Jatropha Oil as Alternative Source of Lubricant Oil

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Abstract: This research investigated the physical properties of Jatropha oil to determine its viability as a clean and renewable source of lubricant oil. The study was performed using a four-ball tribotester, CCD camera, scanning electron microscope, digital microscope and viscosity meter. The experiment was conducted using different temperatures (55, 95 and 125°C) and loads (200, 400, and 600 N). The experiment was performed under the American Society for Testing and Materials (ASTM), number D 4172.The data included the evaluation of anti-wear, anti-friction, coefficient of friction, wear scar diameter and viscosity of Jatropha oil. All results of this research were compared to findings regarding hydraulic oil as a commercial mineral oil- based lubricant to evaluate lubricant ability. The results showed that, using various temperatures and loads, Jatropha oil had a higher lubricant ability compared to hydraulic mineral oil.

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Keywords: Jatropha oil, four-ball tribotester, wear scar diameter, Friction, Wear

1. Introduction

Previous research has confirmed that a primary source of environmental pollution is the burning of mineral and its entrance into the ecosystem (Grant et al., 2008, Mercurio et al., 2004, Bartz, 1998). Mineral oils are the main source of lubricant oil in the world and every year more than 12 million tonnes of lubricants enter into the environment, polluting water, soil and air. Furthermore, sources of mineral oil are limited and will potentially dry up in the near future. Recent research (from this decade) has shown that some kinds of vegetable oils are viable alternatives to mineral oil (Adhvaryu et al., 2006, Aluyor and Ori-Jesu, 2010, Gawrilow, 2003, Castro et al., 2005). Vegetable oils are often renewable, nontoxic, cheap, clean and environmentally friendly (Randles, 1992, Battersby et al., 1992). Masjuki investigated the influence of wear and friction of blended palm oil methyl ester lubricant using a four-ball tribotester and indicated that, at lower loads and temperatures, the wear rate using palm oil methyl ester lubricant was low, under 5%, but in higher loads, the wear rates increase (Masjuki. H. H, 2000). In other research, palm oil was investigated as a lubricant oil and was compared with mineral oil-based commercial engine oil (Masjuki. H. H, 1999). The lubricity of a vegetable oil-based lubricant was investigated using high frequency reciprocal testing to examine viability as a diesel fuel blend/ bio-oil. Results showed that the average friction coefficient of bio oil was less than blended diesel fuel; the amount of friction coefficient of the bio-oil was 0.130 and diesel oil was 0.164(Xianguo Hu, 2010). Jatropha oil, which is derived from Jatropha seeds and found in many countries, such as Malaysia, Indonesia and Thailand, is considered a possible alternative to mineral oil. Liaquat investigated the lubricant ability of Jatropha oil with different percentages of lubricants using a four-ball tribotester and by employing loads of 15kg and 40kg. The results indicated that Jatropha oil with 5% lubricant showed effective anti-wear and anti-friction capabilities. Liaquat also compared 5% Jatropha oil as a lubricant with a normal lubricant (SAE40 Grade) and results showed that 5% Jatropha oil can be used as an alternative lubricant instated of a standard lubricant(Liaquat et al., 2012). Physical properties, such as anti-wear, anti-friction, viscosity index and flash parameter point of PFAD and Jatropha- based lubricants were investigated according to ASTM , number D 4172, method B, using a four-ball tribotester. The results were compared to the physical properties of two mineral oil-based lubricants (Golshokouh et al., 2012). Rathore and Madras studied a supercritical method of biodiesel production of methanol and ethanol from Jatropha oil. They fixed a 50:1 alcohol-to-oil molar ratio under 20 MPa at 300°C for 10 minutes. Around 70% of the Jatropha oil was converted into fatty acid methyl esters and after 40 minutes this amount increased to 85%. They obtained a higher percentage of conversion by controlling and optimising the reactor up to 95% at 400°C(Robles-Medina et al., 2009).

This paper examines the physical properties of Jatropha oil in varying temperatures and loads using a four-ball tribotester and compares the lubricant ability of Jatropha oil with hydraulic oil to analyse its viability as an effective lubricant.

2- Experimental Method

In this research, the four-ball tribotester was utilised to determine the friction torque of experimental lubricant oils. The tribotester is a machine with four balls; Figure.1 shows a schematic diagram of a four-ball tribotester. The first ball is located in top part of the machine and is connected to the drive motor, which drives it. The other balls are fixed together by a ball ring. Three balls and the ring are clenched together with a lock nut. Before beginning the study's experiment, the balls were immersed in the test oil. The heat needed was created by a small heater that was inside the ball pot. The temperature for the test lubricant was measured by a thermocouple. To establish load conditions or desired test method, a suitable force is set in the bottom of the three balls; the three balls are then pressed into the top ball. Next, research is conducted using the acquisition software, CCD Camera and microscope to measure and compare the wear scar on the three lower balls (A. S. M. A. Haseeb, 2010).*fig.1* shows a schematic diagram of four-ball tribotester.

