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Palm Oil Methyl Ester and Its Emulsions Effect on Lubricant Performance and Engine Components Wear


*aCentre for Energy Science, Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

Abstract

The results of an experimental work carried out to evaluate the effect of palm oil methyl esters, also known as palm oil diesel (POD) and its emulsions as alternative fuel on unmodified indirect injection diesel engine's wear and lube oil performance are presented in this paper. Half throttle engine with constant 2500 rpm setting was maintained throughout the wear debris and lube oil analysis such as for a period of twenty hours for each fuel system. The sample of lube oil was collected through a one-way valve connected to the crankcase sump at the interval of four hours. When the engine warmed up, first sample has collected immediately. The same conventional lubricating oil SAE 30 was used for each fuel system. To measure wear metal debris and lubricating oil additives depletion of used lubricating oil, Multi element oil analyzer (MOA) was used. To measure the viscosity of lube oil an ISL automatic houillon viscometer (ASTM D445) has been used. Very satisfactory results have been obtained by comparing the lube oil analysis results of Ordinary Diesel and Palm Oil Diesel and their emulsions with 10 percent water by volume. In crankcase oil samples, accumulation of wear metal debris was lower with Palm Oil Diesel and emulsified fuels compare to baseline Ordinary Diesel fuel. Both Ordinary Diesel and Palm Oil Diesel emulsions with 10 per cent water by volume showed promising trends for resisting wear.

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Keywords: Methyl Ester; Engine Oil; Ordinary Diesel (OD); Diesel Engine Wear;

1. Introduction

Palm Oil Diesel (POD) and its emulsions are compatible as alternative fuels for diesel engine [1, 2]. Now attention has drawn to observe their effect on lub oil and wear of engine components. The injection performance, combustion and atomization characteristics of vegetable oils in both direct-injection and indirect-injection diesel engines are obviously different from those of petroleum derived diesel fuels[3]. Vegetable oils normally produce gumming due to having high viscosity in long period operation;

*Corresponding author. Tel.: +6-03-79674448; fax: +6-03-79674448.
E-mail address: mofijduetme@yahoo.com
the formation of injector deposits, ring sticking and inconsistency with conventional lubricating oils [4]. One sovereign means of oppressing these difficulties is to emulsify these fuels with water, for improving fuel atomization, spray features possibly through the micro-explosion phenomenon [5].

In diesel engine, most of the components normally involved with wear process such as piston, piston ring, cylinder liner, bearing, crankshaft, cam, tappet and valves [6]. Normally wear grit remain in the oil in case of lubrication system. By testing a lube oil sample from the engine after a certain period of operation, lubricant’s ability to continue original function can be measured and also various information on the engine operation and condition can be obtained.

The aim of the present study is to inquiry the effects of ordinary diesel, palm oil diesel and their emulsions on the deterioration of lube oil and wear of the engine components.

2. Experimental Set-up and Procedure

The test was conducted at the Engine Tribology Laboratory, Department of Mechanical engineering, University of Malaya. Isuzu 4FBI horizontally arranged 4-cylinder IDI engine was used for this purpose. The rating of the engine is 39 kW at 5000 rev/min. Wear debris and lube oil have been analysed at half throttle engine setting with running speed of the engine at 2500 rpm for a twenty hours period for each fuel system. At four hours interval through one-way valve (connected to the crankcase sump) the lube oil sample was collected. When the engine warmed up, first sample has collected immediately. The lube oil used was conventional (SAE Grade 30). The composition and properties of fuels are depicted in Table 1 and 2 respectively. The physicochemical characteristics of the crankcase oil are shown in Table 3.

