Experimental Study on Lubricant Properties of Seed Oil

J. Anoop[1], Dr. J Murali Naik[2]
[1]Assistant Professor, Dept of Mechanical Engineering
[2]Associate Professor & HOD, Dept of Mechanical Engineering
[1, 2] Holy Mary Institute of Technology and Science (An autonomous Institute), Hyderabad, India

Abstract- *This study explored the tribological performance of J.curcas seed oil and compared with that of a foreign, 10W-30 Arrow premium synthetic blend plus oil, to see its suitability as base oil for lubricationin wire drawing. The experiment was conducted using a four ball tester. The results showed that unrefined J.curcas oil has higher friction reduction and capability in an unformulated form than the conventional oil and can compete in wear protection when formulated with suitable anti-wear agent (ZDDP additives), hence can be a good alternative base stock oils suitable for wire drawing companies, and other metal working processes from tribological, environmental, and non-food competitive points of view.*

I. INTRODUCTION

Additives are substances formulated for improvement of the anti-friction, chemical and physical properties of base oils (mineral, synthetic, vegetable), (Vander and Victoria, 2014).

Suitable protection of contacting surfaces in a tribosystem against wear and scuffing are key requirements for the selection of a lubricating oil, as well as base oil for formulating lubrication oil that is appropriate for any tribological design. To meet these requirements, most mineral based lubricating oils formulators involve reasonable dose of heavy metal, sulphur and phosphorus additives compounds such as zinc dialkyl-dithio- phosphate (ZDDP) (Lim et al., 2014). Which intensify the environmental hazardous nature of the formulated oils (Yong, 2014).

Vegetable oils for some decades had been identified to be environmentally friendly lubricant base stocks (Quinchia et al., 2014), having some attractive lubricating properties in addition to their non-toxic composition, wholesome biodegradable qualities, and renewability (Baumgart et al., 2010; Salih et al., 2013). One of such advantageous properties is high lubricity, due to the atoms of oxygen present in the ester molecules, causing the molecules to form a monolayer over the metal surfaces (Silva et al., 2013). The attachment of these ester molecules are oriented with hydrocarbon chains almost perpendicular, while the adherent to the metal surfaces is by the polar heads (Pujari, 2013,). The attachments are so strong that they are not easily eroded by water, mechanical or thermal stresses.

The competition noticed between the food sectors and industrial lubricants sectors, as vegetable oils are being engaged for industrial lubricants usage,impelled the search for non-edible oils as suitable means of resolving the problem. Jatropha oil, a non-edible vegetable oil produced from the seeds of j.curcas seed plant is one of the largely investigated oils for industrial and automotive lubrication. Its high viscosity due to the dominant ricinoleic acids, around 90% (Silva et al., 2013), suggests the possibility of its application as lubricating oils. Although, the weakness of vegetable oils in terms of oxidation and thermal stability have placed some limitations on their use as engine oils, they still enjoy being engaged as full or components of total lost lubricants base stocks (Cheenkachorn&Udornthep, 2006). Moreover, those limitations can be overcome by the introduction of the relevant additives. The world production of jatropha plant is around 1.5Mt. Africa, including Nigeria, has a contribution of around 1.08Mt (Fernandez-Martinez & Velasco, 2011). jatropha plant is very productive in most of the parts within Nigeria. The yield of j.curcas seed in Nigeria is rated at between 990- 1,700 kg/ha (Gana et al., 2014), and virtually every part of the country is suitable for jatropha plantation. The average oil content of a jatropha seed on the basis of dry weight is 58%in extreme pressure performance of Nigeria.(Nayak and Patel, 2010). This has attracted the investigation of the lubrication properties of this oil.

In this work, the antiwear and unrefined, mechanically extracted jatropha oil, from thenational research institute for chemical technology (NARICT) in Zaria, Kaduna State, Nigeria is compared with those of high quality conventional oil from a foreign manufacturer, using a four ball tester.

II. FORMULATION PROCESS

Virtually, almost all lubricants require further additives to impart other characteristics of a non tribological nature, such as oxidation resistance, corrosion protection, and detergency. Most cutting fluids, vegetable- and petroleum-based, are compounded or modified to achieve these requirements. Several methods are available to modify these oil lubricants. The important and most commonly used methods are sulfurization and phosphate modification. Hofer, (2015).