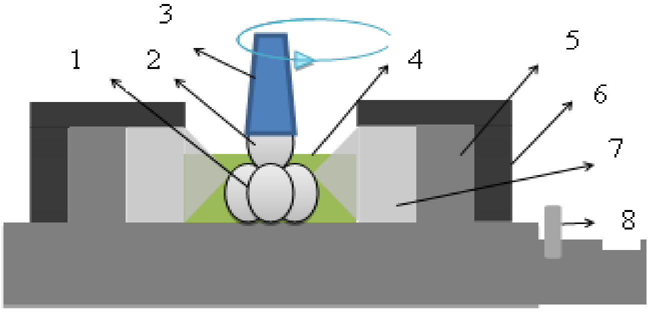


Figure1. *Schematic diagram of four ball wear geometry:*
1 –stationary ball 2 – Rotating single ball 3 – Rotating gripper for upper ball 4 – Test lubricant
5 – Cup for griping stationary three balls 6-lock nut 7-balls ring 8-thermocouple

2.1 Balls Model

The balls used in this experiment are chrome alloy steel balls made of AISI E-52100, with a diameter of 12.7 mm, extra polish (EP) grade of 25 and hardness of 64 to 66 Hrc.

For each new test, four new balls were used. Beforehand, each ball was cleaned with acetone and wiped using a fresh lint-free industrial wipe.

2.2 Lubricant Oils

Jatropha oil and hydraulic oil (high quality lubricant oil) were used in this research. Jatropha oil is a vegetable oil manufactured from the seeds of the Jatropha tree. Jatropha is a deciduous tree that is 3-5m in height(Ariza-Montobbio and Lele, 2010) and can grow in appropriate conditions, to 8-10m. For proper growth, the Jatropha tree needs 3.68 and 2.52 mmol of CO2 and H2O. (Lim and Teong, 2010). This tree can be cultivated on non-agricultural and marginal land. Jatropha seeds can produce 35% oil through extraction and there is an average of 1375 seeds/kg per tree. Jatropha tree can be used 35 to 50 years(Ariza-Montobbio and Lele, 2010). Specific properties of Jatropha oil are as follows: acid value (10.37mg KOH g−1), water content (0.05 %), specific gravity (0.92g ml−1), ash content (0.09 %), density (917±1kg/m3), calorific value (39.071MJ/kg), mass fraction for carbon (76.11 %, w/w), hydrogen (10.52%, w/w), nitrogen (0%, w/w), oxygen (11.06%, w/w) and sulphur (0%, w/w)(Lim and Teong, 2010, Chen et al., 2009, Xu et al., 2011).

2.3 Experimental Condition

These tests were carried out in different temperatures and loads under the conditions set forth by the American Society for Testing and Materials (ASTM). Conditions in this research were as follows: temperature: (55, 95 and 125°C), speed: (1200 ± 60) rpm, time: (60 ± 1) minutes and load: (200, 400 and 600 N). Furthermore, the temperature was kept constant in 75°C when different loads were applied and also load was constant in 392N when different temperatures were under experiment.

2.4 Experimental Procedure

All parts of the four-ball machine and balls were cleaned with acetone before each experiment. The four-ball was set up with desired speed, load, temperature and time. Three clean balls were inserted into the ball pot. The ball lock ring was put in to the ball pot and placed around the balls. The lock nut was clenched onto the ball pot and a torque wrench with a force of 68 Nm was used to tighten it. One ball was inserted into the collection area to taper the end of motor spindle. Around 10 ml of test lubricant was added to the ball pot. The ball pot assembly was placed on the antifriction disk and inside the machine, under the spindle. The thermocouple was connected to the ball pot. A suitable load was added to the loading arm until the digital monitoring showed the desire load had been achieved.

2.5 Viscosity

Viscosity is the general term used to define the internal friction of liquid or gas. Viscosity of liquid has a direct correlation with the thickness of the liquid's film. Viscosity plays an important role in lubricant ability, as it affects the wear rate between sliding surfaces. Viscosity is used to recognize individual grades of oil and for monitoring changes occurring in the oil while in service. An increase in viscosity usually indicates that the used oil has deteriorated by contamination or oxidation. Also, decreased viscosity usually indicates dilution in the oil (Zuidema, 1959). In this study, the viscosity of Jatropha and hydraulic oils were measured by a viscosity meter at designated temperatures (35, 55, 75, 95, 105 and 125° C). *Fig. 2* shows the kinetic viscosity index for Jatropha and hydraulic oil at different temperatures. This figure indicates that, at 35°C, the viscosity of Jatropha oil was less than hydraulic oil, but with an increase in temperature, Jatropha oil had relatively similar viscosity to hydraulic oil. Also, at higher temperatures, Jatropha oil and hydraulic oil had similar viscosity. This figure also shows that the viscosity increased with a decrease in the temperature of the oils because viscosity has an inverse relationship with temperature. This means that viscosity decreases with increasing temperature. Moreover, with an increase in viscosity, the fluidity and dilution of lubricant increases and the lubricant can move more easily. Usually, higher viscosity has better anti-friction ability, however an increase in the viscosity sometimes causes the lubricant to begin to deteriorate with oxidation or contamination (A. S. M. A. Haseeb, 2010).

