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EFFECT OF PALM OIL METHYL ESTER AND ITS EMULSIONS ON ENGINE WEAR AND LUBRICANT DEGRADATION

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Abstract This paper presents the results of an experimental work carried out to evaluate the effect of palm oil diesel (POD, or palm oil methyl esters) and its emulsions as alternative fuels on unmodified indirect injection diesel engine's wear and lubricant degradation. Half throttle engine setting was maintained throughout the wear debris and lube oil analysis, with engine running at 2500 rpm 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 four hours interval. The first sample was collected immediately after the engine had warmed up. The same lubricating oil as conventional SAE 30 was used during all the fuels system. Multi element oil (MOA) analyzer was used to measure increased of wear metals debris and decreased of lubricating oil additives in used lubricating oil. An ISL automatic houillon viscometer (ASTM D445) and Potentiometric titration (ASTM D2896) were used to measure viscosity and total base number (TBN) respectively.The lube oil analysis results for POD, OD and their emulsions containing 10 per cent of water by volume were compared. Very promising results have been obtained. Accumulation of wear metal debris in crankcase oil samples were lower with POD and emulsified fuels compared with baseline OD fuel. Both OD and POD emulsions with 10 per cent water by volume showed promising tendency for wear resistance.

Keywords: Diesel engine wear, Engine oil, Methyl ester, Palm oil diesel (POD) emulsions

INTRODUCTION

In previous findings [Masjuki et al. 1997&2000], POD and its emulsions are proved to be an alternative fuels for diesel engine. Now it is desired to look their effect on lubricating oil and engine's component wear. This is because of their high viscosities - 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 [Ryan et al.,1984]. Having high viscosity, in long term operation, vegetable oils will normally produce gumming, the formation of injector deposits, ring sticking and incompatibility with conventional lubricating oils [Ziejewski et al., 1986]. One feasible means of overcoming these problems is to emulsify these fuels with different proportions of water, leading to improve fuel atomization, spray characteristics possibly through the phenomenon of micro-explosion.

In diesel engine, the components normally subjected to wear process are piston, piston ring, cylinder liner. bearing, crankshaft, cam, tappet and valves [John et al., 1983]. In a lubrication system, wear particles normally remain in the oil. By testing a sample of lube oil from the engine after certain running duration it is possible to measure the lubricant's ability to continue to perform its original function and also to gain information on the operation and condition of the engine.

The present study aims (a) to study the effects of emulsions (of OD and POD) on lube oil deterioration and (b) to investigate the effects of emulsions on wear rate and injector fouling and compare them with baseline ordinary diesel fuel .

EXPERIMENTAL SETUP AND PROCEDURE

The test was conducted at the Tribology and Energy Efficiency Laboratory, Department of Mechanical Engineering, University of Malaya. Half throttle engine setting was maintained throughout the wear debris and lube oil analysis, with engine running at 2500 rpm 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 four hours interval .

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The first sample was collected immediately after the engine had warmed up.

The lube oil used was PETRONAS MOTOLUB XGD (SAE Grade 30). The fuels composition and properties are shown in Table 1 and 2 respectively. The physicochemical characteristics of the crank-case oil are shown in Table 3.

Table –1: Fuels composition

No.	Fuel	Fuel emulsions
1.	OD	100% ordinary diesel
2.	OD90	10% water + 90% ordinary diesel
3.	POD	100% palm oil diesel
4.	POD90	10% water + 90% palm oil diesel

Table –2: Properties of OD and POD

Characteristics	POD	OD
Specific density, g/cm3	0.875	0.832
Kinematic viscosity, @ 40 oC	4.71	3.60
Cetane number	50-52	53
Calorific value, KJ/kg	41300	46800

Table –3: Physicochemical Data Of Petronas Motolub Xgd [Petronas Dagangan]

Characteristics	Units	value
Density @ 15 ^{o} C kg/l		0.890
Flash Point C.O.C.	^{o} C	246
Pour point	^{o} C	-9
Viscosity	cSt	
40 ^{o} C		106
100 ^{o} C		11.90
Viscosity index		95
Sulfated ash		0.82
Neutralization value		
Acid number		0.10
Base number		7
Color (ASTM)		4.0

RESULTS AND DISCUSSION

The test was conducted at Malaysian normal environmental temperature (22 to 33^{o}C). The results of performance, combustion, emissions and smoke agglomerate's micrographs have been shown in [Masjuki et al., 1997]. The results show that Power output is slightly lower when using POD and the emulsified fuels. Emulsification is effective in reducing the emissions levels for CO, CO_2, HC, NOx, SOx and smoke. It also reduces the smoke particulate size marginally and also exhibits lower exhaust gas temperature.