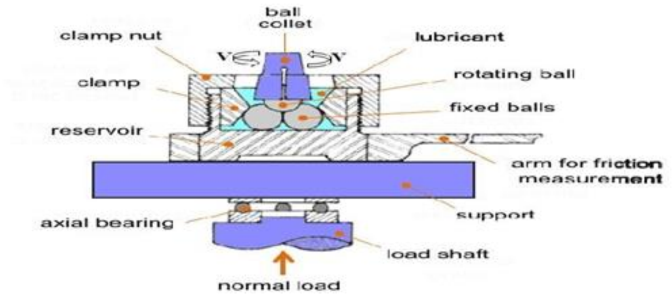

Fig. 2.1 Schematic drawing of four-ball test

III. EXPERIMENTAL

Measurement of friction and wear

This test was carried out based on ASTM D4172 method. A steel ball (comparable to EN 31, 64–66 HRC type), 12.7mm in diameter is thoroughly washed using methanol, wipe dried using industrial tissue paper, mounted on the motor spindle of a four ball tester, and pressed into the cavity of three balls (of the same material, cleaned by the same procedure) clamped in a ball cup filled with lubricant to at least 5mm above the three balls. The ball in the spindle, refer to as the rotating ball normally makes a point contact with each of the three balls in this arrangement (Figure 2.1 above). The setting was loaded to 392 N - static load (indicated by the controller), then the lubricating oil heated to 75°C using an inbuilt heating device, after which the motor spindle was set rotating at 1200 ± 60 rpm for 60 minutes, 10 seconds. The loading, temperature, speed and time were set on a controller, interfacing the four ball machine and a Winducom 2010 software installed on a PC, for the purpose of extracting the experimental data. After the 60 minutes 10 seconds, the three lower balls were removed, cleaned with methane and the scar diameters made on them owing to friction between their contacting surfaces with the top rotating ball were measured using a metallurgical microscope. All relevant data from the software and microscope were recorded and analyzed.

Measurement of Extreme Pressure

The extreme pressure load for the experimented oils was determined based on IP 239 method, similar to ASTM D 2783. The procedure is the same as in ASTM D4172(ASTM, 2010), except that the speed, the time, the temperature in this case were 1760 ± 60 rpm, 10 seconds, and 32 ± 5°C respectively, and the experiment was performed for a load of491N. This procedure was repeated with higher loads in a logarithmic increment as in IP 239 (618N, 785N, 981N, 1030N, 1236N, 1373N …), until welding occurred. The minimum load at which the four balls get welded together was reported as the weld load or load bearing capacity of the oil sample.

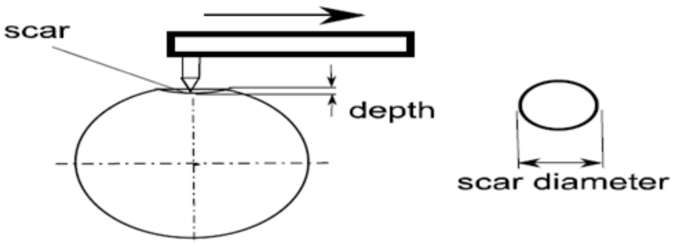

Fig. 3.1 Scar Depth Measuring in a Fix Ball with a Profilometer

Wear Test

In the tribological behavior of the formulations, wear tests were conducted in the four-ball tribometer. The test conditions were chosen from ASTM 4172-94 (2004) standard, that establishes wear tests with sliding speed of 0.45 m/s (1.200 rpm) during 1 hour with normal loads of 392N, the oil bath temperature of 75ºC. The higher normal load, 392N, was chosen to investigate the lubricant behavior under high contact pressures. The objective of the wear tests was to investigate the ability of the lubricants to protect the surfaces against the wear under high contact pressures.

After the tests in the tribometer, the scar diameters were measured in all the fixed balls, in optical microscopic with x-y table, which movement is performed by two micrometers with resolution of 0.01 mm. Each scar diameter was measured in two orthogonal directions.

