the ranges from 12.12 to 20.68 mm^2/sec. On the other hand, at 40°C, the blend lubricant's viscosities were in the range of 161.8 to 594.7mm^2/sec. Figure 1 below is a comparison between the viscosities of the blend samples of castor oil with commercial mineral oil at 75°C before the four-ball tests were carried out. It can be concluded that the viscosities of castor oil blends were higher than the viscosity of 100% commercial lubricant. The highest viscosity of castor oil blend lubricant at 40°C was at 40 % castor oil added lubricant is 594.7mm^2/sec.

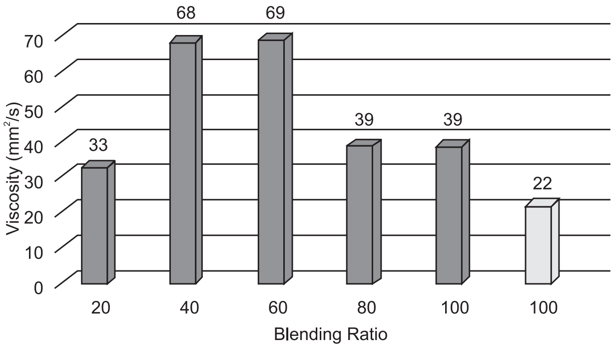

Figure 1: Effect of bio-lubricant blend on viscosity before four ball test at 75°C.

Figure. 2 below shows the comparison of *WSD* between the castor oil blends, neat castor oil and commercial lubricant. For castor oil blends, it may be concluded that the *WSD* of the neat castor oil was higher than the value compared with another oil samples. From the figure, one can also observe that the lower wear occurred at 20% and 40% castor oil blend. On the other hand, for castor oil blends, the higher *WSD* occurred at 80% blend compared to other percentages of blends and comparing with the 100% commercial lubricant. Therefore, the castor oil in 20 and 40% blends works as one of the anti-wear additives and reduces the *WSD*. Tests were performed to investigate the castor oil's friction performance under normal load of 392.4 Newton and at bulk oil temperature of 75°C for 1h with rotational speed of 1200 rpm.

The outcomes of the torque were plotted and are shown in Figure 3 below. The friction torques results of the castor oil blends were compared with the 100%

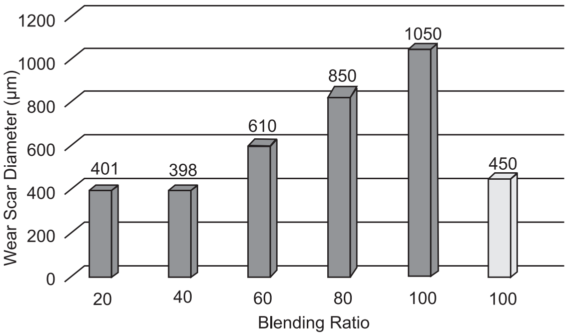

Figure 2: WSD (µm) vs blending ratio.

commercial lubricant oil. For the castor oil, lowest friction torque occurred at 80% (0.10808 Nm) as shown in Figure 3. Therefore, the castor oil blended lubricants have better lubricity abilities in terms of the frictions comparing with the 100% commercial lubricant. The coefficients of friction (COF) for the castor oil blends, the 100% commercial lubricant were investigated.

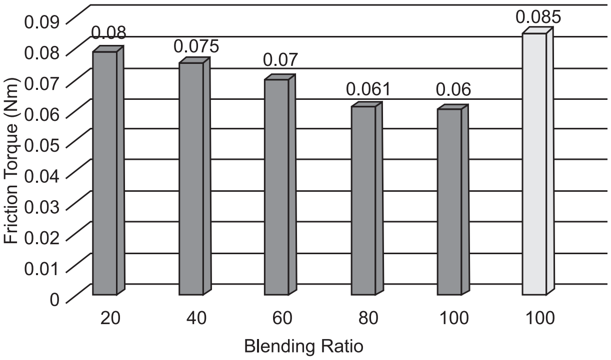

Figure 3: Friction Torque vs Blending Ratio.

Under each exploratory state, the COF were computed, tabulated and the effects were surveyed from Figure 4. For the blends of the castor oil, the lowest COF occurred at 80% (0.06102) as indicated in Figure 4 below. Therefore, when 80% of castor oil blends were used as lubricants, it will give better lubricity capacity as far as friction contrasted with the neat castor oil and the 100% commercial lubricant. FTP was estimated for the neat castor oil.

