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Characteristics of Mixture fuel of Biodiesel from Waste Cooking Oil and Solar used as fuel in Diesel Engine

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Abstract

The Biodiesel from waste cooking oil may be used as an alternative fuel that can replace the solar or diesel fuel. Biodiesel blended with solar (B0) at the certain ratio so that obtained B5, B10, B15 and B20 (B5 is a mixture of 5% biodiesel and 95% solar, etc.) is used as fuel in diesel engines. Then those physical properties are tested to know some parameters such as heating value, cetane number, and flash point. The Performance of Diesel engines is compared to the other engines that use solar (B0). The engine is operated on constant speed 1500, 1750, 2000, 2250 and 2500 rpm. Based on test results show that the B5 fuel obtain is the best performance of the engine at 2000 rpm. At this engine condition, lowest consumption of fule is observed pricisely the specific fuel as 0.34 kg/kWh, thermal efficiency of 24.02% while the value of the effective power on all fuels are similar that is 1.26 kw.

Keywords: *biodiesel, waste cooking oil, solar, diesel engine*

1. 1 INTRODUCTION

Indonesia depends on conventional fuel oil, especially industry and transportation sector. This dependence will further reduce the amount of oil reserves that exist. To reduce this dependence, one of the efforts made by the Indonesian government about national energy policy that concerning in the price, diversification and conversion of energy.

Diversification of energy is using the energy source, one of which is biofuel, which is available energy in Indonesia. The provision and the using of biofuels as the other alternative fuels, is an instruction that emphasized the importance of biofuel development (Development Policy of Renewable Energy and Energy Conservation, Energy Department and Mineral Resources).

The vegetable oils which potentially substitute Diesel fuel is waste cooking oil originated from deep frying tofu, because of the amount of waste cooking oil is abundant. Biofuels as raw material for biodiesel production have the advantages considering to the use of Diesel engines such as:

- Having better lubrication properties so that it can extend the life of the engine
- As a safe fuel and easy to handle and non-toxic.
- Having exhaust gas which is relatively clean [6].

One of the energy diversification efforts through blending biodiesel and petroleum diesel because the greater blending ratio of the biodiesel and solar, the better reducing emissions [9].

The mixture of biodiesel and diesel fuel produced is necessary to be tested in the Diesel engine. It is intended to determine the performance of Diesel engines using a mixture of biodiesel and solar as fuel.

Before the test directly in Diesel engines, it must be known whether biodiesel and Diesel fuel blends is suitable to diesel fuel standards [7]. Bello et al. [4] made researchs on characteristics of biodiesel and Diesel oil mixtures. The research shows that B20 is the best blend of based on the heating value and cetane number applied in diesel engines with a pretty good performance.

Diesel fuel is a result of petroleum fractions having boiling point between 175 to 370°C and used as fuel in Diesel engines. The Diesel engine was invented and patented by Rudoph Diesel, 1892. Diesel engine works with a lower maximum speed than petrol engines which often have speed above 4000 rpm. Most of diesel engines work at speed between 50 to 2.500 rpm. Diesel engine working with the rotation speed of less than 500 rpm is called as diesel engine with a slow engine revolution, but up to 1.200 rpm is called high engine revolution, while between both of them are called medium engine revolution.

Diesel fuels have the following properties:

- High flame point (40°C to 100°C).
- Density around 0.82 g/l - 0.86 g/l.
- Capable of producing large heat 10,500 kcal/kg.

Hydrocarbon and non-hydrocarbon commonly compounds contained in diesel or fuel diesel. Hydrocarbon compound contained indiesel fuel such as paraffinic, naftenik, olefins and aromatics. While non-hydrocarbon compounds consisted of non-metallic elements, S, N, O and metal elements such as vanadium, nickel and iron. Cetane number is the number indicating the quality and diesel or biodiesel fuel capability to flame. Cetane number depended on percent volume of cetane ($C_{16}H_{34}$) in a cetane mixtures with alfametil-naphthalene ($C_{10}H_7CH_3$). Normal cetane has a cetane number 100 while alfametil-naphthalene has cetane number 0.