Wear Debris Analysis

Iron (Fe). The iron concentration is shown in Figure 1. The Fe content for OD , POD and their emulsions are initially at 1 ppm. It is observed that the highest level of iron is detected from pure conventional diesel and the lowest is from pure palm oil diesel fuel. This seems to indicate that POD fuel acts as lubricant between the piston ring and cylinder liner, shaft, valve train and gears. As for emulsified fuel (due to the present of fatty acid in POD fuel), it is observed that the iron level drops as the percentage of water increases. This indicates that the presence of water in fuel lowers the combustion temperature as well as

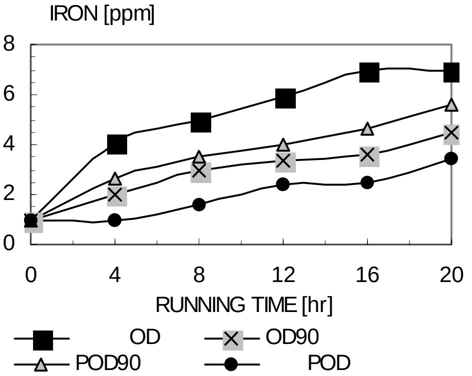

Fig.1 Variation of iron concentration vs running hour

lowers the exhaust temperature as shown in [Masjuki et al.,1997]. Hence the wear rate reduces between engine rubbing components. It is found at the end of 20th hour, OD produces iron concentration of 7 ppm followed by POD90 (6 ppm), OD90 (5 ppm) and POD (3 ppm).

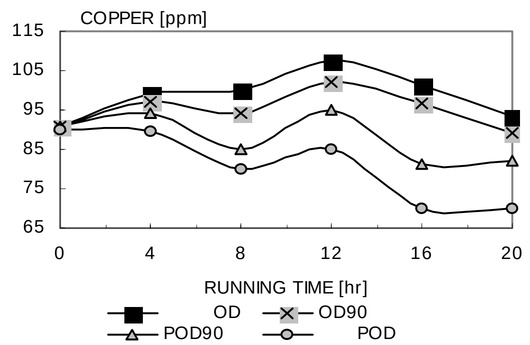

Fig. 2 Variation of copper concentration vs running hour

Copper (Cu). The copper concentration is depicted in Figure 2. The concentration of copper is sometimes in conjunction with lead readings and bearings are the most common sources of copper debris. Based on the wear debris analysis it is observed that OD produces the highest level of copper concentration throughout the 20 hours engine run followed by OD90. Both

POD90 and POD produce lower copper concentration in comparison to OD and OD90. This means that POD and POD90 and even OD90 bear an anti-wear characteristics in comparison to OD fuel. The lowest level of copper debris is produced by POD fuel throughout the 20 hours engine run, indicating that the presence of fatty acids in POD [4] reduces the friction values under boundary lubrication conditions precipitously. It can be noted POD contains two major fatty acids are palmitic (40-46 5 %) and stearic (3.6-4.6 %). At the end of 20 hours engine run, the highest value of copper is found by OD (93 ppm) followed by OD90 (89 ppm), POD90 (82 ppm) and POD (70 ppm).

Additive Elements Analysis

Phosphorus (P). Phosphorus acts as anti-wear and antioxidant additive in typical commercial lube oil. Figure 3 shows that the phosphorus concentration depletion is normal and negligible. However, the

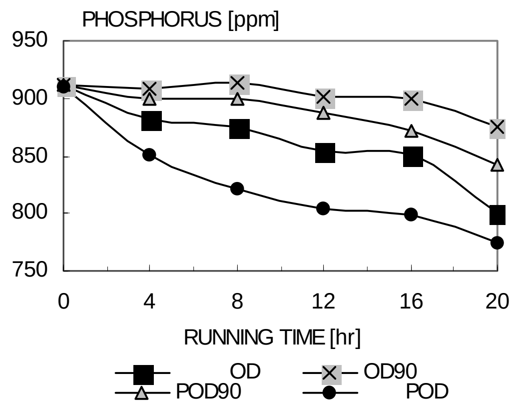

Fig.3 Variation of phosphorus concentration vs running hour

phosphorus concentration depletion for POD and OD fuels are slightly higher than emulsified fuels (emulsion of OD and POD). It can be explained that no additive depletion by precipitation from fuel or additive under treatment took place. The trends are shown in figure 3. At the end of 20 hours engine run, the highest amount of additive is found during OD90 (875 ppm) fuel, followed by POD90 (842 ppm), OD (801 ppm) and POD (775 ppm).

