Proceedings of Mechanical Engineering Research Day 2015, pp. 53-54, March 2015

Investigation on oxidation of jatropha oil

A.M.H.S. Lubis[1,*], B. Ariwahjoedi[2], M.B. Sudin[3]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2)] Department of Fundamental and Applied Science, Universiti Teknologi PETRONAS,
Bandar Seri Iskandar, 31750, Tronoh, Perak, Malaysia.
[3)] Department of Engineering, School of Engineering Science and Technology, Nilai University
No. 1, Persiaran Kolej, 71800, Nilai, Negeri Sembilan, Malaysia

[*]Corresponding e-mail: munir@utem.edu.my

Keywords: Jatropha, lubricant, oxidation

ABSTRACT – Oxidation is an undesired process in lubrication application. The application of jatropha oil as alternative lubricant base stock has emerged recently. However, the low resistance to oxidation of most natural plant seed oil has limited its application as lubricant. In this work, the oxidation of jatropha oil has been studied. The oil was oxidized by air bubbling method at 95±3°C for 72 hours in the presence of copper. The viscosity and functional group changes due to oxidation were studied before and after oxidation test. Jatropha oil was found oxidized by autoxidation mechanism to produce hydroperoxide, aldehyde and ketone which capable to increase viscosity of the oil.

1. INTRODUCTION

Natural plants seed oils have been used to lubricate parts in motion long time ago before the industrial revolution era. Today, due to environmental issues, the application of these kind oils has emerged again. Not only because it environmentally friendly but also the availability and renewability of these kind of oils.

Jatropha oil (JO) is currently considered as main source for diesel oil substitute [1]. However, jatropha oil it was also found that JO possess good lubrication properties which make it possible to consider as alternative source of lubricant [2]. It has good wear preventive characteristics either used in native oil or as additives in mineral base commercial lubricant oil.

Although application of jatropha oil as alternative lubricant has its own advantage, it also has several disadvantages that will limit its function in lubricating parts. One of the disadvantages is the resistances to oxidation. Resistance to oxidation is very important for a lubricant since it is determine the service life of the lubricant. This process is capable to initiate tribo-chemical degrading process due to the heat generated friction.

It is known that the fatty acid alkyl chain contained in most plant seed oil is susceptible to oxidation both at double bonds and adjacent allylic carbons [3]. Jatropha oil is found to has about of 29-44.2% of linoleic acid (C18:2) [4]. Thus, presence of this double carbon fatty acid is believed will influence its oxidative resistance when used as lubricant due to heat generated friction. In this study, the oxidation of jatropha oil was investigated

2. METHODOLOGY

2.1 Material

Crude jatropha oil (CJO) is used as main lubricant in this research. The oil was obtained from local market, used as sample without any treatment.

2.2 Oxidation Test

The oxidation test was carried out by air bubbling method. Jatropha oil (100 mL) was heated up to 95±3°C in a flask for 72 hours and 10±0.5 L/h air was flown into the oil. A copper strip was used a catalyst and drawn into the oil. Temperature of the oil samples and the rate of air flow were checked periodically to maintain them to be constant. Oxidative behavior of the oil samples was determined from the changes of viscosity after the test.

2.3 Viscosity

Viscosity of oil samples were measured at 40°C using capillary viscometer according to ASTM D-445-04 standard method (Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity).

2.4 Functional Group Analysis

Fourier transform infrared spectroscopy (FTIR) analysis was applied to examine functional groups of the oil sample before and after oxidized. A Shimadzu FTIR-8400S analyzer within scanning range of 600 – 4000 cm^{-1} was employed. This method has found as a very useful method to study oxidation of lubricant [5].

3. RESULTS AND DISCUSSION

In the frictional system, the frictional heat generated during process of friction could accelerate the oxidation. The oxidation process will result in the increase on oil viscosity, reduction of the oil polarity, formation of sludge and varnish, corrosion of the metal surfaces, *etc* [6]. These effects of oxidation will significantly reduce friction and wear prevention properties of the oil. Figure 1 shows the viscosity changes due to prolong heating on the jatropha oil. It can be seen that the oxidation process has increased the

CJO viscosity up to 68.2 % from the initial value (32.9 cSt) after heated for 72 hours.