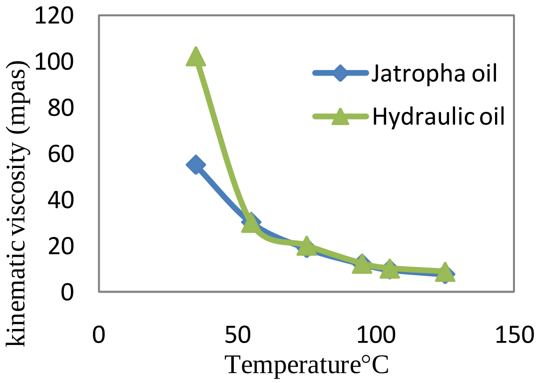


Figure 2. *Kinematic viscosity measured for Jatropha and hydraulic oil under different tested temperature*

2.6 Wear

Wear is the slow process of removing material from sliding contacts and solid surfaces, resulting in damage to a contact surface. There are several types of wear, such as abrasion, plough, fatigue, in corrugation, cavitation and erosion. Some wear is known to result in irreversible changes in contact surfaces and the development of gaps between contacting parts. For this research, a CCD camera was used to capture and measure the wear scar diameter (WSD) on ball surfaces. The wear was measured using the average horizontal and vertical scars. The average scar diameter is determined via arithmetic mean value of the three average diameters of bottom specimen ball scar according to ASTM D4172-94 (reapproved 2009) standard from the ball surface.

3- Result and discussion

The lubricant properties of Jatropha oil were investigated with a four-ball tribotester placed in different temperatures and loads. The tests present an opportunity to discuss the anti-friction and anti-wear ability of Jatropha oil as an alternative source of lubricant oil compared to mineral oil-based lubricants.

3.1 Effect of temperature and load on Coefficient of Friction

Equation (1) shows the relationship between coefficient of friction, temperature and load. Coefficient of friction has an inverse relationship with temperature and load. *Fig.3* shows the influence of incremental temperature changes on the coefficient of friction for Jatropha and hydraulic oil at 55, 95 and 125°C. *Fig.3* clearly shows that with temperature changes, the coefficient of friction of Jatropha oil remained constant. However, coefficient of friction in hydraulic oil increases with an increase in temperature. This figure also indicates that in this experimental condition, Jatropha oil has higher anti-friction ability than hydraulic mineral oil-based lubricant. *Fig.4* also illustrates the effect of load on the coefficient of friction. This figure clearly shows that coefficient of friction increases with an increased load for Jatropha and hydraulic oils. However, the amount of coefficient of friction for Jatropha oil was less than hydraulic oil. The coefficient of friction was calculated using the following formula (Husnawan et al., 2007):

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

Where, μ = coefficient of friction, T= frictional torque in kg/mm, W = applied load in kg, r = distance from the center of the contact surfaces on the lower balls to the axis of rotation, which is 3.67mm.

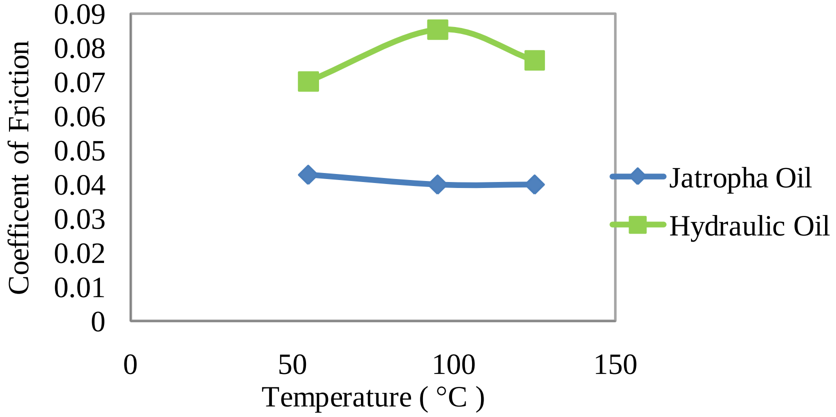


Figure 3. *Effect of Temperature on coefficient of friction for Jatropha, engine and hydraulic oil in55, 95and 125°C*

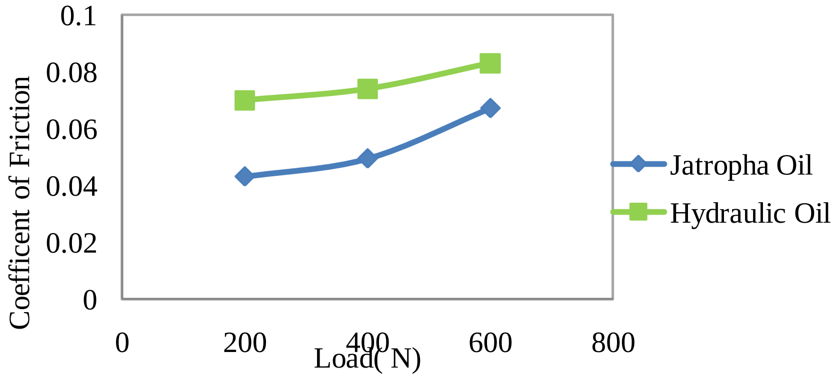


Figure 4. *Effect of load on coefficient of friction for Jatropha and hydraulic oil in200, 400and 600N*

3.2 Wear Scar Diameter (WSD) Analysis

The wear scar diameter of Jatropha and hydraulic oil under different temperatures are shown in *Fig.5*. According to this figure, the coefficient of friction increases with an increase in the temperature of Jatropha oil and decreases with an increase in the temperature of hydraulic oil. *Fig. 6* shows the wear scar diameter of Jatropha and hydraulic oil in different loads. This figure clearly shows that Jatropha oil had a lower wear scar diameter than hydraulic oil. Also, according to *Fig.6*, wear scar increased with an increase in the load of experiment oils. On average, the amount of wear scars in ball specimens of Jatropha oil was less than in hydraulic oil, and this shows that the anti-wear ability of Jatropha is more than hydraulic mineral oil.

