Preliminary Feasibility Studies of Vegetable Oil as Substitution to Mineral Lubricant

Muhammad Aizat bin MD Alias
*Muhamad Azwar bin Azhari**
Faculty of Engineering Technology,
Universiti Teknikal Malaysia Melaka, Malaysia
**azwar@utem.edu.my*

ABSTRACT

The negative factor of mineral oil such as non-biodegradable and toxic influence many researcher to discover the new alternatives lubricant in order to substitute the mineral oils. However, there is restriction when using vegetable oil as lubricant which is there have low oxidation stability which can leads to low lubricity performance. This paper studies the physical and chemical properties in terms of coefficient of friction, wear scar diameter and flash point of vegetable oils and mineral oils. It is expected that the vegetable oils have a higher value of a flash point than mineral oils and lower lubricity performance than mineral oils due to the presence of additive in mineral oils.

Keywords: *Palm Oil, Corn Oil, Canola Oil, Bio-Lubricant*

Introduction

A substance that separating two contacting surface in relative motion with a purpose to reduce the friction between them is called a lubricant. Every mechanical or electrical part involving movements need lubricants in order to minimized friction and wear. Some machinery equipment needs lubricant for energy consumptions. According to Ahmed and Nassar, back in time before centuries, lubricants were introduced by farmers to lubricate the axle of their ox carts [1]. Other than that, another prove was found to show that the lubricant has been used several thousands of years before centuries (BC). Caines et al., stated on the book that there is historical artifact of various forms of primitive bearings on years B.C in the Middle East and traces of bituminous substances adhering on a primitive bearing that contain in

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2017-02-13
Accepted for publication: 2017-05-31
Published: 2017-08-15

Mesopotamia potter's wheel dating from 4000BC [2]. An Egyptian mural dating to about 2000 B.C illustrate a liquid (either water, natural oils, grease or blood) were assumed as lubricant being poured ahead of transporting sledge that carried a statue[2].

The application of animal fats and vegetable oils as lubricants was widely used before a year of industrial revolution came. Anderson stated that during 16th century, lubricants were made of animal oils, vegetable oils, animal oils or mixture two of it [3]. An example of natural lubricants that were used to lubricated wooden charts wheels and bearings were beewax, animal tallow and water. Therefore, the lubricant and the usage of it a not a new thing as they have been used thousand years before and improvise from time to time to fulfill today needs [4]. According to [3], the usage of petroleum is not a new thing as it has been use since the ancient Assyrians used it for lighting, an Egyptians used for embalming and for American Indians used crude petroleum as for medicines. About two hundreds year before, the petroleum based product such as mineral based lubricant demand started to increases due to the industrial revolution era. From time to time, increasing of industrialization, modernization and development causing the high demand of petroleum, consequently made the oil reserve decreases and causing an increasing of oil prices [5].

The drawback of using this type of non-renewable resource lubricant is that it can contaminate and imposed negative effects to the environment such as surface water and ground water contamination, air pollution, soil contamination and consequently made the agricultural product and food contaminated due to their inappropriate use [6]. According to Shashidhara and Jayaram, about 80% of all occupational diseases of operators were due to skin contact with mineral based cutting fluids. Industries do not have efficient management systems that propose an alternative of a proper way of disposal of these non-biodegradable products [7], hence became an environmental threat [8]. Therefore, there is an issue due to the difficulties of disposing of the waste oil [4]. At this circumstance, an alternative way to overcome the environmental issues arise by developing a bio-lubricant that are more environmentally friendly, non-toxic and renewable resources for a better future [9]. Hence, this study will involve of use of vegetable oil as a replacement for mineral based oil as alternative to overcome these issues.

Vegetable oil are suitable candidate to develop as bio-lubricant and as an important alternative solution to substitute the conventional lubricant. This is because vegetable oil based lubricant are biodegradable, renewable source and nontoxic compared to petroleum based lubricants [4]. Studies reported by Petlyuk and Adams stated that vegetable oils have a better lubricating abilities than conventional (synthetic and mineral based oil) due to the large amount of unsaturated and polar ester groups contain in vegetable oils [10]. Besides that, vegetable oil can act as anti-wear additives and friction modifiers, due to strong interactions with the lubricated surfaces. Their Amphiphilic Nature gives them a good film or force relationship and provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear due to long fatty acid chains and the presence of polar groups in the vegetable oil structure [11].

