Palm Fatty Acid as a New Renewable Source for Industrial Lubricant

Iman Golshokouh[1*], S. Syahrullail[2], Ehsan Kianpour[3]
[1]Department of Mechanical Engineering, Islamic Azad University, Izeh Branch, Izeh, Iran
[2]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310, UTM Skudai, Johor
[3]Department of Mechanic, Najaf Abad Branch, Islamic Azad University, Najaf Abad, Iran
*E-mail: golshokooh@yahoo.com

Abstract

The sources of petroleum are being reduced from day to day and petroleum is a major source of environmental pollution. Many researchers are trying to find other alternatives, namely renewable and green energy sources to substitute the petroleum in every sector. One of the best alternative sources for petroleum is bio oils. In this paper, a comparative study of friction and wear was carried out using four balls tester. Palm Fatty Acid distillate (PFAD) and additive free paraffinic mineral oil were used as lubricants. PFAD is a product from refined crude palm oil. It exists in light brown solid at room temperature. For the wear test, the research was done with two kinds of oils under ASTM condition in which applied load is 392N. The sliding speed was 1200rpm under lubricant temperature of 75 degree Celsius. The experiment was r un for 3600 seconds. The experimental results demonstrated that the PFAD exhibited better performance in terms of friction and wear compared to paraffinic mineral oil.

Keywords: Palm Fatty Acid oil, four balls, vegetable oil, wea, friction

Introduction

Lubricants based mineral oils have been used in many kinds of industrial lubricants since many years ago. Lubricants are used in industrial gears and hydraulic systems, automotive engines, transmission and hydraulic systems, as well as in metalworking applications but for two main reasons scientists have made a serious attempt to replace a new renewable source instead of mineral oils. Additive materials have influenced the wear and friction performance of environmentally adapted lubricants. Firstly, Today's pollution in the environment is one serious danger to all people, animals and plants. Some main sources of environmental pollution in the world are acid rains, smog, heavy metals, pesticides, petroleum, mineral oil and derivations from them. Mineral oil has polluted nature with burning or entering in air, running water and seas. Some pervious study showed petroleum and mineral oil had negative effects on the fish life and other aquaticsBAKER, (Ogata and Miyake 1977; Takizawa , 1972; Sudo, 1965; J.M,1968).

More than this, mineral oil can penetrate into plants. After penetrating into a plant, the oil may travel in the intercellular spaces and possibly into the plant vascular system. Cell membranes will be damaged by penetration of oil into hydrocarbon molecules, leading to leakage of cell contents, and as a result enter the cells. Oils reduce transpiration rate, with blocking stomata and intercellular spaces (Baker, 1969; Beevers, 1953; Bartholomew and E.T,.1936; Council Oil Pollution Research Unit, 1968; Czernik Sand Bridgwater, 2004). Mineral oils also lead to air pollution and create some phenomena such as global warming and greenhouse gas. (Especially oil spills like the case of Exxon Valdes). [Lubricants based on renewable resources are environmentally compatible alternatives to mineral oil products]. Secondly, the source for mineral oil is limited and in the near future mineral oil will be finished. The original scenario of the Club of Rome from 1985 had turned out to have been over-pessimistic; mineral oil has a finite resource. Besides, the availability of mineral oil is highly dependent on political considerations. This reason is enough to try to replay a new alternative source instead of mineral oils. Vegetable oil is a promising alternative because it has several advantages; it is environmentally-friendly, renewable, cheap and takes easily with simple manufacturing process, where there is an acute need for modern forms of energy. Therefore, in recent years several research has ben carried out to use vegetable oils in order to make all kinds of mineral oils. For example, lubricant oils, diesel oils and biofuel oils. Researchers used very new methods to extract oil from biomass such as pyrolysis, fast pyrolysis, thermochemical process, flash pyrolysis and vacuum pyrolysis (Yang and Blanchette, 2009; Masjuki and Maleque, 2004; Hofbauer and Gasification, 2009; Barber, 2004; Bridgwater and Maniatis , 2001; Koppejan and van Loo, 2009). After extracting oils from biomass, much research was done to replace bio oils with mineral oils. For example Masjuki did some studies in the palm oil and mineral oil-based commercial lubricating oil to use in engine and compare friction, wear, viscosity, lubricant degradation and exhaust in the same condition for them (Maleque and Masjuki, 2000) Also Maleque investigated effects of friction, wear and viscosity on tribological properties of palm oil metyl ester blended lubricant and showed at lower load temperatures, the wear rate unde 5% palm oil metyl ester lubricant are lower, whereas at higher loads, the wear rates are higher. Also the viscosity decreased with an increase in temperature but increased with increasing load(Stachowiak and Batchelor, 1993). Moreover, several biodegradable oils, in particular vegetable-based oils, possess a good lubricating ability, often much better than mineral or conventional (Krˇzan, Viˇzintin,2004; Industrial Research Organisation, 2008). Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, and sunflower oil, rapeseed oil, and canola oil have been used to produce lubricants. In this research we calculated the amount of friction and wear under American society for testing and materials (ASTM) condition between Palm Fatty Acid Distillate (PFAD) and paraffinic mineral oil. This experiment was done with the four balls wear tester machine and CCD camera was used to capture and measure the wear scar diameter (WSD). In this study we present result of a comparison between Palm Fatty Acid Distillate (PFAD) that produced from refining crude palm oil that is a kind of vegetable oil with paraffinic mineral oil under SATM condition.