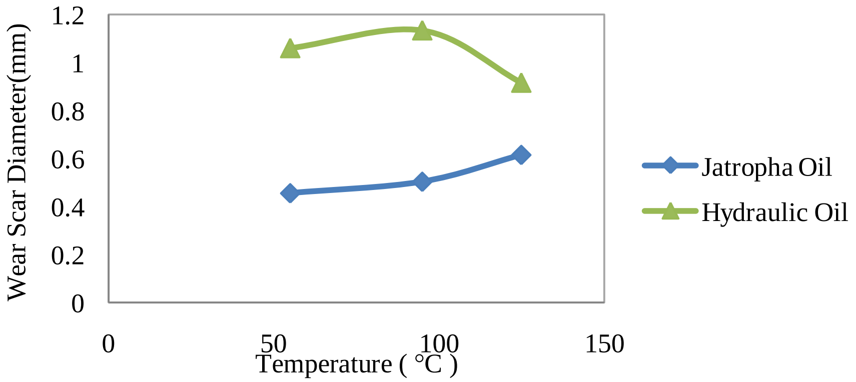


Figure 5. *Effect of Temperature on Wear Scar Diameter (WSD) for Jatropha and hydraulic oil in 55, , 95and 125°C*

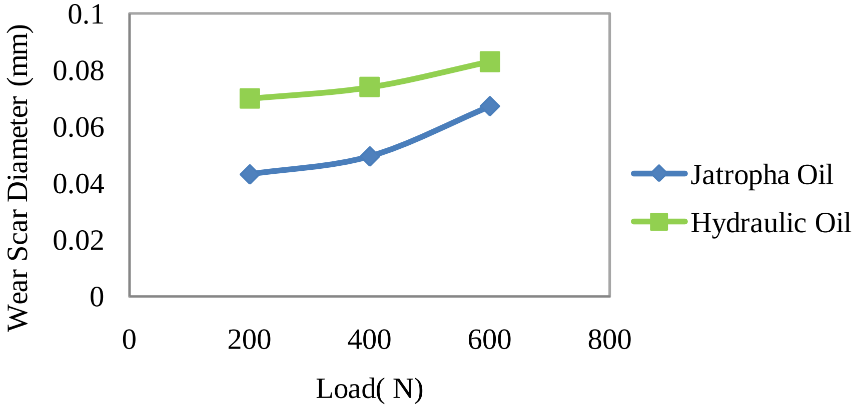
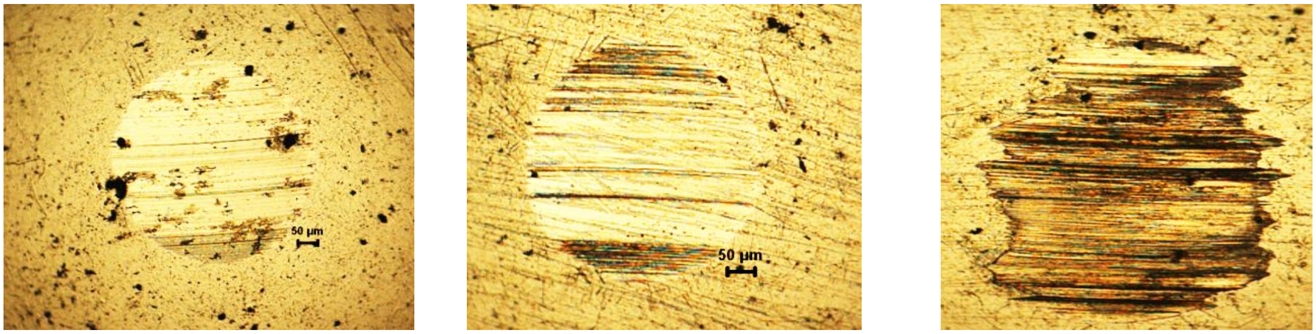


Figure 6. *Effect of load on wear scar diameter for Jatropha and hydraulic oil in200, 400and 600N*