2.1. Tables

Table 1 Composition of fuels

<table>
<thead>
<tr>
<th>No</th>
<th>Fuel</th>
<th>Fuel emulsions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OD</td>
<td>100% ordinary diesel</td>
</tr>
<tr>
<td>2</td>
<td>OD90</td>
<td>10% water + 90% ordinary diesel</td>
</tr>
<tr>
<td>3</td>
<td>POD</td>
<td>100% palm oil diesel</td>
</tr>
<tr>
<td>4</td>
<td>POD90</td>
<td>10% water + 90% palm oil diesel</td>
</tr>
</tbody>
</table>

Table 2 Characteristic of POD and OD

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>POD</th>
<th>OD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific density, g/cm³</td>
<td>0.875</td>
<td>0.825</td>
</tr>
<tr>
<td>Kinematic viscosity, @ 40°C</td>
<td>4.71</td>
<td>3.55</td>
</tr>
<tr>
<td>Cetane number</td>
<td>50-52</td>
<td>53</td>
</tr>
<tr>
<td>Calorific value, KJ/kg</td>
<td>41300</td>
<td>43</td>
</tr>
</tbody>
</table>

Table 3 Physicochemical data of lube oil [SAE Grade 30]

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density @ 150 C kg/l</td>
<td>0°C</td>
<td>0.890</td>
</tr>
<tr>
<td>Flash Point C.O.C</td>
<td>0°C</td>
<td>246</td>
</tr>
<tr>
<td>Pour Point</td>
<td>0°C</td>
<td>-9</td>
</tr>
<tr>
<td>40</td>
<td>0°C</td>
<td>106</td>
</tr>
<tr>
<td>100</td>
<td>0°C</td>
<td>11.90</td>
</tr>
<tr>
<td>Viscosity index</td>
<td></td>
<td>95</td>
</tr>
<tr>
<td>Sulphated ash</td>
<td></td>
<td>0.82</td>
</tr>
<tr>
<td>Acid number</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>Base number</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Color (ASTM)</td>
<td></td>
<td>4.0</td>
</tr>
</tbody>
</table>
3. Results and Discussion

The test was conducted in the normal environmental of Malaysia, temperature range (22°C to 33°C). The results of performance, combustion, emissions and smoke agglomerate's micrographs have been shown in [1, 2]. The results showed that when POD and the emulsified fuels is used power output is slightly lower. For reducing the emissions levels of CO, CO2, HC, NOx, SOx and smoke, emulsification is effective. It also shows lower exhaust gas temperature and reduces the smoke particulate size marginally.

3.1. Wear debris analysis

Iron (Fe): The concentration of iron is shown in Figure 1. The iron (Fe) content for ordinary diesel (OD), palm oil diesel (POD) and their emulsions are initially at 1 ppm. It is observed that pure conventional diesel provide the highest level of iron and while pure POD fuel gives lower. This indicates that POD fuel acts as lubricant between the piston rings the cylinder liner, shaft, valve train and gears. As for emulsified fuel, it is observed that iron concentration lower with compare to OD fuel. It is clear that the presence of water in fuel lowers the combustion temperature and exhaust temperature [2]. Hence the wear rate lessens between engine friction components. At the end of 20th hour it is found that ordinary diesel produces iron concentration of 7 ppm followed by palm oil diesel 90 (6 ppm), OD90 (5 ppm) and POD (3 ppm).

Copper (Cu): The concentration of copper is depicted in Figure 2. The most common sources of copper concentration are bearing. Based on the wear debris analysis it is observed that the highest level of copper concentration produced by OD throughout the 20 hours engine run followed by OD90. Both POD and POD 90 produce lesser copper concentration with compare to OD and OD90. This means that POD 90, POD and even OD90 bear anti-wear characteristics with compare to OD fuel. The lowest level of copper debris is produced by POD fuel throughout the 20 hours engine run because of the presence of fatty acids such as stearic (3.6 – 4.6%) acids, palmitic (40 – 46.5%) in POD [4].Highest value of copper is found at the end of twenty hours engine run by OD (95 ppm) followed by OD90 (89 ppm), POD90 (82 ppm) and POD (75 ppm).

![Fig.1 Iron concentration variation vs. running hours.](image1)
![Fig.2 Copper concentration variation vs. running hours.](image2)

3.2. Additive elements analysis
Phosphorus (P): Phosphorus acts as anti-wear and antioxidant additive in typical commercial lube oil. Phosphorus concentration ionization is normal and negligible as shown in Figure 3. However, the phosphorus concentration depletion for emulsified fuels is slightly lower than POD and OD fuels (emulsion of OD and POD). It can be explained that no additive depletion by precipitation from fuel or additive under treatment took place. After 20 hours running of engine, the highest amount of additive is found in OD90 (880 ppm) fuel, followed by POD90 (846 ppm), OD (801 ppm) and POD (775 ppm).