IV. RESULTS AND DISCUSSION

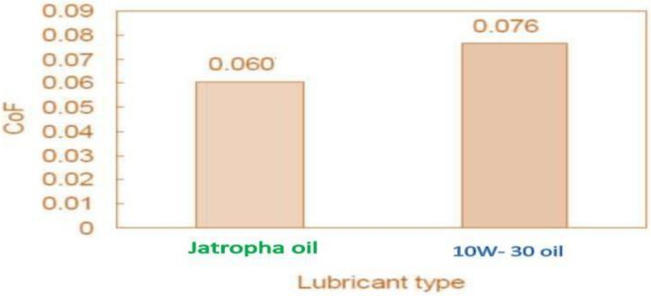

Figure 4.1: Coefficient of frictions of oils under wear test

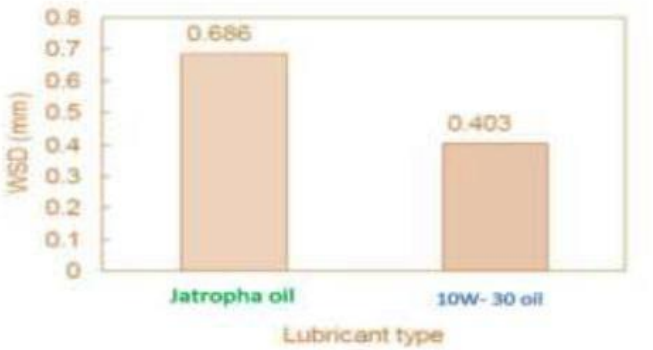

Figure 4.2 Average wear scar diameters of the steel balls in oil

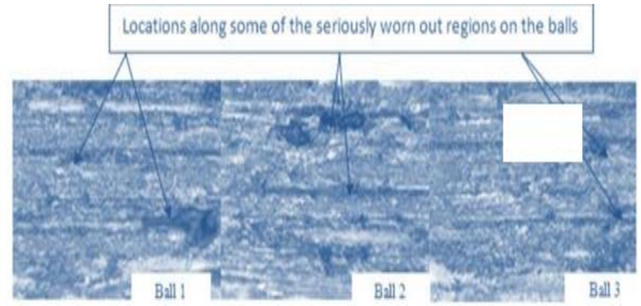

Figure 4.3 Morphology of worn balls in conventional oil (scale of 100)

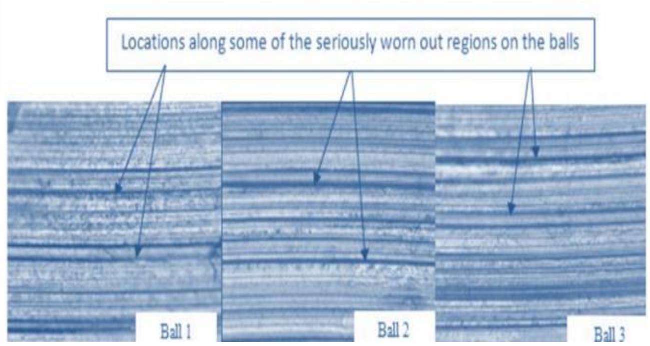

Figure 4.4Morphology of worn balls in J.curcas oil (scale of 100)

The morphology of the surfaces of the three lower balls in each of the oils examined under high magnification factor (500×) of the microscope are shown in Figures 4.3 and 4.4.Figure 4.3 shows the worn surfaces in the mineral oil. The surfaces have more uniform wear. This should be due to the effectiveness of the antiwear additives. The surfaces revealed the strength of the tribochemical reaction between the additives and the surfaces of the balls which made the surfaces very resistant to mechanical shear and abrasive wear. The furrows on the surfaces of the balls injatropha oil (Figure 4.4) are indications of the absence of antiwear additives. The bonding between the oil molecules and the ball surfaces are more of physical with weaker chemical layer, which is not a very good arrangement for this tribosystem, being more a boundary lubrication system. Once the physical bonding is sheared by constantly attacking mechanical shearing due to the top rotating ball, the chemical bonding are soon overcome and the direct metal-to-metal contact are ensured. This results in the tearing of particles from each surface. The torn out particles will in-turn aggravate the wear by acting as abrasive substances in the system. That informed the nature of the deep groves on the scarred surfaces of the balls. The uniformity of the groves showed how uniform the vegetable oil molecules oriented themselves on the contacting surfaces of the balls.

4.8 Extreme pressure (EP)

The CoF data plotted in Figure 4.4 shows that jatropha oil has better lubricity performance for almost all the regime of loading under EP test. Even at higher loads, it has manifestly demonstrated lower CoF than the commercial mineral-based formulated oil. This proves why wax ester extracts from vegetable oils are proposed for used as friction modifiers in industrial and automotive lubricants (Bart et al., 2012).

