Effects of Using Biodiesel on Engine Generator Components

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ABSTRACT

The purpose of using biodiesel in automobile is to save petroleum fuel consumption and improve air quality. In low composition, biodiesel has been used by the Indonesian people and have chances to be increased. The advantages of biodiesel on the engine performance have been known as well as emissions and lubrications, while the long-term effects on the engine components are still a lot of studies and researches. Wear of engine components used in an engine can be predicted by used oil analysis. This paper presents used oil analysis resulted from two series of identical tests using 3.5 kVA engine generators fuelled by 5% biodiesel (BS_5) and 50% (BS_50) in composition. Used oil analysis was done after completion of 100 hours durability tests. The results indicated that the effect of the difference in composition was not significant to the used oil conditions and component wears.

Keywords: Engine Generator, Used Oil, Biodiesel, Metals Wear

1. INTRODUCTION

The use of biodiesel fuel in automotive is to save fuel consumption from petroleum and improve air quality. Biodiesel fuel sold in the domestic Indonesian market, named Bio-solar, is a mixture with a composition of 5% to 10% pure biodiesel and have chances to be increased in quantity. The basic parameters of biodiesel will have slightly different characteristic to the petroleum diesel.

Research on the use of biodiesel is mostly done around the world. Research aimed to optimize both quantity and quality. The advantages of biodiesel in terms of performances and emissions compared to petroleum diesel also have been known. The effects of using biodiesel associated with the engine components is still a topic of research interest.

Some properties of biodiesel such as viscosity, density and surface tension are higher. The properties lead to imperfect fuel spray and produce lubricating oil dilution and result on the components wear and corrosion as well as reducing oil lifetime. Oxidation products on used engine oil of an engine fuelled by biodiesel are also aggressive towards soft metals such as Pb and Cu bearing component materials [1]. Besides corrosive to metals Pb and Cu, the results on the test bench oxidation test method ASTM D6594 also showed decreasing in viscosity, TBN and increasing TAN after completion of heating 135 °C for 160 hours [2]. The study by the same method coupled with testing engine for 300 hours showed the results where the negative effects of increasing wear of metals Pb and Cu in the presence of Fatty Acid Esters Methyl biodiesel in the engine lubricant [3]. Besides corrosive to soft metals, dilution of biodiesel in the lubricant oil also improves oxidation thereby increasing the buildup of deposits on pistons [4]. In some cases, due to the properties quality of biodiesel causes problems on fuel supply system and the accumulation of debris on the injector choking [5].

Tests and reviews papers which consistent with the results reported by other researchers [6, 7]. A study found that the usage of biodiesel which reflect the wear of metal engine component condition with normal levels. The wear metals are monitored including Fe, Al, Cu, Pb, Cr and Si. Only the Cu metal that higher than the other samples, which is probably derived from a cooler material [8].

Testing of the usage biodiesel in engines that give different results indicated the formation of carbon deposits fewer and wear metals were lower [9]. Some researchers also reported a decline in deposit formation in the components around the engine due to
lower soot formation from biodiesel [10]. However, reports regarding the effect of biodiesel on engine lubricants oil lead to dilution into the engine and resulting in serious damage or engine failure has not been found.

A comparative test of usage biodiesel between 5% composition of biodiesel (95% Bio-solar+5% biodiesel) with 50% composition (50 % Bio-solar+50% biodiesel) has been carried out in the Center for Thermodynamics, Motor and Propulsion (BTMP). The test was carried out for 100 hours using engine-generator. Evaluation of the effects to the generator engine components was done through the used oils analysis.

This paper reports the results of the used oils analysis after completion of the tests. The purpose of this study was to determine the amount of dilution of biodiesel fuel (fuel diluents) to the engine generator oils after 100 hour durability test and evaluate the effect of the usage of biodiesel fuel to the used oils conditions and engine components wears.

II. METHODOLOGY

The engine generators durability test was done in test cell 10 of The Center for Thermodynamics, Engines and Propulsion using two series of identical tests. The specifications of the test engine generators used are shown in Table 1.

<table>
<thead>
<tr>
<th>Test Engine</th>
<th>YANMAR™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Type</td>
<td>Dongdong 3.5 kVA</td>
</tr>
<tr>
<td>Engine Type</td>
<td>J48</td>
</tr>
<tr>
<td>Coolant</td>
<td>Air</td>
</tr>
<tr>
<td>Stroke</td>
<td>4 – stroke</td>
</tr>
<tr>
<td>Engine capacity</td>
<td>200 cc</td>
</tr>
<tr>
<td>No of cylinder</td>
<td>1</td>
</tr>
<tr>
<td>Rpm</td>
<td>3000</td>
</tr>
<tr>
<td>Generator Type</td>
<td>Revolving Field AC</td>
</tr>
<tr>
<td>Output Power</td>
<td>3.5 kVA</td>
</tr>
</tbody>
</table>

During the test, the generators was using engine oil MEDITRAN S™, produced by Pertamina Co, SAE 40 API service CF/CF-2. Used oil analysis performed at an independent laboratory Petrolab Services Co, Rawangmangun, Jakarta.

