The effect of use of biodiesel B30 from palm oil to degradation of oil lubrication in 1-cylinder diesel engine 4-stroke

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Abstract. New alternative fuels are needed to reduce the fossil fuels. Biodiesel from palm oil is one alternative fuel to replace fossil fuel. This is because Indonesia is the largest producer of palm oil in the world. There are several analyzes that the use of palm oil causes a significant decrease in the viscosity of lubricating oil. A research is carried out to evaluate the effect of B30 biodiesel from palm oil on the degradation of diesel engine lubricating oil. The method used is experiment with testing diesel engines endurance referring to the standards of the Engine Manufacture Association (EMA) to determine differences in lubrication degradation. As a result, B30 biodiesel from palm oil causes greater degradation in lubricating oil than using Dexlite diesel fuel. Biodiesel B30 causes lubricating oil to decrease its viscosity by 46.98%, increase the viscosity index by 7.84%, increase in the flash point, increase in the pour point some 3°C and decrease in the base number by 4.62% and 3.6026% less water content.

1. Introduction

To reduce petroleum or fossil fuels consumption, government requires the use of biodiesel. Now, biodiesel fuel has attracted a concern from researchers, with the aim to reducing the use of fuel from petroleum and utilize renewable energy resources. Biodiesel is selected as an alternative fuel because of its advantage in reducing emissions if compared to conventional diesel fuel.

However, from some researches it is shown that biodiesel can affect the performance of diesel engine. Hanif [1] in his research about the influence of palm oil biodiesel reported that the use of palm oil biodiesel resulted in an increase in fuel consumption of diesel engines by 11.93% to 13.48%, decreasing in thermal efficiency decreased by 2.96% to 5.33%, and volumetric efficiency is relatively same as a pure diesel fuel engine.

Nurhadi [2] in his research about the use biodiesel on patrol vessel resulted that the use of biodiesel causes a decrease in the load, power, and temperature of the exhaust gas from the vessel's main engine rather than using High Speed Diesel (HSD) fuel. On the other hand the use of biodiesel causes an increase in the number of fuel consumption when compared to the use of HSD.

Pandey et. al. [3] in his research on the effect of karanja oil methyl ester caused a decrease in the main brake power on the 780 HP engine. Yuksek et. al. [4] in this research, rapeseed biodiesel isn’t cause a significant difference in performance. However, biodiesel causes increase in fuel consumption by 6%. The use of rapeseed biodiesel causes decrease in CO and THC emission, but increase in NOx emission.

However, the effects of biodiesel on diesel engines for long-term isn’t widely known. One of the problems in using biodiesel is lubricating oil degradation. The properties of lubricating oil like viscosity,
viscosity index, flash point, pour point, base number and water content will be changes, increase or decrease [5,6,7]. Deterioration in the lubricating characteristics of oil is due to oil degradation and ageing because of prolonged, repeated mechanical, thermal, environmental stresses and contamination with foreign particles.

Interestingly all these factors are inter-related and work synergistically to worsen the oil condition [8]. The additional lubricating property of biodiesel fuel due to higher viscosity as compared to diesel fuel resulted in lower wear of moving parts and thus improved the engine durability with a bio-diesel fuel [9]. In this research discusses the effect of B30 biodiesel from palm oil on the degradation of diesel engine lubricating oil based on lubricating oil properties.

The function of the lubrication itself is to reduce the presence of friction between the metal and other engine components so that it can reduce the risk of damage to the engine part. In addition, lubrication is useful to reduce heat arising from friction, and restore engine power wasted to fight friction. The working principle of the lubrication system is to flow fuel on engine components that rub against each other when the engine starts. The rubbing surface makes the lubricating oil so that there is no direct contact with these components. A good quality lubrication system can make a engine more durable and engine performance is also better. Conversely, a poor quality lubrication system can make the engine become damaged faster and engine performance is not optimal [10].

The difference in characteristics of the lubricating oil which is lacking, is more influential on the wear process of engine components. As a result, each type of oil causes different levels of wear to accumulate quite a long time. This is what makes the component wear conditions of each machine will be different. The heat from combustion in the engine will break the oil composition if excess heat and release carbon particles, over time it will obviously accumulate and form a sludge [11].

The use of coconut oil results in a decrease in viscosity lubricating oil drastically. The use of biodiesel B20 palm oil also causes a decrease in the viscosity of the lubricating oil from 16.1 cSt to 10.7 cSt, and causes an increase in density from 0.865 g/cm³ to 0.903 g/cm³ [12]. This is worse than the use of pure diesel in diesel engines which causes a decrease in viscosity from 16.1 cSt to 11.1 cSt and causes an increase in the density of lubricating oil from 0.865 g/cm³ to 0.895 g/cm³ [13]. The use of biodiesel from a mixture of 20% carbohydrate oil (KOME20) causes an increase in density, a decrease in viscosity, decreasing the value of the total base number (TBN) and increasing the flash point in the lubricating oil is higher than the use of fuel from petroleum [9].