The increase is shown in Figure 5 below. For the blends of castor oil, the highest FTP occurred at 40% (153.35). Therefore, when 40% of castor oil was used as lubricant, in a way it has the likelihood of decreasing lubricant film to break down, thereby increasing the lubricity, as compared to 100% commercial lubricant.

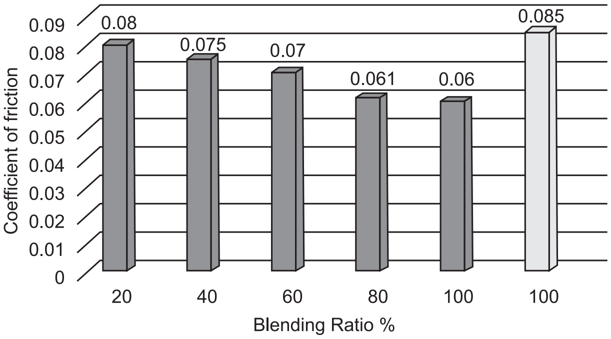

Figure 4: COF vs Blending Ratio.

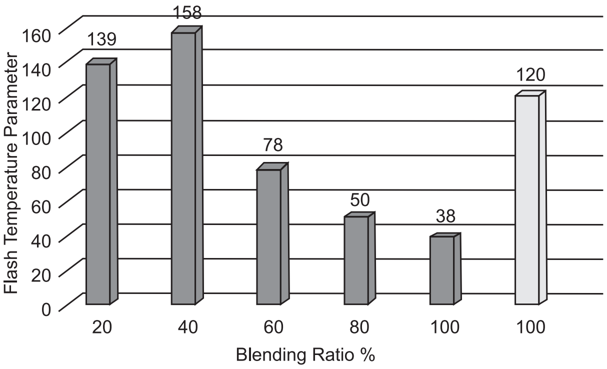

Figure 5: FTP vs Blending Ratio.

From Figure 6 below, it can be seen that the wear scar for all mixes of the castor oil with mineral engine oil was found to be circular except the case of (D) which having a pyramidal shape. In addition, the size of scar diameter increases with increase in blending ratio as compared with the neat castor oil. The edges

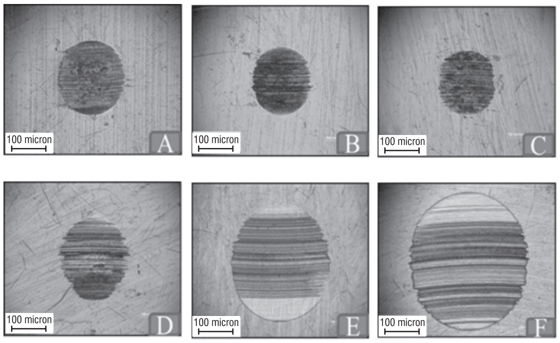

Figure 6: Optical micrographs of wear area on the balls surface for castor oil with mineral oil blends (magnification 10X and 100 micrometers): (A) E100%; (B) CA20%; (C) CA40%; (D) CA60%; (E) CA80%; (F) CA100%.

are frequently ragged and sometimes may be obscured by metal, for the blending ratio of 80%. Some of the grooves were deep (dark region) and some were shallow (light color region), and for the 40% and 20% blends can see the occurrence of oxidation.

CONCLUSION

Study shows that 80% of castor oil blend lubricant upgrades a lubricants performance, based on the lower COF and lower value of friction torque, as compared to the 100% commercial lubricant. Also, wear scar diameter for the castor oil has lower value at 40% blending ratio. This suggests that blend of castor oil with lubricant has potential for acting as a nti-wear lubricant. Analysis also suggests that the castor oil has the potential in becoming a partial alternative bio-lubricant. This is because blends do not give any negative effect on the wear phenomena and lubricating performance.