Prior to durability testing for 100 hours, both engines were overhauled to ensure the condition of engine components still good and working properly. Once re-assembled the engine components, the engine made a run-in for 10 hours using diesel fuel (Bio-solar).

During durability test, a dummy load was used to accommodate the electricity generated by the test generator. The dummy load was in the form of a series of light and loaded 75% of the maximum load (Figure 1). During durability test, the test generators was turning on continuously (24-hours per day) except when checking the condition if there were problems that interfere with engine performance.

The fuel was a blend of 5% and 50% pure biodiesel (palm methyl ester) with 95% and 50% Bio-solar respectively. Bio-solar is a brand of diesel fuel produced by Pertamina Co. (Bio-solar have max 10% FAME content). The specifications of pure biodiesel (palm methyl ester) are shown in Table 2.
Table 2. Specification of Pure Biodiesel

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>METHOD</th>
<th>SPECIFICATION</th>
<th>UNIT</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (at 40°C)</td>
<td>EN ISO 12185</td>
<td>850 – 890</td>
<td>kg/m³</td>
<td>856</td>
</tr>
<tr>
<td>Viscosity (at 40°C)</td>
<td>ASTM D 445</td>
<td>2.3 – 6.0</td>
<td>mm²/s</td>
<td>5.07</td>
</tr>
<tr>
<td>Flash Point, PMCC</td>
<td>ASTM D 93</td>
<td>120 Min</td>
<td>°C</td>
<td>176</td>
</tr>
<tr>
<td>Cloud Point</td>
<td>ASTM D 2500</td>
<td>18 Max</td>
<td>°C</td>
<td>18</td>
</tr>
<tr>
<td>Water Content</td>
<td>EN ISO 12937</td>
<td>0.05 Max</td>
<td>%wt</td>
<td>0.041</td>
</tr>
<tr>
<td>Acid Number</td>
<td>ASTM D664</td>
<td>0.8 Max</td>
<td>mg KOH/g</td>
<td>0.196</td>
</tr>
<tr>
<td>Free Glycerol</td>
<td>ASTM D6584</td>
<td>0.02 Max</td>
<td>%wt</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total Glycerol</td>
<td>ASTM D6584</td>
<td>0.24 Max</td>
<td>%wt</td>
<td>0.199</td>
</tr>
<tr>
<td>Alkil Ester</td>
<td>EN 14103</td>
<td>96.5 Min</td>
<td>%wt</td>
<td>99.28</td>
</tr>
<tr>
<td>Monoglyceride Content</td>
<td>EN 14105</td>
<td>0.8 Max</td>
<td>%wt</td>
<td>0.642</td>
</tr>
</tbody>
</table>

III. RESULTS AND DISCUSSIONS

The test results are shown in Table 3. Both the test results show in consistency. Both results indicate the condition of the lubricant oil tested is still good to be used. The all the parameters indicate the value relatively low comparing to the limit. The diluted fuel (fuel diluents) entered into the engine oil which was tested by distillation method show the same results, that is 1%. This value is within the tolerance limits that are commonly used in the amount of 5% [11].

Table 3. Used Oil Analysis

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>METHOD</th>
<th>UNIT</th>
<th>BS_5</th>
<th>BS_50</th>
<th>LIMIT *)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viskosity @40°C</td>
<td>ASTM D445-09</td>
<td>cSt</td>
<td>13.47</td>
<td>13.17</td>
<td>Max 99-188</td>
</tr>
<tr>
<td>TBN</td>
<td>ASTM D2896-07a</td>
<td>mg KOH/g</td>
<td>11.74</td>
<td>12</td>
<td>Min 4</td>
</tr>
<tr>
<td>CONTAMINANTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natrium (Na)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>2</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Silikon</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>9</td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>WEAR METAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferro (Fe)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>40</td>
<td>40</td>
<td>125</td>
</tr>
<tr>
<td>Cuprum (Cu)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>3</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>5</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>ASTM D5185-09</td>
<td>ppm</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>FTIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soot</td>
<td>ASTM E2412-04</td>
<td>abs/0.1mm</td>
<td>0.03</td>
<td>0.04</td>
<td>0.8</td>
</tr>
<tr>
<td>Oxidation</td>
<td>ASTM E2412-04</td>
<td>abs/0.1mm</td>
<td>0.04</td>
<td>0.17</td>
<td>0.5</td>
</tr>
<tr>
<td>Nitration</td>
<td>ASTM E2412-04</td>
<td>abs/0.1mm</td>
<td>0.04</td>
<td>0.06</td>
<td>0.5</td>
</tr>
<tr>
<td>Sulfation</td>
<td>ASTM E2412-04</td>
<td>abs/0.1mm</td>
<td>0.05</td>
<td>0.07</td>
<td>0.5</td>
</tr>
<tr>
<td>Glycol</td>
<td>ASTM E2412-04</td>
<td>%</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Water content</td>
<td></td>
<td>%</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>OTHERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentane Insolubles</td>
<td>ASTM D893</td>
<td>%</td>
<td>0.071</td>
<td>0.92</td>
<td>-</td>
</tr>
<tr>
<td>Toluene Insolubles</td>
<td>ASTM D893</td>
<td>%</td>
<td>0.015</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Fuel diluents</td>
<td>ASTM D322-97</td>
<td>%vol</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