3.3. Lubricating oil viscosity

Referring to Figure 4, demonstrate a similar trend in viscosity of all fuel systems throughout the test at 40°C, except for the baseline OD fuel system. It shows a sudden increase in viscosities from 100 cSt to 108 cSt at the 8th hour, pointedly due to oxidation, exhalation of lighter oil ingredients and contamination by insolubles. Tribologically, adequate lubrication to critical engine parts may not be provided by thickened oil and the anti-wear agent may also be depleted.

It can be summarized by chemical analysis results obtained from used lube oil samples that emulsified fuels for both POD and OD provide better viscosity performance than the baseline OD fuel since emulsified fuels can maintain more uniform viscosity level than of OD fuel. After 20 hours running of engine viscosity of OD is found 108 cSt followed by OD90 (102 cSt), POD (99 cSt) and POD90 (97.5 cSt).

4. Injector Observations

At the end of each running test of all fuel system visual inspection is carried out at the injector nozzles and it shows little polymerization of the fuels took place. Slight differences in color and texture are observed while carbon deposits are comparable in amount. Around the injector tip greater carbon deposit and varnish are noticed during the use of OD fuel system,. The injector surface using OD emulsions is generally dirtier rather than using POD emulsions. It is seemed that operation of the fuel injector is influenced by the percentage of water in fuel.

5. Productions and Economy

Malaysia is listed as the biggest palm oil producer and exporter in the world. In 2010, export earnings by palm oil exceeded that of oil products (Malaysia exports some petroleum products after refining) and gas. That has made palm oil the biggest single export revenue earner for the country. Unlike oil and gas, which has a heavy foreign content, palm oil production is virtually 100% local. In 2010, the palm oil
industry earned nearly RM 45,000 million in exports and RM 36,000 million in 2009 (MPOB). Malaysia Palm Oil Board (MPOB) formerly Palm Oil Research Institute of Malaysia (PORIM) has taken an initiative since 1988 to look at the possibilities of converting oil palm products into fuels. One of the first products was the use of methyl ester of palm oil as diesel substitute. The use of methyl esters as fuel proved technically very suitable obtained by MPOB, Malaysia [7].

![Image of current price of various fuels](image)

**Fig.6 Current price of various fuels**

Although there is a general interest in using and producing biodiesel, the economics have not yet appeared favorable. The production cost of biodiesel is dependent on the regional prices of biofuel, labour, land and processing plant cost etc. Figure 6 shows a comparison of the cost of diesel fuel to the cost of energy equivalent amount of palm oil and other vegetable oils as currently in year 2011. From the Figure, it is observed that it is not yet economical to use palm oil as well as other biodiesels. However biodiesel is being used as alternative fuel in diesel engine with some government subsidy in some countries like Austria (from rapeseed methyl ester) and in Thailand (palm oil diesel is being used in agricultural sectors) [8]. In Malaysia, some useful area has been selected where the POD will be used with government subsidy such as agricultural, constructions and other related power plants [5].

6. Conclusions

The following conclusions may be drawn from the present study:

- Lower wear debris material (Fe, Cu) is produced by POD followed by emulsified fuels and OD.
- Emulsification fuels such as OD90 and POD90 show good performance in terms of maintaining anti-wear additive as P. Fuel POD uses more anti wear additive in comparison to other fuels.
- Viscosity level is within the range of 80 to 120 cSt as shown by POD and emulsified fuels.
- Emulsified POD is effective to reduce the carbon deposits on injector tips and they performed better due to less carbon at nozzle tips.
- Government subsidy is needed to use biodiesel because the current price of biodiesel is more than diesel fuel.

Concluding remark is that Palm Oil Diesel (POD) reduces wear debris materials with ascending use of lubricant reserve additive materials that need to be investigated.
Acknowledgements

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References