Moreover, Fox and Stachowiak claimed that vegetable oils are particularly effective as boundary lubricants as the high polarity of the entire base oil allows strong interactions with the lubricated surfaces [12]. Boundary lubrication performance is affected by attraction of the lubricant molecules to the surface and also by possible reaction with the surface. According to Shashidhara and Jayaram, it is expressed that most of the vegetable oil that were tested exhibit low values of friction than mineral oil during stamping operation [7].

Material and Methodology

In this study, three difference commercialized cooking oil which is palm oil, corn oil and canola oil are selected as the lubricant in order to substituting a conventional lubricant. After the samples were prepared, it were tested using a Fourball Tribotester and confirm with the ASTM standard D4172. This standard of procedure was used to determine the properties of the lubricant at the standard temperature, speed and load. The results that can be gained from this type of test are the coefficient of friction and wear scar diameter that occurs on the bearings by using a specified type of oil. In general, three 12.7 mm diameter steel balls were clamped together and covered with the lubricant to be evaluated. A fourth steel ball, referred to as the top ball, was pressed with a force of 392 N [40 kg] into the cavity formed by the three clamped balls for a three-point contact. The temperature of the test lubricant was regulated at 75 °C and then the top ball was rotated at 1200 rpm for 60 min. The lubricants were compared by using the average size of the scar diameters worn on the three lower clamped balls.

In this study, kinematic viscosity for different lubricant sample also was measured. An instrument that measuring kinematic viscosity of the sample a Kittiwake Heated Viscometer. The kinematic viscosity a measured by a time taken of the metal ball travel inside the internal tube when the instrument tilted side to side. Other than that, the sample also were tested by using Pensky Marten Closed Cup Flash Point (ASTM D93). This standard of procedure was used to determine the property of the lubricant flash point temperature.

Results and Discussion

Table 1: Properties of Difference Type of Lubricant

Oil Sample	Properties			
	Coefficient of Friction	Wear Scar Diameter (µm)	Kinematic Viscosity (cSt)	Flash Point (ºC)
Palm Oil	0.125	144	43.3	248
Corn Oil	0.120	141	38.26	250
Canola Oil	0.122	145	38.78	242
Mineral Oil	0.075	85	103.3	206

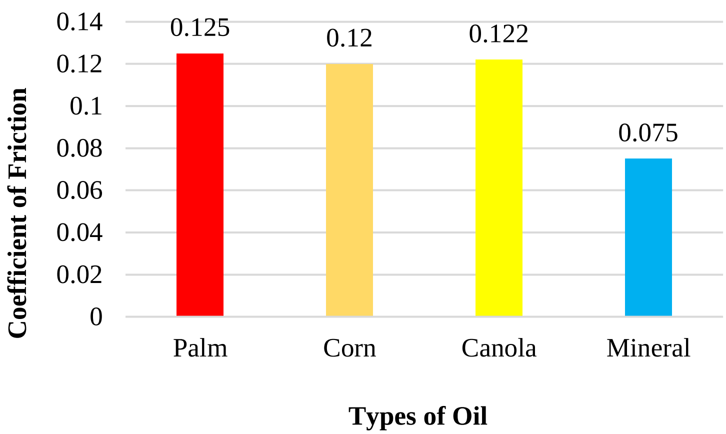

Figure 1: Coefficient of Friction for Different Oil Sample

The prepared oil samples were tested using Four-ball Tester and the results are displayed in Figure 1. From Figure 1, it is observed that the coefficient of friction for palm oil reads at 0.125. From the four ball tests, it was also observed that the coefficient of friction for corn oil and canola oil were at 0.120 and 0.122 respectively. However there is a comparatively low coefficient of friction was exhibited by petroleum based lubricant where the result read 0.075. A study conducted by Syahrullail et al., [13] reported that the vegetable oils have poor corrosion protection during higher pressure operation due to the presence of oxygen double bond. During a four ball test, the oxygen double bond contained in the chemical structure of vegetable oils tends to react with ball bearing. Therefore, the material became a third body abrasion mechanism in between of the top and bottom ball bearing contact surfaces, as a consequence, it would increase the frictional resistance and coefficient of friction. [13] This finding has a same trending result reported by Nuri et al., [14] which stated that the value of coefficient of friction by using a pin on disk test for corn oil without the presence of additive (ZDDP) showed an increased trend as the load were also increased. These results were supported by the previous study done by [4] which showed that the coefficient of friction for commercialized cooking corn and canola oil also have a higher coefficient of friction.