*1 Source: Petrolab Services Co.
The property of viscosity show little difference, 13.47 cSt and 13.17 cSt. This value is still low compared to the value in allowing limit. The value of Total Base Number (TBN) show little difference. Value of Total Base Number (TBN) shows the content of additives in lubricants. The content of additives in lubricant serves to neutralize the alkaline acid oxidation products. Oxidation processes which caused by prolonged use and overheat produce some acid components which corrosive to metals.

Besides the acid products, the oxidation produced other insoluble materials in the lubricant and dirt on the various engine components lubricated. The increasing in viscosity and decreasing in TBN indicate the oil lubricants oxidation. By 1% fuel dilution, resulted only 0.3 cSt viscosity differences and 0.26 mg KOH/g on TBN. These little differences due to fuel dilution in the used oil still low at 1%.

The test results show the content of wear metals more consistent. The difference in biodiesel composition does not affect to the wear of metals Fe, while for metals Copper (Cu) and aluminum (Al) increasing by 1 ppm. Wear of metal Fe relatively higher compared to other metals. Wear of metal Fe are 40 ppm, either for 5% biodiesel fuel or 50%. This value is quite high at 32% of the allowable wear, while the wear metals Cu and Al, 11% and 24% respectively. Fe content is probably derived from components of cylinder liners, valve (valve), rod cam (camshaft) and gear. Metal Al is the material of the piston while the Cu component derived from bearing or bushing. Thus, it can be understood that the wear of metals derived from the friction resulting from the piston lubrication arrangement set and cylinder walls.

Another test that produced almost the same on Fe metal wear which is higher than the other metals as described in reference [12]. Tests performed on a single-cylinder marine diesel engines, four-stroke, and swirl chamber with air conditioning for 150 hours using 100% rapeseed methyl ester (RME). After 150 hours of testing the fuel dilution into lubricant oil was 3.5%. The biodiesel dilution resulted declining in the value of TBN and viscosity of the lubricant. The fall in viscosity lubricant resulted in the ability of coating metal surfaces rubbing two also declined. This condition occurs in the cylinder liner wall components that have the main material is Fe with its lubricating properties that have a dominant contribution of friction. Friction on engine components is highest in the composition of the ring - cylinder wall causing wear on the cylinder wall that is Fe higher [13].

The difference in biodiesel fuel composition indicate having effect on PI and TI values. The difference in composition result 0.85% for PI and 0.2% for TI. These values are around 28% and 10% of maximum value for oil replacement. Pentane Insoluble value (PI) and Toluene insoluble (TI) provides an indication of lubricant start oxidizing. PI indicates the total insoluble in the lubricant, while TI shows in-soluble of inorganic materials. As a general guide to the boundary lubricant oil replacement, maximum values 3% of PI and maximum 2% of TI [14]. This value is consistent to the results of FTIR test that detects low oxidation. The values are 0.04 and 0.17 for 5% biodiesel and 50% respectively. Likewise FTIR other test parameters which detects the presence of oxidation, nitrification, soot and sulfation. For higher biodiesel composition, test for PI and TI show higher result, but it is difficult to justify how significant effect of biodiesel composition to the PI and TI in the used oil. While the content of glycol and water is not detected. Nitrification is another form of oxidation. Soot and sulfation derived from products of combustion in the engine that went into the lubricant (diluted). Glycol was derived from cooling system leak [15]. These parameters are the components that can degrade performance of a lubricant.

**IV. CONCLUSION**

After 100 hours of two identical durability tests on 3.5 kVA engine generators using a blend 5% and 50% of pure biodiesel (palm methyl ester) with diesel (Bio-solar) produced by Pertamina Co., resulted on the same 1% fuel dilution on the engine generator oils. The fuel dilution didn’t result significant effect on the engine oils degradation. The effects of fuel dilution showed no significant difference effects to the engine generator components after completion of the tests.

**REFERENCES**


[14]. Marbach, H.W. and Frame, E.A. Investigation of Portable Army Oil Analysis Requirements for Application. (1999) U.S. Army TARDEC Fuels and Lubricants Research Facility and (SwRI), Southwest Research Institute, San Antonio, TX.