3.3 Wear worn surface characteristics

Fig.7 to *10* shows the results of an examination of wear scar on ball specimens for Jatropha and hydraulic oils using different temperatures and loads. *Fig.7* and *8* show the ball specimens of Jatropha and hydraulic oil at different temperatures; these figures show that wear scars on the balls' surfaces increase with an increase in temperature. Furthermore, comparisons between *fig. 7* and 8 clearly show that wear scar on Jatropha ball specimens are smaller than wear scars on hydraulic oil ball specimens. *Fig. 9* and *10* illustrate wear scar on ball specimens of test oils using different loads; these figures indicate that wear scar has directly impacted by an increase in the loads of both test oils. However, the increase of Jatropha oil was less than hydraulic oil in same conditions. *Fig.11* shows wear scar on ball specimens of Jatropha oil in different temperatures. This figure clearly shows that the ball surface of Jatropha oil at 55°C (*Fig.11a*) was covered with small pits. Small pits appeared on the ball surface due to material transfer between contact parts, as reported by (Masjuki and Maleque, 1997). Also, several parallel grooves were observed on the ball specimens of Jatropha oil at 75° and 125°C. The debris from the detached ball bearing can create abrasion on the ball surface, as parallel grooves appear without material transfer(Singh and Gulati, 1991). *Fig.12* shows wear scar on the ball surface of hydraulic oil at different temperatures. Metal transfer and shallow grooves in this oil are clearly visible at 55°C. Adhesive wear occurs between surfaces if the lubricating film has been broken down and cannot totally separate the contact parts from each other, causing material transfer between contact parts(Masjuki and Maleque, 1997). Also, deep grooves with several pits were observed on the hydraulic ball specimens at 95°C. Light ploughs on the worn surface with spots of material transfer exhibiting that abrasive wear was the dominant wear mechanism (*Fig.12b*). Furthermore, deep plough on the worn surface, with spots of material transfer exhibiting abrasive wear was the dominant wear mechanism on a hydraulic ball surface at 125°C. *Fig.13* shows wear scar on the Jatropha ball specimens in different loads. In this figure, can observe several instances of micro cutting on ball surfaces under load 200N (*Fig.13a*). Micro cutting happens when the adhesive wear occurs between surfaces and the lubricating film has broken down. Also, the ball surfaces of Jatropha oil in load 400 and 600N were covered with deep parallel grooves and material transfer from the contact surface (*fig.13b and c*). *Fig.14* shows a wear scar on the hydraulic ball specimen in different loads. According to this figure, small pots and shallow grooves were observed on the ball surface of hydraulic oil in load 200N (*Fig.14a*) and deep ploughs with micro cutting were observed in load 400N (*Fig.14b*). *Fig.14C* also shows deep ploughs and plastic deformation on the ball surface of hydraulic oil. The plastic flow on the surface was caused by adhesive wear in the mechanism and usually left some cavities on the surface; this phenomenon indicates that the lubricant layer had thinned out and the risk of lubricant film breakdown was higher(Ren et al., 2010)

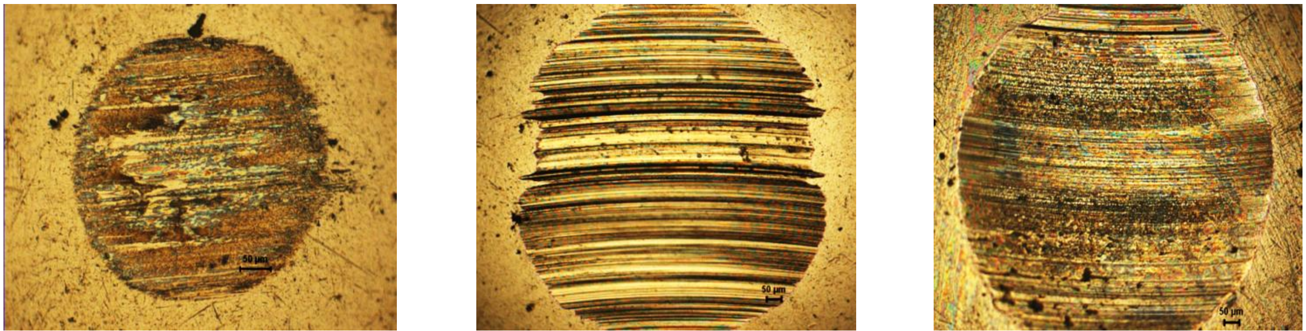


(a) Magnification 463X and 50 µm

(b) Magnification 463X and 50 µm

(c) Magnification 463X and 50 µm

Figure 7. *Optical micrographs of wear area on the balls surface of jatropha oil. (Magnification 463X and Pome 100 µm) (a) 55°C, (b) 95°C, (c) 125°C*

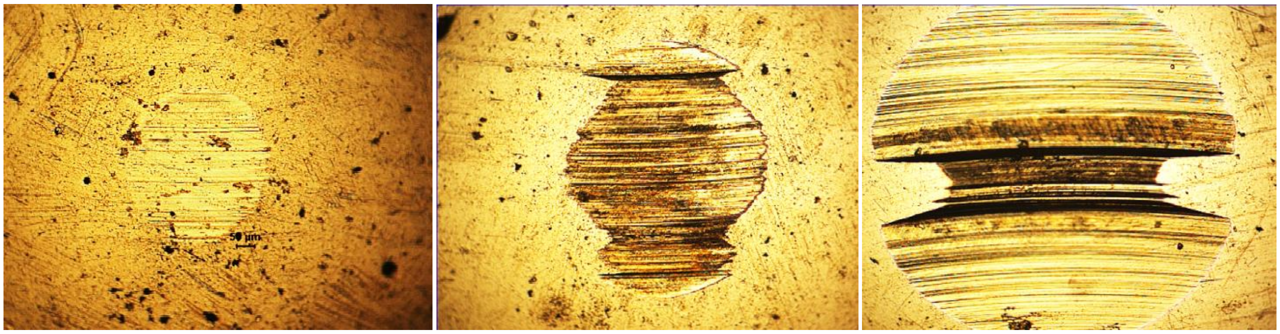


(a) Magnification 463X and 50 µm

(b) Magnification 463X and 50 µm

(c) Magnification 463X and 50 µm

Figure 8. *Optical micrographs of wear area on the balls surface of hydraulic oil. (Magnification 463X and Pome 100 µm): (a) 55°C, (b) 95°C, (c) 125°C*