From Figure 4.5, point A to point B represents the compensation line of the tribosystem with convetional oil as the lubricating oil, where the loading on the lower three balls neither cause seizure nor welding. Point B is the last non-seizure load. The average wear scar diameters within the stated load regime in conventional oil are quite interestingly low. B to C is incipient seizure region, where the lubricating film experiences a temporal break-down. Point C to D is region with immediate seizure, indicating increasing wear scar, leading to the welding of the four balls together at point E (ASTM, 2009) under the lubrication of the commercial oil

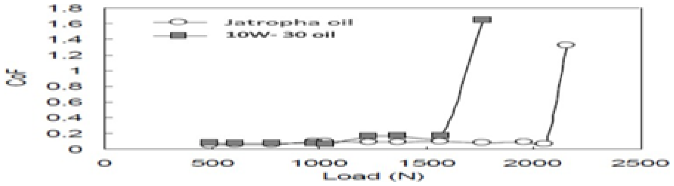

Fig. 4.5 Coefficient of friction (CoF) against load (L) in EP test

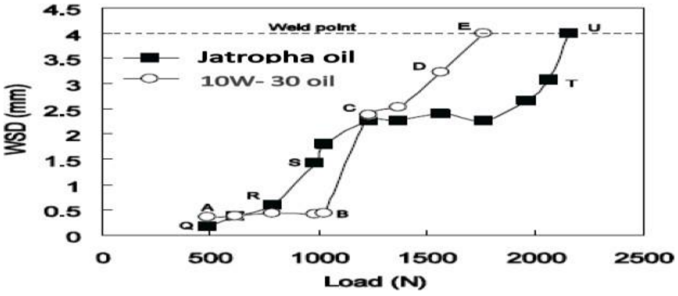

Fig. 4.6 Average wear scar diameter against applied load

The corresponding regions and locations with jatropha oil as the lubricant in the four ball cup tribo-setting are Q to R (compensation line), R (non-seizure load point), R to S (incipient seizure region), S to T (immediate seizure region), and U as the weld point. Points E and U have indeterminate average wear scars diameters, as the four balls were actually welded together in each case. The immediate seizure region in jatropha oil is quite longer than in conventional oil, implying a more durable resistance to wear at higher load. The attachment of the polar heads of the hydrocarbon chains of these oil molecules to the contacting surfaces of the balls were so strong for the intermediate mechanical loads to brush them off. Moreover, the hydrocarbon chains must be the long type, which immunethe surfaces from severe wear at these loads contrary to the case in engine oil. jatropher oil demonstrated a higher weld load (2158N) compare to conventional oil (1766N). These may suggest that extreme pressure is not a very critical subject as friction and wear. Hence, the oil may just need to be sufficiently equipped against friction and wear. This may be the reason for the quite lower EP load of the commercial oil, and this will give preference to jatropha oil which had demonstrated higher weld load. The picture of the welded steel balls in the two lubricants are shown in Figure 4.6

Fig 4.7 Welded balls in the experimental oil

V. CONCLUSION

This work concluded that the highertribological performance of jatropha oil over the commercial oil shows that, if other properties of the oil are improved on to make it meet the requirements as lubricant for elevated temperature wire drawing, it can be a better lubricating oil than the mineral based oils in the market. Jatropha oil as oil base stock, blended with effective anti-wear/extreme pressure additives and friction modifiers will significantly reduce the lost energy of the fuel due to friction, thereby combating the low mechanical efficiency, This will surely be an environmentally friendly lubricating oil and its waste products, and a potential cost effective product suitable as lubricating oil for metal working processes in Nigeria.

REFERENCES

[1] Ajithkumar, G., 2009. Analysis, modification and evaluation of the cold flow properties of vegetable oils as base oils for industrial lubricants, Cochin University of Science and Technology.

[2] ASTM. 2010. ASTM D4172 Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four- Ball Method), ASTM International. West Conshohocken, pp. 5.

[3] ASTM D2783. Standard Test Method for Measurement of Extreme-Pressure Properties of Lubricating Fluids (Four-Ball Method), ASTM International. West Conshohocken, pp. 9.

[4] Bart, J.C., Cavallaro, S., Gucciardi, E. 2012.Biolubricants: Science and technology. Elsevier.

[5] Baumgart, P., Canzi, G., Hanashiro, T., Doezema, L.A., Siniawski, M.T. 2010. Influence of fatty acid additives on the tribological performance of sunflower oil. Lubrication Science, 22(9), 393-403.

[6] Cheenkachorn, K., Udornthep, I. 2006. A Development of Fourstroke Engine Oil Using Palm Oil as a Base Stock.The 2nd SEE.

[7] Fernandez-Martinez, J.M., Velasco, L. 2011.Castor.in: Technological Innovations in Major World Oil Crops, Volume 1: Breeding, (Ed.) S.K. Gupta, Vol. 1, Springer Science & Business Media, pp. 238-239.