Density shows a weight ratio of per unit volume. The density of diesel fuel is measured using ASTM D1298 and has units of kilograms per cubic meter (kg/m^3). Calorific combustion value is a heat energy contained in each unit fuel mass. Calorific value can be measured with bomb calorimeter. Flash point is a point when the condition of the lowest temperature for certain fuel can ignite itself. It is concerned with safety in the storage and handling of fuel [8].

Biodiesel is the name for fatty esters type, generally is mono alkyl esters made from vegetable oils. Solar or diesel fuel derived from petroleum has a lower oxidation stability as low as a mixture of biodiesel and diesel fuel. The oxidation stability determine the fuel storage stability and oxidation stability that is suitable to whatever fuel is the basic requirement to ensure the operation of the fuel injection of a good diesel engines and save from damage. Biodiesel from waste cooking oil is also suitable to the requirements of SNI for biodiesel [5].

In general, the difference of diesel engine fuel to petrol engine is the difference in fuel ignition system. On diesel engine, in the suction stage just inhale the air into the cylinder so that it does not mix with the fuel. During compression, the temperature and pressure in the cylinder continues to rise and in the end of the compression stroke, fuel is sprayed into the cylinder and contact with hot air causing combustion. Gas combustion products that have high pressure and temperature can push the piston to perform the next action steps that will move up again and do the exhaust steps [3].

Diesel engines with high engine revolution require the characteristics.which is accorded to auto ignition (the ability flame by itself), then have a good drainage capability of fuel, easy to be atomized, and lubrication.

The physical properties of biodiesel mixture from wasste "tahu" cooking oil with solar neccessary to be known to measure the performance of diesel engines such as viscosity, cetane number, density, calorific value of the combustion and moisture content also the sediment.

The characteristics of the biodiesel and solar mixtures from waste cooking oil is suitable to the requirements of national standard specifications as the diesel motor fuel. Biodiesel from waste cooking oil with the solar can be mixed as an alternative fuel.

Table 1. Ratio between biodiesel from waste cooking oil, solar and SNI requirement for biodiesel

Physical Properties	Unit	Biodiesel From Waste Cooking oil	ASTM Standard (Solar)	SNI Biodiesel
Flash point	°C	170	Min.100	Min.100
Viscosity (40°C)	cSt.	4,9	1,9-6,5	2,3-6,0
Cetane number	-	49	Min.40	Min.48
Cloud point	°C	3,3	-	Maks.18
Sulfur content	% m/m	<< 0,01	0.05 max	Maks.0,05
Calorific value	kJ/kg	38.542	45.343	--
Density (15°C)	kg/l	0,85	0,84	0,86-0,90
Free Glycerin	wt.%	0,00	Maks.0,02	Maks 0,02

In this study, was developed by considering all characterisctics besides cetane number and calorific value, but the other parameters also seen such as the flash point, water content, viscosity and density of blending biodiesel from waste cooking oil that applied in diesel engines T85D.

From the above explicattions, the problem to be disscussed in this study are :

- How the characteristics of biodiesel mixtures fuel from waste cooking oil with solar, based on the flash point, water content, heating value, cetane number, viscosity and density.
- How the influenceof biodiesel mixture fuel and solar to the performance of diesel engine T85D.

The purposes of the study are as follows :

- To know the characteristics of flash point, water content, heating value, cetane number, viscosity and density of biodiesel mixtures from waste cooking oil with solar.

- To know performance of parameters of diesel engines such as torque, effective Power, specific fuel consumption and thermal efficiency, due to the influence of fuel mixtures ratio of biodiesel from waste ‘tahu” cooking oil with solar.

This research may contribute to the users of diesel fuel which is substituted with biodiesel (transportation, industry, etc) and giving the contribution in the research future as a reference.

2. METHOD AND PROCEDURE

The methodology used in this study an experimental method using a mixture of biodiesel and diesel fuel with pilot scale in the biodiesel laboratory and in applied into diesel engine types Didacta Italy Test Bed TD5D in Energy Conversion Laboratory, Faculty of Engineering, Sriwijaya University and Laboratory DIKLAT PT. Pertamina Plaju.

Fuel mixing between diesel and biodiesel is done with varying ratios such as B0, B5, B10, B15 and B20, for example, B5 (95% diesel and 5% biodiesel).