Wear scar diameter

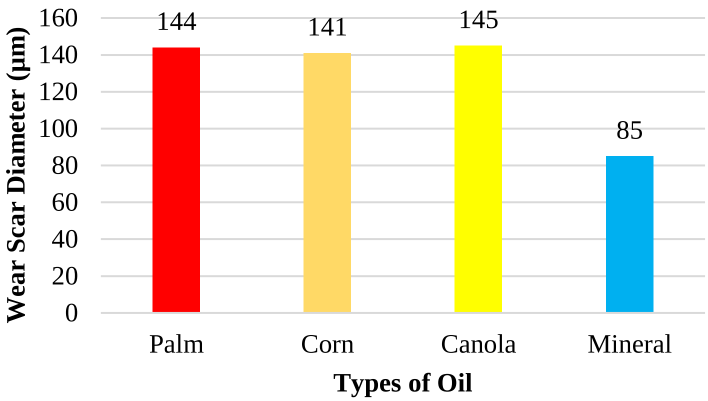

Figure 2. Wear Scar Diameter for Different Oil Sample

Referring to Figure 2, it can be seen that the result of wear scar diameter of palm oil, corn oil, canola oil are relatively larger compared to mineral oil. Palm oil, corn oil and canola oil displayed a wear scar diameter of 144 µm, 141 µm and 145 µm respectively. On the other hand mineral based lubricant exhibited a wear scar diameter of only 85 µm. Wear scar diameter is a property that can show the lubricant performance in terms of lubricity. Besides that, there is a relationship between the coefficient of friction and wear scar diameter. Based on the result, it shows that all of the value of wear scar diameter for vegetables oil sample a higher than mineral oil sample as the coefficient of friction also higher. This findings correlate with [13] which the results displayed that the palm oil have larger wear scar diameter than commercial stamping oil (represent mineral oil) due to oxygen element contained in vegetable oil chemical structure that led to oxidation. This result is also supported by Srivastava and Sahai [15] and Azhari et al., [16] which stated that oxygen element contained on the vegetable oil will react with free radical hence forming peroxide radical that causing oxidation. The oxidation reaction will react on the surface of the ball bearing, hence making the ball bearing producing high wear rate which led to higher friction (coefficient of friction) and larger wear scar. [13] This finding correlates with previous study done by [4] which discovered that a pure commercialized cooking oil (canola and corn oil), have a higher wear scar diameter and coefficient of friction. Therefore, the larger wear scar diameter is the outcome when using vegetable oil as lubricant, hence it is showed that the vegetable oil has a low lubricity characteristic.

Kinematic Viscosity

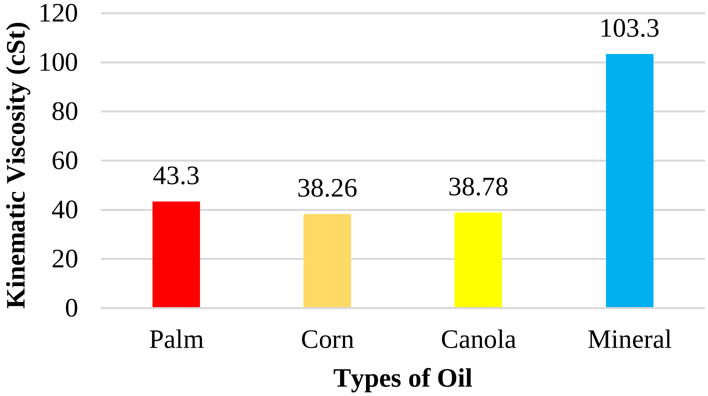

Figure 3: Kinematic Viscosity for Different Oil Sample

Based on the result as depicted in Figure 3, it is shown that vegetable oil (palm oil, canola oil and corn oil) are less viscous than mineral oil. From the result obtained in Figure 3, it was observed that the palm oil, corn oil and canola oil exhibit a lower value of kinematic viscosity at 40°C which is 43.3 cSt, 38.26 cSt and 38.78 cSt respectively. Meanwhile, mineral based lubricant displayed a higher value of kinematic viscosity which is 103.3 cSt, which means that the mineral oil based lubricant a more viscous than all vegetable oil sample. A higher value of kinematic viscosity indicate that the lubricant are suitable for high speed and low loads application, meanwhile, on the other hand, a lubricant with lower kinematic viscosity are suitable for low speed and high loads application. [17]

