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Tribology Evaluation of Jatropha as a New Environmental Source of Lubricant

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Abstract

Lubricant oils play an important role in manufacturing processes for reducing friction and wear between contact surface parts at different speeds, loads and temperature. The main source for lubricant oils is mineral oil, but this source is being reduced from day to day and it is a major source for environmental pollution in the world. This research as a comparative study of friction, wear and viscosity was carried out on Jatropha oil and engine oil-based commercial lubricating oil. Wear and friction were measured with four balls Tribotester and CCD camera according to the American Society for Testing and Materials (ASTM) standard, speed (1200 rpm), load (392N) and temperature 75° C. Results show that Jatropha oil has a better condition in friction and wear instead of engine oil with base lubricant.

Keywords: Jatropha oil, renewable lubricant, vegetable oil, wear, friction

Introduction

Mineral-based lubricant oils have been used in all kinds of applications since many years ago but nowadays for two main reasons scientists are trying to find a new alternative renewable source instead of mineral oils. Firstly, the use of mineral oils causes pollution to the environment that is harmful to all people, animals and plants. Mineral oil has polluted nature through burning or entering into the air, inland water resources and seas. Previous studies showed that petroleum and mineral oil have deleterious effects on the fish life and other aquatics (Deshimaru, 1971; Ogata and Miyake,1973; Sudo, 1965; Takizawa, 1972). Mineral oils also have hazardous effects as air pollution contributors and cause such phenomena as global warming and greenhouse gases (Grant and Beer.2008; Reijnders and M.A, 2008). Secondly, the source for mineral oil is limited and in the near future will deplete. In addition, the availability of mineral oil is highly dependent on political considerations. For these concerns, researchers are obliged to do research on a new alternative source. Vegetable oils are promising alternatives because they have several advantages such as being environmentally friendly, renewable, cheap and easily manageable with simple manufactory processes whereas there is an acute need for modern forms of energy. Therefore, in recent years, several researches have been studying how to use vegetable oils to create all kinds of synthetic mineral oils, for example, lubricant, diesel, and biofuel oils. Besides, they have come up with novel methods to extract oil from biomass such as pyrolysis, fast pyrolysis, thermo chemical process, flash pyrolysis and vacuum pyrolysis (Czernik and Bridgwater, 2001; Demirbas,2009; Husnawan , Saifullah, 2007; Bridgwater and Maniatis,2004; Koppejan and van Loo, 2009; Yang, and Blanchette, 2004). For example, Masjuki did a number of researches on the palm oil and mineral oil-based commercial lubricating oil to be used in engine and compared friction, wear, viscosity, lubricant degradation and exhaust based on the same experimental conditions (Masjuki and Maleque , 1999). Maleque investigated the effects of friction, wear and viscosity on tribiological properties of blended palm oil methyl ester lubricant and showed that at lower load and temperature, the wear rate using palm oil methyl ester lubricant was low, under 5%, whereas at higher loads, the wear rates were higher. Also, the viscosity decreased with an increase in temperature but increased with increasing load(Maleque and Masjuki, 2000). Moreover, several biodegradable oils, in particular vegetable-based oils, possess a good lubricating ability that is often much better than mineral or conventional synthetic oils (Stachowiak and Batchelor, 2004; Krˇzan and Viˇzintin, 1994). Furthermore, vegetable-based oil products hold a great potential for stimulating the rural economic development because farmers would benefit from increasing demand for vegetable oils. Various vegetable oils, including palm, soybean, sunflower, rapeseed, and canola oils have been used to produce lubricants (Y. Takizawa, 1972). In this research, researchers calculated the amount of friction and wear using American Society for Testing and Materials (ASTM) condition between Jatropha oil and Engine mineral oil. In this experiment we used the four balls wear tester machine, CCD camera, viscosity meter and microscope to capture and measure the wear scar diameter (WSD) and friction.

Experimental Conditions

In this research, the four balls tester machine was utilized to determine the lubricant physical properties. In this machine, there are four balls amongst which three balls are fixed together with a ball ring then these balls and the ring are tied together with a lock nut and the last ball or top ball is connected to the drive motor and driven with it. Three balls must be immersed in the test lubricant before starting the experiment. In order to do this experiment, there was a need to heat and force for pressing four balls together connected to the drive motor so that it will be driven. Three balls were immersed in the test lubricant before starting the experiment. A small heater inside the ball pot will create the needed heat. The heat and lubricant temperature will be measured by a thermocouple. As for the loading condition or desired test method, suitable force will be set in the bottom of the three balls and three balls will be pressed to the top ball (Le´sniewski and Krawiec, 2008). After the lubrication test, researchers used the acquisition software and microscope for measuring and comparing the wear scar on the three lower balls. Figure 1 show that a schematic representation of four balls Tribotester.