Lubricating Oil Viscosity

Referring to Figure 4, all the fuel systems demonstrate a similar trend in viscosity throughout the 20-hours running test at 40^{o} C (without noticeable oil thickening or thinning being observed), except for the baseline OD fuel system. It shows a sudden rise in viscosities from 100 cSt to 108 cSt at the 8yth hour, possibly due to oxidation, evaporation of lighter oil components and contamination by insolubles.

Tribologically, thickened oil may not provide adequate lubrication to critical engine parts and the anti-wear agent may also be depleted. This phenomenon may explain the presence of relatively higher wear debris concentration of iron and copper elements in lube oil samples when using pure OD fuel.

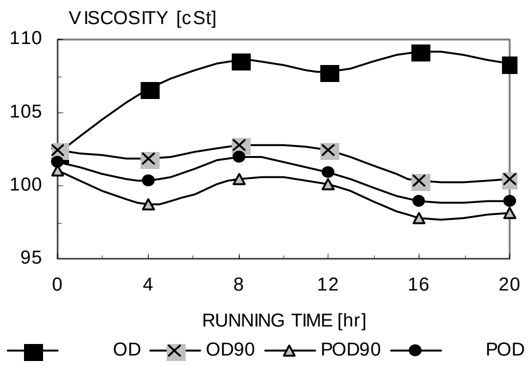

Fig. 4 Variation of lube oil viscosity vs running hour

Figure 4 also shows that the viscosities of all the fuels used appear to be constant. However, the baseline OD shows a higher level in viscosity. Results obtained from chemical analysis of lube oil samples also show that emulsified fuels for both POD and OD have a better viscosity performance than the baseline OD fuel since emulsified fuels are capable of maintaining a more uniform viscosity level than OD fuel. At the end of 20 hour engine run, viscosity of OD is found 108 cSt followed by OD90 (100 cSt), POD (99 cSt) and POD90 (98 cSt).

Total Base Number (TBN)

TBN is a measure of the lube oil's alkalinity which is an indication of its ability to counter the corrosive

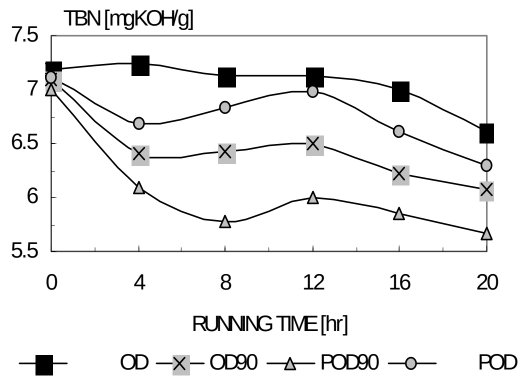

Fig. 5 Variation of total base number vs running hour

effects of high sulphur diesel fuels. Figure 5 generally shows that TBN depletion is negligible as all lies within the allowable limits for SAE 30 motor oil. Based on the wear debris and chemical analysis, it is noted that there is no direct correlation of TBN with wear rate. This agrees well with the findings of Shukla et al, although they used methanol fuel [Shukla et al.,1991]. At the end of 20 hour engine run, TBN of OD is found 6.60 mgKOH/g followed by POD (6.30 mgKOH/g), OD90 (6.07 mgKOH/g) and POD (5.67 mgKOH/g).

Injector Observation

Visual inspection of the injector nozzles at the end of each running test for all the various fuel system shows little polymerization of the fuels took place. Deposits of carbon were comparable in amount but slight differences in color and texture were observed. Using OD fuel system , greater carbon deposit and varnish were noticed around the injector tip. The surface of injector using OD emulsions is generally dirtier than using POD emulsions. The percentage of water in fuel seems to influence the operation of the fuel injector.

The findings here shows that increasing the water content will reduce the alcohol content in the fuel system, thus resulting in heavier carbon deposit. This is due to the loss of dispersancy in lube oil since alcohol has a good solvent action [Carroll et al., 1984] it has a strong affinity for dirt particles and surround each with oil soluble molecules which keep sludge and varnish from agglomerating thus keeping the debris in suspension in a very fine state of dispersion in lube oil.

CONCLUSIONS

The following conclusions may be drawn from the present study:

(a) Emulsions of POD and OD improve the anti-wear characteristics of the engine components compared with using pure OD fuel.

(b) Emulsification of POD will prolong the service life span for lube oil since they are capable of maintaining a constant viscosity and TBN levels in lube oil.

(c) Emulsified POD with water seemed to be effective in reducing the carbon deposits on fuel injector nozzles and they performed better as they developed less carbon deposits on the injector tips.

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