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 (Stachowiak and Batchelor, 1993). After the lubrication test, researchers used the acquisition software and microscope for measuring and comparing the wear scar on the three lower balls.

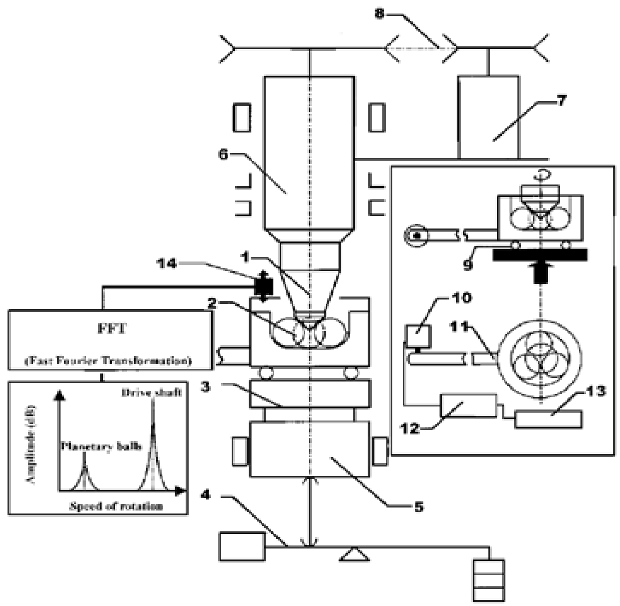

Figure. 1 Schematic of modified four ball machine: (1) coated cone and collet; (2) planetary balls; (3) heater; (4) loading lever; (5) loading piston; (6) spindle; (7) driving motor; (8) belt drive; (9) thrust bearing; (10) force transducer; (11) torque arm for friction measurements; (12) digital readout; (13) printer; (14) accelerometer

The balls in this experiment are chrome alloy steel made from AISI E-52100, diameter of 12.7 mm, extra polish (EP) grade of 25 and hardness of 64 to 66 Hrc. Also for Each new test, new four balls were used and all balls were cleaned with acetone and wiped using a fresh lint free industrial wipe.

These tests were carried out under the American society for testing and materials (ASTM) condition and usage from ASTM D4172 method test B. In this condition, Temperature: 75 ± 20ºC, Speed: 1200 ± 60 rpm, Time: 60 ± 1 min, and Load: 392 ± 2 N.

- 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.

Result and discussion

Viscosity

The viscosity for PFAD was 9.5 mili Pa.s (mPa.s), and 18.8 mPa.s for Paraffinic oil.

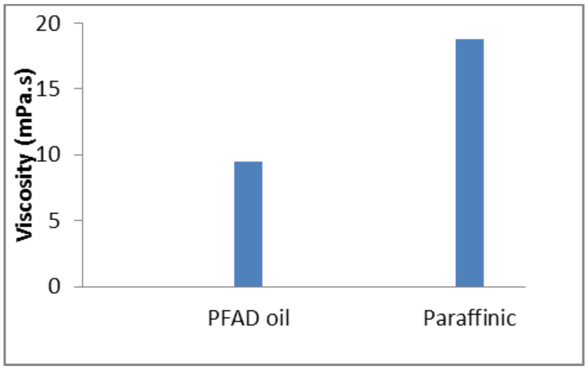

Figure 2. Amount of Viscosity for PFAD and Paraffinic oils.

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. Also, there are several types of wear, such as adhesive, abrasive, fatigue, erosive, cavitation, oxidative, fretting, melting, diffusive, impact and corrosive. Lubricant oils play major roles for reducing wear. Table (1) shows the amount of wear for PFAD and Paraffinic oil in major and minor cases. Figure 3 shows the amount of wear on the ball surface for four experiments with PFAD and Paraffinic oils as the lubricants. In these experiments, the average for the wear scar area for three balls with PFAD was 0.5625 mm2. The amount for Paraffinic mineral oil was 1.124mm2.