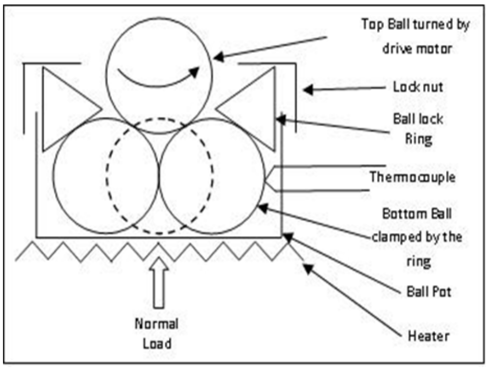

Figure 1. Schematic representation of modified four-ball machine

This study used chrome alloy steel balls. These balls are made of AISI E-52100, diameter of 12.7 mm, extra polish (EP) grade of 25 and hardness of 64 to 66 Hrc. For each new test, another new four balls would be used. Beforehand, all of them were cleaned with acetone and wiped using a fresh lint free industrial wipe.

Jatropha oil is a vegetable oil produced from the seeds of the Jatropha curcas, a plant that grows in marginal lands. When Jatropha seeds are crushed, the resulting Jatropha oil can be processed to produce bio oils for industrial planning. In this research, Jatropha oil was investigated to find new and alternative sources for lubricant oil. Also, one of the best engine oil quality was used for the experiment.

These tests were carried out under the American Society for Testing and Materials (ASTM) condition and ASTM D 4172 method test B. Conditions for experiment: Temperature: (75 ± 2)°C, Speed: (1200 ± 60) rpm, Time: (60 ± 1) minutes and Load: (392±2)N.

Experimental procedure

- Before starting to do the experiment, all parts of ball were cleaned with acetone and then wiped.
- Four balls machine was set up with correct speed, temperature and time.
- Three clean balls inserted to ball pot then the ball lock ring was put inside the ball pot and around the three balls.
- Lock nut was tied on the ball pot and torque wrench was used to fasten it with the force 68 Nm.
- One clean ball in collet was put in and inserted to tapper at the end of motor spindle.
- Test lubricant was added to ball pot assembly around 10 ml that lubricant must become 3 mm above the tip of the ball.
- Ball pot assembly was put in on the antifriction disk inside the machine and under the spindle.
- Thermocouple wire was connected to ball pot assembly.
- Load was added or removed to loading arm until that digital monitoring showed the correct load for experiment.
- In ASTM D 4172 method test B, amount of load is 392 N and in four balls test machine the load cell is fitted at a distance 80 mm from the center of spindle.
- Wear was measured with average of horizontal and vertical scars with CCD camera.

Viscosity is a very important parameter for a lubricant, as it affects the film thickness and therewith the wear rate of sliding surface. It is used for the identification of individual grades of oil and for monitoring the changes occurring in the oil while in service. Increased viscosity normally shows that the used oil has been deteriorated by contamination or oxidation. Also, decreased viscosity usually indicates dilution in the oil. The viscosity was measured with a viscosity meter for the particular four oils in the experiment temperature (75 ° C)

In ASTM D 4172 method test B, the amount of load was 392 N and in the four-ball tests machine, the load cell was fitted at a distance of 80 mm from the center of spindle. Besides, the wear was measured with the average of horizontal and vertical scars with CCD camera from the ball surface (Nadkarni, 2008)

Result and discussion

Viscosity

The results of the study show that viscosity for Jatropha was, 16 mPa.s and for engine oil was, 18.8 mPa.s. Figure 2 compares viscosity for Jatropha oil and Engine oil in the same condition.

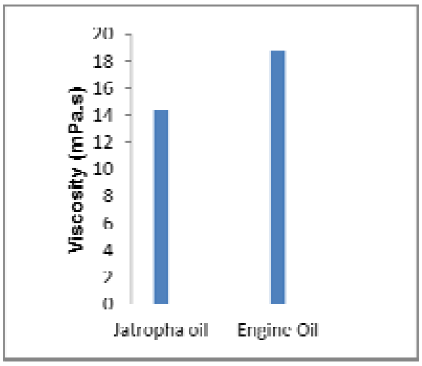

Figure 2. Amount of Viscosity for Jatropha and engine oils

Wear scar diameter

In general, wear is the erosion or sideway displacement of material from its "derivative" and original position on a solid surface performed by the action of another surface. Lubricant oils play major roles for reducing wear. In these experiments, the average for the wear scar area for three balls for Jatropha oils was 0.160 mm2, and for engine mineral oil was 1.124 mm 2.

Figure 3 shows the pictures of wear scars on the ball surface taken with CCD camera for Jatropha and engine oils.

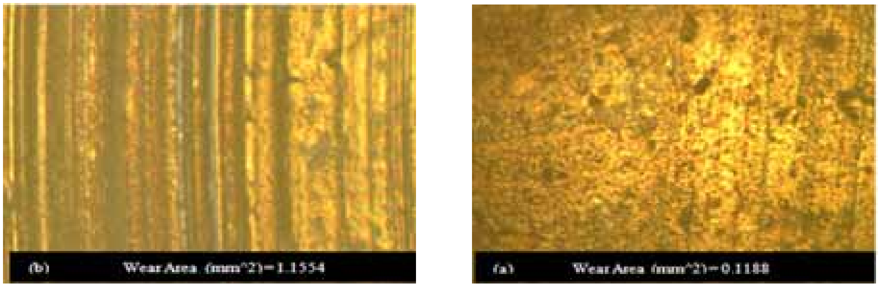

Figure 3. Optical micrographs of wear area in the balls surface: (a) Jatropha oil, (b) engin oil.