Flash Point

From the results obtained in Figure 4, it is shown that the flash points of palm oil, corn oil, and canola oil are better than mineral oil itself. Palm oil, corn oil and canola oil displayed a good flash point which is 248°C, 252°C and 242°C respectively. On the other hand, mineral based lubricant displayed a lower flash point than vegetable oil which is only 205°C. A higher flash point indicated that the lubricant is suitable for an application for a higher temperature like transformer oil. This statement correlates with studies conducted by Abeysundara et al., [18], Biermann and Metzger [19] which stated that bio-lubricant such as sunflower oil and soya bean oil were used as transformer oil due to their flash and fire point value which were higher than mineral oil. [7] reported that Neem oil and Karanja oil passed under emulsion stability test at normal and high temperature which is a suitable property as a cutting fluid.

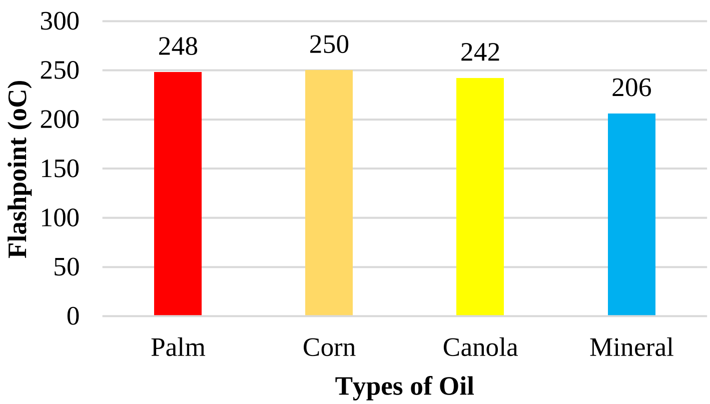

Figure 4: Flash point for Different Oil Sample

Meanwhile, Robert et al., [19] reported that the characteristic of the lubricant that were used as engine oil were depending on the temperature and it should be designed so that the lubricant at optimum condition when it operates at steady state operating temperatures which ranged between 100°C and 110°C. Hence, based on the result, vegetable oils displayed a more superior property compared to mineral oils as their flash points are higher than mineral oil. Furthermore, the vegetable oils meet the requirement of standard in terms of flash point property as they fall within the range of specification for the conventional lubricants by referring the Standard Specification for Performance of Active API Service Category Engine Oils (ASTM D4485).

This finding is also supported by Gawrillow [20], Honary [21] and Aluyor et al., [22] which stated that the vegetable oils have low volatilities as exhibited by their higher flash point compared to mineral lubricant.

Conclusions

The results from this study exhibited that mineral oil has a better lubricity performance in terms of coefficient of friction and wear scar diameter than vegetable oils due to the presence of additive in the mineral oil. In terms of flash point, mineral oils have lower flash point than vegetable oils because vegetable oils consist of low volatilities compound on it. With a higher value of flash point, it showed that the usage of vegetable oils is applicable in industrial for a high temperature application such as electrical insulating oil or for an internal combustion engine application. Vegetable oils may not be suitable to be used as lubricants in their natural form due to their poor thermo-oxidation stability, low temperature behavior and other tribo-chemical degrading processes that occur under severe conditions of temperature, pressure shear stress and environment. Although the values of the coefficients of frictions and wear scar diameters were slightly larger compared to the results shown by the commercial mineral oil, this problem could be solved by adding proper additives. An additive such as anti-oxidations, anti-friction and anti-wear can be proposed to be added into vegetable oils to enhance vegetable oil in terms of lubricity performance. Therefore, the vegetable oils can be a substitution of mineral oils as industrial lubricant in order to preserve a good environment and a better future for the next generation.

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