Figure 3 shows the pictures of wear scars on the ball surface taken with CCD camera for PFAD and Paraffinic oils. According to these data and after comparing the amount of wear area balls between all experimental oils, it can be seen PFAD oil has a better condition and more stability against wear and Paraffinic oil has the lowest stability against wear.

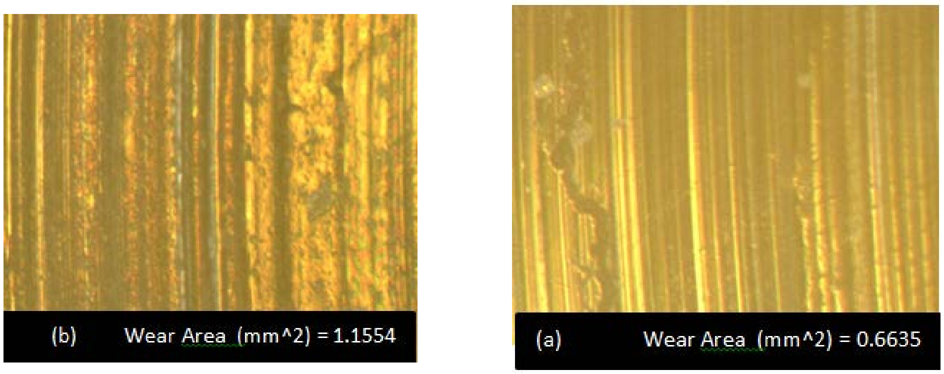

Figure 3. Optical micrographs of wear area in the balls surface. (a) PFAD oil,(b) Paraffinic l oil.

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 PFAD and Paraffinic oil in one hour. It is clear that, Hydraulic mineral oil with lubricant base had the highest amount of Friction Torque (0.1392N.m) compared with other oils. The Paraffinic 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. Also the lowest amount for Friction Torque was PFAD with 0.0492N.m. After a few minutes, the PFAD graph showed a slow decrease and this trend remained constant until the end of processes.

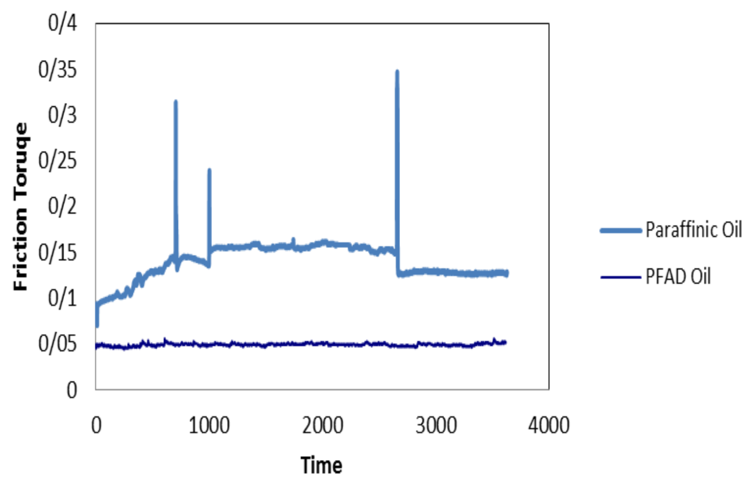

Figure 4: The preparation between friction torque and time of PFAD and Paraffinic oils

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 of the center of the contact surface from the lower load to the axil. Figure 5 shows the comparison of coefficient of friction for PFAD and paraffinic oils in 60 minutes and under the same condition. It is clear that, the highest coefficient of friction is for paraffinic oils with μ= 0.07977 and amount of coefficient friction is for PFAD with μ = 0.0297

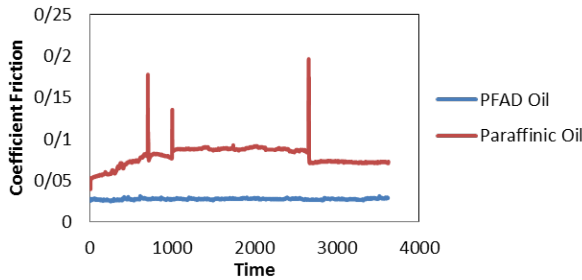

Figure 5: the preparation between coefficient of friction and time of PFAD and Paraffinic oils

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 of the above analysis and discussion, the following conclusions can be drawn:

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

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