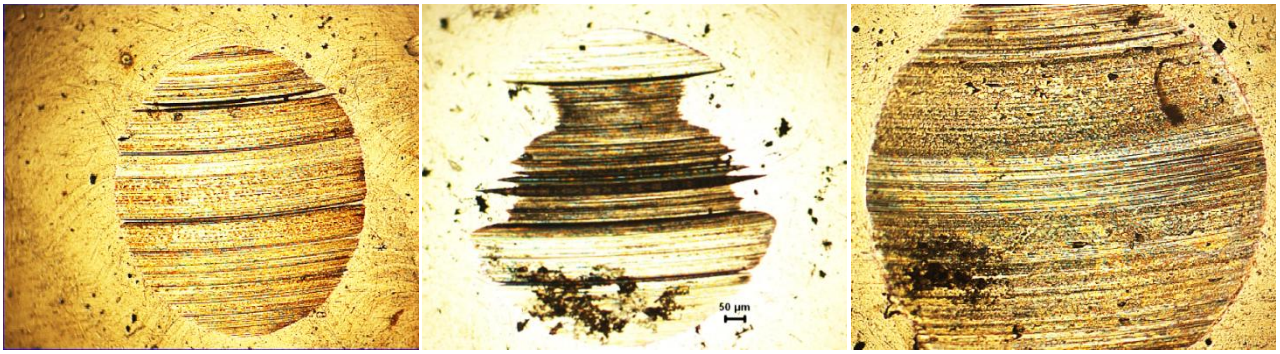


(a) Magnification 463X and 50 µm

(b) Magnification 463X and 50 µm

(c) Magnification 463X and 50 µm

Figure 9. *Optical micrographs of wear area on the balls surface of jatropha oil. (Magnification 463X and Pome 100 µm): (a) 200N, (b) 400N (c) 600N.*



(a) Magnification 463X and 50 µm (b) Magnification 463X and 50 µm (c) Magnification 463X and 50 µm

Figure 10. *Optical micrographs of wear area on the balls surface of hydraulic oil. (Magnification 463X and Pome 100 µm): (a) 200N, (b) 400N (c) 600N.*

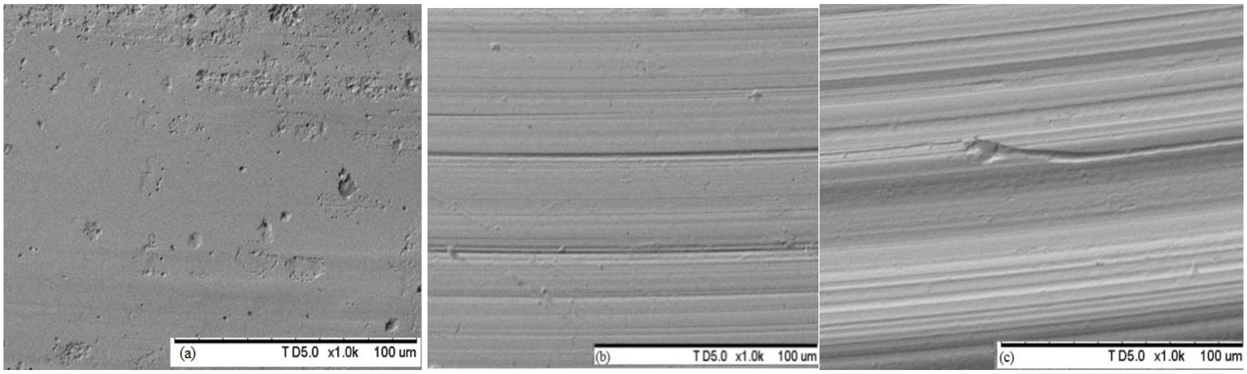


Figure 11. *Wear scar on the balls specimens in different temperature of jatropha oil (a) 55°C, (b) 95°C, (c) 125°C*