Friction torque is the force between two objects that causes one of them to rotate around an axis. Figure 4 shows and compares the amount of Friction Torque for, Jatropha, and engine oil in one hour. It is clear that engine mineral oil with lubricant base had the highest amount of Friction Torque (0.1392N.m) compared with Jatropha oil. The Engine oil graph shows that the Friction Torque had a steady upward trend after starting the experiment, and then it remained constant until 48 minutes. After this time, amount of friction decreased slightly and then it remained constant until the end of experiment. The Friction Torque for Jatropha oil was less than half of engine oil (0.06089Nm). Jatropha oil, in the primary seconds after starting the experiment had some rises but fell after 10 minutes. It then demonstrated a constant trend.

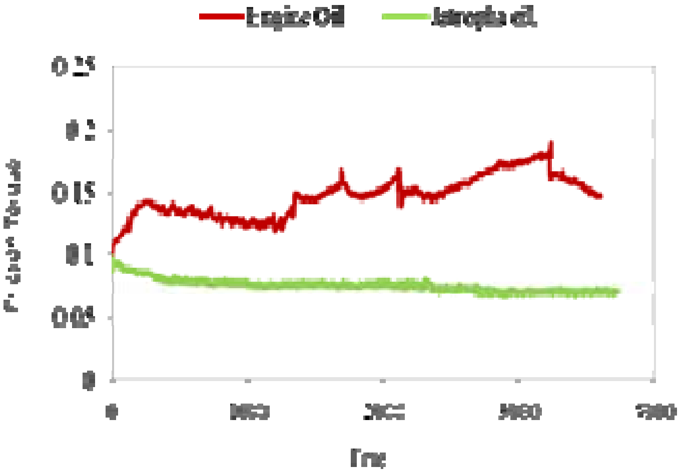

Figure 4. Preparation between friction torque and time of Jatropha oil and engine oils

Friction Torque

Coefficient of Friction (CoF) is a dimensionless scalar value compared to a described ratio of friction force between two bodies and is usually the force pressing them together. The surfaces at rest are relative to each other, μ=μs, where μs is the coefficient of static friction. This is usually larger than its kinetic counterpart is. For surfaces in relative motion, μ = μk where is μk the coefficient of kinetic friction. The Coulomb friction is equal to Ff, and the frictional force on each surface is exerted on the direction opposite to its motion relative to the other surface. In this study, the coefficient of friction was measured for the oils according to IP-239 and it is expressed as follows:

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

In this formula, μ is the coefficient of friction; T is the friction torque in kg.mm, W is the load applied in kg and r is the distance from the center of the contact surface from the lower load to the axis (M. Husnawan and M.G. Saifullah, 2007). Figure 5 shows the comparison of coefficient of friction for Jatropha oil and engine oil in 60 minutes and under the same condition. It is clear that, the coefficient of friction for engine oil with μ= 0.07977 is more than Jatropha oil with, μ=0.0346.

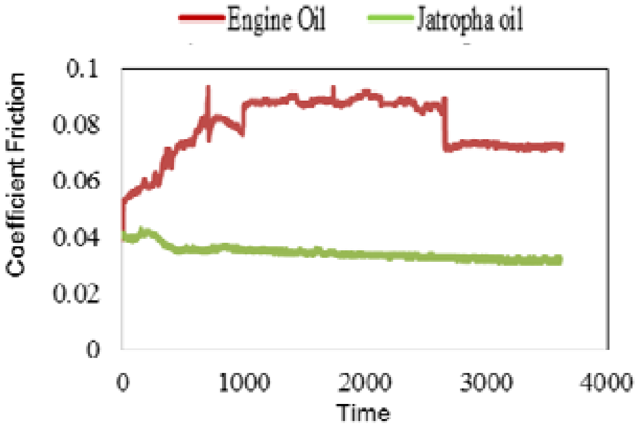

Figure 5. Preparation between coefficient of friction and time of Jatropha and engine oils

Conclusion

This research compares two types of natural vegetable oils against another two well-known mineral oils containing additive materials. Interestingly, the vegetable oils have better properties outrunning the two main essential parameters in industrial activities. In continuation from the above analysis and discussion, the following conclusions can be drawn:

- Jatropha oil with lubricant base, in comparison with Jatropha, and Engine oil also with lubricant base, has better antifriction properties.
- The models show significant effects of time on the friction for the vegetable and mineral oils. For example, for Jatropha oil with the spent time, the friction would decrease but increased for the Engine oil.
- Jatropha oil has a better condition against wear in comparison with other oils. The results also show that engine oil has the best condition against wear after Jatropha.
- Engine oil has a better viscosity than Jatropha oil.

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