REFERENCES

1. *Bari, S., Lim, T. H., and Yu, C. W. (2002), "Effect of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine", Renew. Energy, Vol. 27, pp.339–351*
2. *Boerlage, G. (1933), "Four-ball testing apparatus for extreme pressure lubricants", Engineering, Vol.136, pp.46-47.*
3. *Bongfa, B., Atabor, P. A., Barnabas, A., and Adeoti, M. O. (2015),"Comparison of lubricant properties of castor oil and commercial engine oil", Journal of Tribology, Vol.5, pp.1-10.*
4. *Golshokouh, I., Golshokouh, M., Ani, F. N., Kianpour, E., and Syahrullail, S. (2013), "Investigation of the physical properties for jatropha oil in different temperature as lubricant oil", Life Science Journal, Vol.10, pp.110-119.*
5. *Golshokouh, I., Syahrullail, S., Ani, F. N., and Masjuki, H. H. (2014), "Investigation of Palm Fatty Acid Distillate Oil as an Alternative to Petrochemical Based lubricant", Journal of Oil Palm Research, Vol.26, pp.25-36.*
6. *Hayati, I. N., Yaakob, B. C. M., Chin, P. T., and Idris, N. A. (2009), "Thermal behavior of concentrated oil-in-water emulsions based on soybean oil and palm kernel olein blends", Food Research International, Vol.42, pp.1223–1232.*
7. *Ing, C. T., Rafiq, A. K. M., Azli, Y., and Syahrullail, S. (2012), "The effect of temperature on the tribological behavior of RBD palm stearin", Tribology Transactions, Vol.55, pp.539–548.*
8. *Jabal, M. H., Ani, F. N., and Syahrullail, S. (2014), "The Tribological Characteristic of the Blends of RBD Palm Olein with Mineral Oil using Four-ball Tribotester", Jurnal Teknologi, Vol.69, pp.11-14.*
9. *Kalin, M., and Vizintin, J. (2006), "A comparison of the tribology behavior of steel/steel, steel/DLC and DLC/DLC contacts when lubricated with mineral and biodegradable oil", Wear, Vol.261, pp.22–31.*
10. *Maleque, M. A., and Masjuki, H. H. (1997). "Investigation of the anti-wear characteristics of palm oil methyl ester using a four-ball tribometer test", Wear, Vol.206, pp.179–186.*
11. *Maleque, M. A., Masjuki, H. H., and Haseeb, A. S. M. A. (2000), "Effect of mechanical factors on tribological properties of palm oil methyl ester blended lubricant", Wear, Vol.239, pp.117–125.*
12. *Masjuki, H. H., and Maleque, M. A. (1997). "Investigation of the anti-wear characteristics of palm oil methyl ester (POME) contaminated with lube oil using a Four-ball machine of IP239 standard", Wear, Vol.206, pp.179-186.*
13. *Nosonovsky, M. (2000), "Oil as a lubricant in the ancient middle east", Tribology Online, Vol.2-2, pp.44–49.*
14. *Quinchia, L. A., Delgado, M. A., Valencia, C., Franco, J. M. and Gallegos, C. (2010), "Viscosity modification of different vegetable oil with EVA copolymer for lubricant applications", Industrial Crops and Products, Vol.32, No.3, pp.607-612.*
15. *Shanhua, Q., Xuliang, C., Liguo, L., and Qingzhong,*

L. (2016), "Tribological Properties of the Castor Oil Affected by the Additive of the Ionic Liquid [HMIM] BF4", ASME. Journal of Tribology, Vol.138, pp.14501-14505.

16. *Syahrullail, S., Nakanishi, K., and Kamitani, S. (2005), "Investigation of the effects of frictional constraint with application of palm olein oil lubricant and paraffin mineral oil lubricant on plastic deformation by plane strain extrusion", Japanese Journal of Tribology, Vol.12, pp.877–885.*

17. *Syahrullail, S., Zubil, B. M., Azwadi, C. S. N., and Ridzuan, M. J. M. (2011), "Experimental evaluation of palm oil as lubricant in cold forward extrusion", International Journal of Mechanical Sciences, Vol.53, pp.549–555.*

18. *Wan-Nik, W. B, Ani, F. N., and Masjuki, H. H. (2005), "Thermal stability evaluation of palm oil as energy transport media", Enegy Conversion And Management, Vol.46, pp.2198-2215.*

19. *Wan-Nik, W. B, Ani, F.N., and Masjuki, H. H. (2005), "Rheology of bio-edible oils according to several rheological models and its potential as hydraulic fluid", Industrial Crops and Product, Vol.22, pp.249 -255.*

20. *Wan-Nik, W. B., Maleque, M. A., Ani, F. N., and Masjuki, H. H. (2007), "Experimental investigation on system performance using palm oil as hydraulic fluid", Industrial Lubrication and Tribology, Vol.59, pp.200-208.*