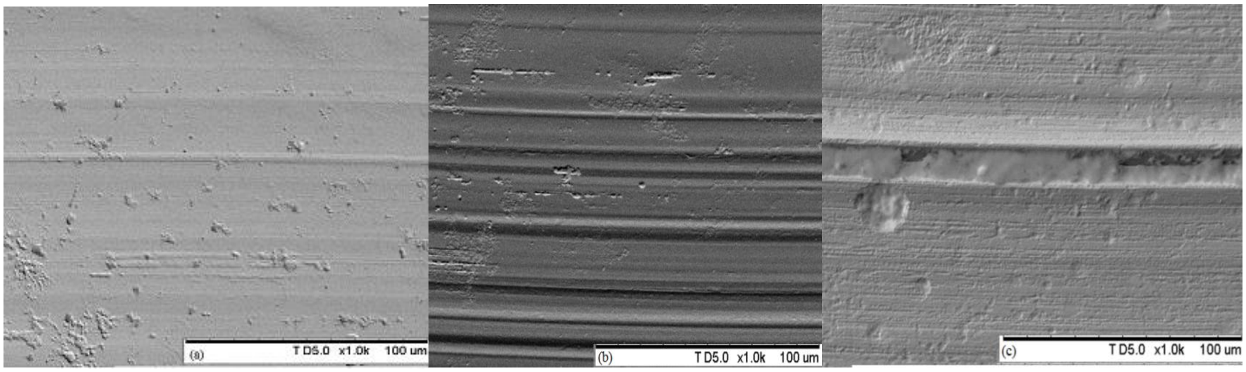


Figure 12. *Wear scar on the balls specimens in different temperature of hydraulic oil(a) 55°C, (b) 95°C, (c) 125°C*

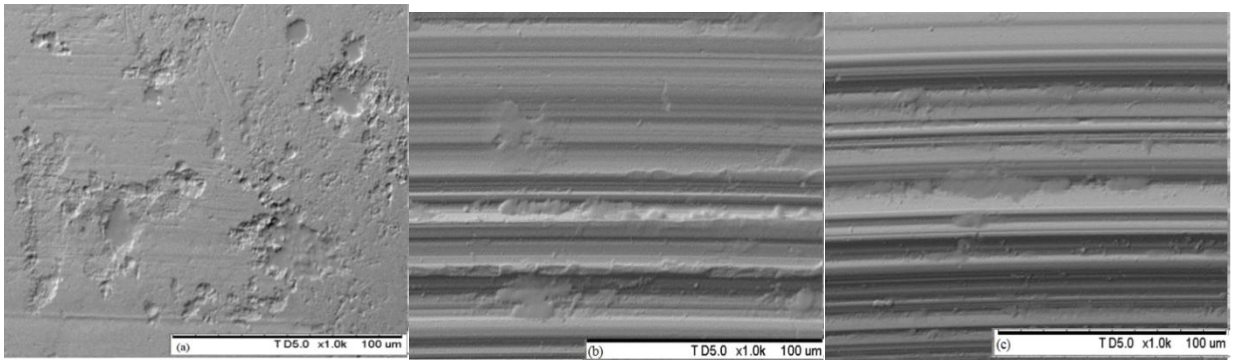


Figure 13. *Wear scar on the balls specimens in different loads of jatropha oil. (a) 200N, (b) 400N (c) 600N.*

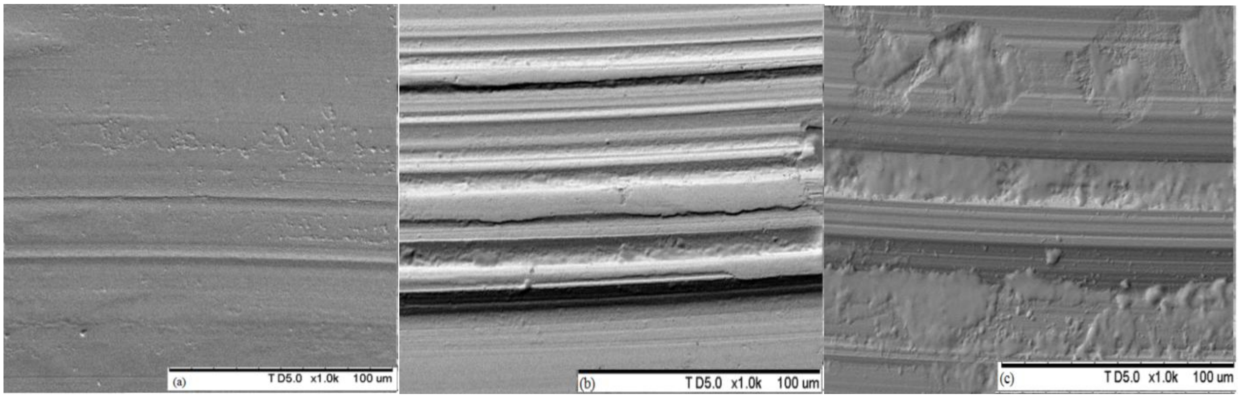


Figure 14. *Wear scar on the balls specimens in different loads of hydraulic oil. (a) 200N, (b) 400N (c) 600N.*

4. Conclusion

These tests were performed on different temperatures and loads of Jatropha and hydraulic oil based - lubricant and using a four-ball tribotester. The conclusions drawn are as follows:

i- The coefficient of friction increase with increase the temperature and load.

ii- The wear diameter of the ball specimens increases with an increase in temperature and load.

iii- Jatropha oil has better anti-friction and anti-wear ability than hydraulic oil.

vi- The highest value for viscosity index was found in hydraulic oil.