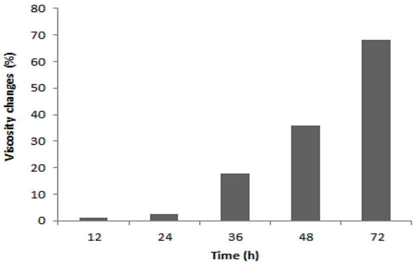

Figure 1 Effect of oxidation to jatropha oil viscosity

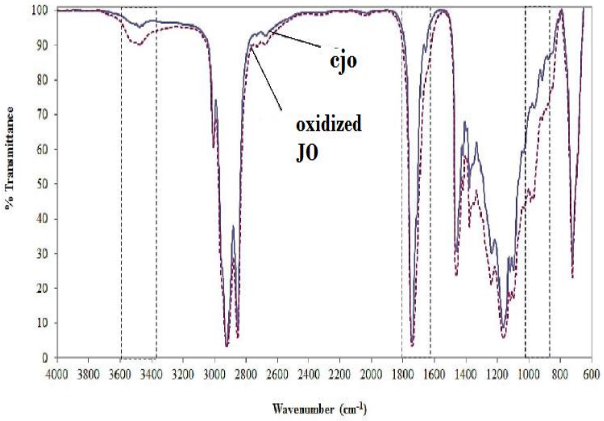

Figure 2 FTIR spectra of crude and oxidized jatropha oil

Figure 2 shows the FTIR spectra of jatropha oil oxidized by prolong heating. Most f the peaks were similar before and after the heating at except three regions. The unsaturated (double carbon) bonds contained in most vegetable oil are known prone to oxidation [6]. The oxidation of unsaturated fatty acids contained in the oil taken place by auto-catalytic (autoxidation) process which once started, the reaction is self-propagating and self-accelerating although also can be accelerated by presence of catalysts such as metal, heat and light [3]

The autoxidation of fatty acid is typically consisting of initiation, propagation, and termination process [7]. In initiation process, a-methylenic H atom is abstracted from the unsaturated molecule to form an alkyl radical which generates free radicals ($RH \rightarrow R\bullet + H\bullet$). Since the free radical is highly reactive, it can react with atmospheric oxygen, thus a simple reaction resulting from the radical nature of the oxygen molecule produces a peroxy radical ($R\bullet + O_2 \rightarrow ROO\bullet$). Disappearance of peaks at 1658 and 1710 cm-1 band, which typically show C=C bond vibration, is believed associated with oxidation attack to the double bond (-HC=CH-) at the unsaturated site. In the propagation reactions, the peroxy radical reacts with another unsaturated molecule (RH) to form a hydroperoxide (ROOH) and a new unstable methyl radical (R•). A spectra change was observed at the range of 3700 – 3500 cm^{-1} band which is typically associates with hydroxyl functional group. This indicates the formation of hydroperoxide in the oxidized jatropha oil (ROOH). These hydroperoxide produced are unstable and may degrade to radicals that accelerate propagation of the reactions ($ROOH \rightarrow RO\bullet + \bullet OH$). As a new free radical is generated, more oxygen is incorporated into the system and the newly propagated radical then reacted with oxygen again to produce another peroxy radical ($RO\bullet + RH + O_2 \rightarrow ROH + ROO\bullet$ and $OH\bullet + RH + O_2 \rightarrow ROO\bullet + H_2O$) . These reactions are known as branching steps of the fatty acid autoxidation process and could produce other secondary products such as aldehydes (RCHO) and ketones (RCOR) Appearance of two new spectra peaks at 990 and 970 cm^{-1} band along with disappearance of peak at 905 and 865 cm^{-1} band is related to formation of dimer carboxylic acid in the oil. The occurrence of this acid is evidently showed that the oxidation proceeds to formed aldehyde and ketone after the branching process. The aldehyde and ketone then undergo further reactions to form carboxylic acids as well as other high-molecular-weight species that thicken the oil.

4. CONCLUSIONS

Autoxidation is considered as main mechanism of jatropha oil oxidation. This process typically attack the double bond site of the jatropha oil fatty acid to produce hydroperoxide, aldehyde and ketone which increase viscosity of the oil

5. REFERENCES

[1] Achten, W.M.J., L.Verchot, Y.J. Franken, E. Mtahijs, VP. Singh, R. Aerts, and B.Muys, "Jatropha Bio-diesel production and use," *Biomass and Bioenergy*, vol. 32, pp. 1063 - 1084, 2008.

[2] Lubis, A.M.H.S., M.B. Sudin, B. Ariwahjoedi, "Investigation of Worn Surface Characteristics of Steel Influenced by Jatropha Oil as Lubricant and Eco-friendly Lubricant Substituent," Journal of Applied Science, vol. 10, pp. 1797 - 1802, 2011

[3] Scrimgeour, C., "Chemistry of Fatty Acids," in *Bailey's Industrial Oil and Fat Products*, F. Shahidi, Ed., 6th ed: John Wiley & Sons, Inc, 2005.

[4] Guebitz, G. M. , M. Mittelbach, and M. Trabi, "Exploitation of the tropical oil seed plant Jatropha curcas L.," *Bioresource Technology*, vol. 67 pp. 73-82, 1999.

[5] Vlachos, N, Y. Skopelitis, M. Psaroudaki, V. Konstantinidou, A. Chatzilazarou, E. Tegou, "Applications of Fourier transform-infrared spectroscopy to edible oils," *Analytica Chimica Acta* vol. 573-574, pp. 459-465, 2006.

[6] Crawford, J., A. Psaila, and S.T. Orszulik., “Miscellaneous additives and vegetable oil " in *Chemistry and Technology of Lubricant*, R. M. Mortier, *et al.*, Eds., 3rd ed: Springer, 2010

[7] Aguilar, G., G. Mazzamaro and M. Rasberger, "Oxidative Degradation and Stabilisation of Mineral Oil-Based Lubricants," in *Chemistry and Technology of Lubricants*, 3rd ed: Springer, 2010.