In the application of biodiesel to engines, it is determined from the nature of biodiesel which is regulated in the Indonesian National Standard (SNI) 7182: 2012. Shown in Table 1 below.

| Properties          | Unit | Indonesia National Standard |
|---------------------|------|-----------------------------|
| Cetane Number       | cSt  | Min. 51                     |
| Viscosity at 40°C   | cSt  | 2.3 – 6.0                   |
| Density             | kg/m³| 850 – 890                   |
| Flash Point         | °C   | Min. 100                    |
| Pour Point          | °C   | Max. 18                     |
| Low Heating Value   | kJ/kg| -                           |

2. Methodology

2.1. Biodiesel Production

In this research, palm oil processed become biodiesel with transesterification method. Methanol and KOH were used as catalyst in this process. Then, B100 from palm oil blend with B20 biodiesel from the government. The composition of the blend is 1 : 7 with the B100 is less than B20. Laboratory testing is done for determine the properties of B30 palm oil biodiesel. The properties which tested are kinematic viscosity, density, flash point, pour point, and low heating value. This properties were tested will be
compared with diesel fuel. Table 2 shown the comparison of biodiesel and diesel fuel properties based on laboratory test.

| Properties               | Biodiesel B30 Palm Oil | Indonesia Biodiesel Standard | Diesel Fuel |
|--------------------------|------------------------|------------------------------|-------------|
| Cetane Number            | 69.8                   | Min. 51                      | 56.7        |
| Viscosity (40°C) [cSt]   | 4.43                   | 2.3 – 6.0                    | 2.92        |
| Density [kg/m³]          | 856                    | 850 – 890                    | 845.7       |
| Flash Point [°C]         | 96                     | Min. 100                     | 65          |
| Pour Point [°C]          | -4                     | Max. 18                      | -3          |
| Low Heating Value [kJ/kg]| 45,470.97              | -                            | 47,054.2    |

To be able to make palm oil biodiesel steps are carried out that are the process of making a methoxide solvent, the transesterification process, the washing process, the sedimentation process and the drying process. Preparation of methoxido solvent is done by mixing methanol and KOH in a ratio of 1: 6. For each requirement of 1 liter of palm oil, 166 ml of methanol and 4 grams of KOH are needed. The sample and the methoxid solvent are put into a place. The mixture is then stirred using a stirrer while heated using a heater with a temperature maintained at 65 °C for 1 hour. After heating and stirring using a stirrer, the mixture is allowed to stand for 1 night to separate methyl esters and glycerin. The top product is in the form of methyl esters and the bottom product in the form of glycerin. Methyl esters are put into a place to be washed. Next, aquades are added to the place in a ratio of 1: 1 with methyl esters. Then 0.5% vinegar was added from 1000 ml of methyl ester. This washing process uses substitution by using air bubbles to bind the glycerol that has been bound to methanol with water. This process requires a minimum of 8 hours. The next step are settling or sedimentation processes for 24 hours so that the solvent separates between glycerol and methyl ester. The result of washing in the form of methyl ester is removed and put into a glass beaker, then dried by heating with a temperature of 80-100 °C. This process is intended to reduce the water content in oil. The dried methyl ester is cooled to room temperature. Biodiesel production process shown in Figure 1 below.

![Biodiesel production process](image)

**Figure 1. Biodiesel production process**

### 2.2 Experiments

The experiment is carried out by testing the durability of diesel engines using the method of the Engine Manufacture Association (EMA). Tests were carried out for 200 hours with variations in rotation and load including: [14]

- a. low idle (30 minutes): At no load, the throttle was varied to achieve the manufacturer’s recommended curb idle, (850 rpm, no load);
- b. idle high (30 minutes): The load was set at 25% of maximum torque and the throttle is varied to achieve an engine speed of 90% of rated speed (1,980 rpm, 750 watts);
- c. rated power speed (60 minutes): The engine was operated at full throttle, a load was applied until the engine speed decreases to the manufacturer’s specified rated speed, (2,200 rpm, 250 watts);
- d. maximum torque speed (60 minutes): The engine was operated at full throttle, a load was applied until the engine speed decreases to the speed of rated torque as described by the manufacturer, (1,900 rpm, 3,000 watts).

The steps are carried out sequentially, after completing the maximum torque speed stage, the steps will be repeated until the time accumulates to 200 hours. Step of experiments on diesel engine shown in Figure 2 below.
Figure 2. Step of experiments

3. Results and Discussion

To determine the effect of the use of biodiesel B30 palm oil on lubricating oil degradation, a lubricating oil test was conducted. Testing is done by taking a sample of lubricating oil after being tested on diesel engine with biodiesel B30 palm oil for 200 hours. Then the sample is tested in the laboratory to test the properties of the lubricating oil.