Reference

1. A. S. M. A. HASEEB, S. Y. S., M. A. FAZAL, H. H. MASJUKI 2010. effect of temperature on tribological properties of palm biodiesel. *energy,* 35**,** 1460-1464.
2. ADHVARYU, A., BIRESAW, G., SHARMA, B. K. & ERHAN, S. Z. 2006. Friction behavior of some seed oils: biobased lubricant applications. *Industrial & engineering chemistry research,* 45**,** 3735-3740.
3. ALUYOR, E. O. & ORI-JESU, M. 2010. The use of antioxidants in vegetable oils–A review. *African Journal of Biotechnology,* 7.
4. ARIZA-MONTOBBIO, P. & LELE, S. 2010. Jatropha plantations for biodiesel in Tamil Nadu, India: Viability, livelihood trade-offs, and latent conflict. *Ecological Economics,* 70**,** 189-195.
5. BARTZ, W. J. 1998. Lubricants and the environment. *Tribology international,* 31**,** 35-47.
6. BATTERSBY, N., PACK, S. & WATKINSON, R. 1992. A correlation between the biodegradability of oil products in the CEC L-33-T-82 and modified Sturm tests. *Chemosphere,* 24**,** 1989-2000.
7. CASTRO, W., WELLER, D. E., CHEENKACHORN, K. & PEREZ, J. M. 2005. The effect of chemical structure of basefluids on antiwear effectiveness of additives. *Tribology International,* 38**,** 321-326.
8. CHEN, W.-H., CHEN, C.-H., CHANG, C.-M. J., CHIU, Y.-H. & HSIANG, D. 2009. Supercritical carbon dioxide extraction of triglycerides from< i> Jatropha curcas</i>

L. seeds. *The Journal of Supercritical Fluids,* 51**,** 174-180.

9. GAWRILOW, I. Year. Palm oil usage in lubricants. *In:* Proc. 3rd Global Oils and Fats Business Forum. USA, October, 2003.
10. GOLSHOKOUH, I., ANI, F. N. & SYAHRULLAIL, S. Year. Wear resistance evaluation of palm fatty acid distillate using four-ball tribotester. *In:* AIP Conference Proceedings, 2012. 928.
11. GRANT, T., BEER, T., CAMPBELL, P. K. & BATTEN, D. 2008. Life cycle assessment of environmental outcomes and greenhouse gas emissions from biofuels production in Western Australia. *Department of Agriculture and Food Government of Western Australia, Western Australia*.
12. HUSNAWAN, M., SAIFULLAH, M. & MASJUKI, H. 2007. Development of friction force model for mineral oil basestock containing palm olein and antiwear additive. *Tribology International,* 40**,** 74-81.
13. LIAQUAT, A., MASJUKI, H., KALAM, M. & RASYIDI, A. 2012. Experimental Analysis of Wear and Friction Characteristics of Jatropha Oil Added Lubricants. *Applied Mechanics and Materials,* 110**,** 914-919.
14. LIM, S. & TEONG, L. K. 2010. Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview. *Renewable and Sustainable Energy Reviews,* 14**,** 938-954.
15. MASJUKI, H. & MALEQUE, M. 1997. Investigation of the anti-wear characteristics of palm oil methyl ester using a four-ball tribometer test. *Wear,* 206**,** 179-186.
16. MASJUKI. H. H, M. M. A., HASEEB ASMA 2000. effect of mechanical factors on tribological properties of palm oil methyl ester blended lubricant. *wear,* 239**,** 293-299.
17. MASJUKI. H. H, M. M. A., KUBO. A 1999. palm oil and mineral based lubricant-their tribological and emission performance. *Tribology International,* 32**,** 304-314.
18. MERCURIO, P., BURNS, K. A. & NEGRI, A. 2004. Testing the ecotoxicology of vegetable versus mineral based lubricating oils: 1. Degradation rates using tropical marine microbes. *Environmental Pollution,* 129**,** 165-173.
19. RANDLES, S. 1992. Environmentally considerate ester lubricants for the automotive and engineering industries. *Journal of Synthetic Lubrication,* 9**,** 145-161.
20. REN, S., MENG, J., LU, J., YANG, S. & WANG, J. 2010. Tribo-physical and tribo-chemical aspects of WC-based cermet/Ti< sub> 3</sub> SiC< sub> 2</sub> tribo-pair at elevated temperatures. *Tribology international,* 43**,** 512-517.
21. ROBLES-MEDINA, A., GONZÁLEZ-MORENO, P., ESTEBAN-CERDÁN, L. & MOLINA-GRIMA, E. 2009. Biocatalysis: towards ever greener biodiesel production. *Biotechnology advances,* 27**,** 398-408.
22. SINGH, H. & GULATI, I. 1991. Tribological behaviour of base oils and their separated fractions. *Wear,* 147**,** 207-218.
23. XIANGUO HU, Y. X., QIONGJIE WANG, CHUAN LI, XIFENG ZHU 2010. Characterization of the lubricity of bio oil/diesel fuel blends by high frequency reciprocating test rig. *Energy,* 35**,** 283-287.
24. XU, R., WANG, R. & LIU, A. 2011. Expression profiles of genes involved in fatty acid and triacylglycerol synthesis in developing seeds of Jatropha (< i> Jatropha curcas</i> L.). *Biomass and Bioenergy,* 35**,** 1683-1692.
25. ZUIDEMA, H. H. 1959. *The performance of lubricating oils,* Reinhold Publishing Corporation.

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