The properties of the lubricating oils tested included kinematic viscosity at 40°C, kinematic viscosity at 100°C, viscosity index, flash point, pour point, total base number (TBN) and water content. Table 3 shown the result of laboratory test about lubricating oil properties after 200 hours between Biodiesel B30 and diesel fuel.

| No. | Parameter               | Lubricating oil before 200 hours (new) | Lubricating oil running with diesel fuel after 200 hours | Lubricating oil running with B30 after 200 hours | Method         |
|-----|-------------------------|----------------------------------------|----------------------------------------------------------|-------------------------------------------------|----------------|
| 1   | Viscosity at 40°C       | 145.80 cSt                             | 80 cSt                                                   | 78 cSt                                         | Viscometri     |
| 2   | Viscosity at 100°C      | 14.90 cSt                              | 14 cSt                                                   | 7 cSt                                          | Viscometri     |
| 3   | Viscosity index         | 102                                    | 99                                                      | 107                                            | ASTM D 2270    |
| 4   | Flash point             | 230 °C                                 | >230 °C                                                  | >230 °C                                        | ASTM D 93      |
| 5   | Pour point              | -12 °C                                 | -3 °C                                                   | 0 °C                                           | ASTM D 97      |
| 6   | Total base number       | 11.70 mgKOH/g                          | 11.38 mgKOH/g                                           | 10.84 mgKOH/g                                  | ASTM D 2896-03 |
| 7   | Water content           | 0.0786 %                               | 3.733 %                                                 | 0.1307 %                                      | Gravimetric    |

Based on test result in Table 3, can take some analysis about lubricating oil properties after 200 hours running. At 40°C, the use with diesel fuel has decreased viscosity by 45.13%. Whereas the lubricant oil with biodiesel B30 palm oil decreased viscosity by 46.5%. Both of these lubricants have values that exceed the permissible standards. And B30 decreased viscosity greater than diesel fuel. At 100°C, the use of diesel fuel has decrease viscosity by 6.04%, while the use of biodiesel B30 palm oil decreased viscosity by 53%. The decrease in viscosity can be caused by fuel dilution and water content in biodiesel which contaminates the lubricating oil.
About the viscosity index, the use of biodiesel B30 palm oil to affect the change in the value of the viscosity index. Lubricating oil after being tested using diesel fuel has a viscosity index value 99. This value decreased by 2.94% from the value of the viscosity index in new lubricating oils. Whereas the lubricating oil after being tested by using Biodiesel B30 Palm Oil has a viscosity index value of 107. This value has increased by 7.84%. Shown in Figure 3 below.

![Figure 3. Value of viscosity index](image)

For flash point, the new lubricating oil has a flash point of 230°C. While the lubricating oil on the engine tested with biodiesel B30 palm oil and diesel fuel has a flash point more than 230°C. This proves that the use of both fuels causes an increase in flash point and meets the standard. Shown in Figure 4 below.

![Figure 4. Value of flash point](image)

For pour point, the use of biodiesel B30 palm oil greatly influences changes in the pouring point of lubricating oil. This is evidenced by the results of tests on lubricants with diesel fuel showing an increase in pour point value of 9°C. Whereas the engine tested using biodiesel B30 palm oil increased in the pour point value of 12°C. Pour point is affected by the hydrocarbon composition of the oil the lubricant itself. In general, what can affect the pour point value is the parafin content of the lubricating oil. Lubricating oil will pour more easily if it has a high parafin content. Shown in Figure 5 below.
Figure 5. Value of pour point

For base number, the use of biodiesel B30 palm oil has an effect on changes in TBN value. Lubricating oil in engine tested using diesel fuel decreased TBN value of 0.32 mgKOH/g or 2.7% from the initial TBN value. While the lubricating oil on engine tested with Biodiesel B30 Palm Oil has decreased the value of TBN by 0.86 mgKOH/g or 7.35%. The high decrease in TBN is due to the fact that biodiesel fuel has a higher acid number than diesel fuel. Shown in Figure 6 below.

Figure 6. Value of TBN

About water content, the addition of water content in the lubricating oil tested with biodiesel B30 palm oil is 0.0521%. Whereas the diesel fuel lubricant oil increased in water content of 3.6547%. The low water content in biodiesel fuel is likely to be an influence of the lubricity properties of biodiesel fuels. Shown in Figure 7 below.

Figure 7. Value of water content
4. Conclusions
Based on the results of experiments and laboratory tests that have been carried out the effect of the use of biodiesel B30 palm oil on the degradation of lubricating oil can be concluded that the use of biodiesel B30 palm oil causes greater degradation in lubricating oil than the use of diesel fuel. Evidenced by the lubricating oil tested with biodiesel B30 palm oil has a 46.98% greater decrease in viscosity, in viscosity index of 7.84% greater increase, increase in flash point, increase in pour point up to 3°C, and decrease in TBN to 4.62%, and 3.6026% less water content than lubricating oils tested with diesel fuel.

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