After mixing solar and biodiesel then be done characteristics testing in order to know whether the characteristics of the mixture can actually be used as fuel for diesel engines. Therefore, the characteristics of the test results is expected to approach characteristics of diesel. Which some of the characteristics that are considered important include heating value, cetane number, flash point, viscosity and density.

This test aims to determine the diesel engine performance by using solar and biodiesel mixtures. The quantities defined and measured are engine revolution (n), graduation (R), the air pressure difference (ΔP), and the number of fuel volume consumed per unit time (v/t) during the operation of the fuel. After a specified quantity above obtained and used in the calculation and measurement, it can obtaine achievment parameters of diesel engines.

3. RESULTS AND DISCUSSION

Diesel fuel used before blended with biodiesel, firstly analyzed calorific value, cetane number, flash point, viscosity, density, and water content, then at each mixing (B5, B10, B15, B20), parameters above are analyzed again, then see how characteristics changes in fuel as shown in the Table 2.

Calorific value of pure diesel fuel without the addition of biodiesel, B0 is 44477,179 kJ/kg, while calorific value of pure biodiesel is 36 508 kJ/kg, after blending with biodiesel (B5, B10, B15, B20), calorific value analyzed show a decrease while increasing the percentage of biodiesel added, the graph can be seen in Table 1. According to [4], this decrease in calorific value depends on the composition of fatty acids contained in the biodiesel raw materials.

Table 2. Specification of the fuel mixture of diesel-biodiesel

Ratio	Calorific value (kJ/kg)	Flash point (°C)	Cetane Number	μ (CSt)
B0	44477,179	59	48	2,5
B5	44355	58,88	51,1	2,9
B10	44330,398	62,22	50,5	3,0
B15	44323,555	62,22	50,04	3,1
B20	44287,882	62,22	49,6	3,4

At Figure 2, shows that the higher ratio of the mixtures, the higher viscosity value of the solar and biodiesel mixtures, While in the highest ratio (B20), is obtained viscosity 3.4 mm^2/sec. It shows that biodiesel from waste cooking oil has a higher viscosity than diesel, but this value is still suitable in the standard (SNI) as can be seen in Table 2 as a fuel for diesel engines.

At Figure 3, shows the flash point of diesel fuel (B0) 59°C is slightly higher than the flash point fuels B5 58.88°C. For fuels B10, B15 and B20 show that the highest flash point value 62.22°C, as a result influenced by the fuel composition.

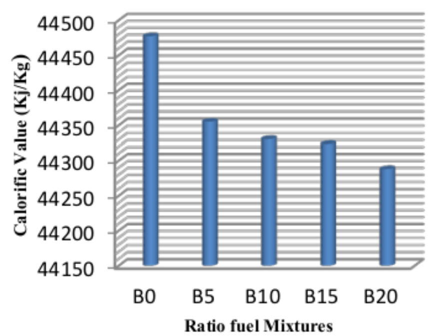

Figure 1. RatioSolar and Biodiesel Mixtures againts to calorific value

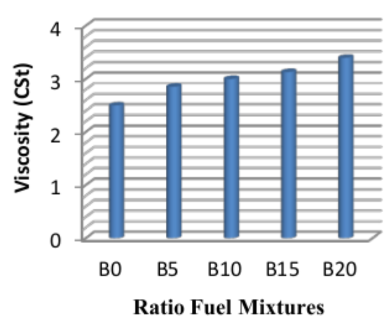

Figure 2. RatioSolar and Biodiesel Mixtures againts to Viscosity

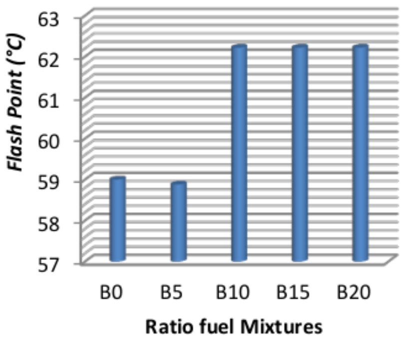

Figure 3. Ratio Solar and Biodiesel Mixtures against to *Flash Point*

Cetane number of diesel fuel (B0) is the lowest of fuel mixture (B5, B10, B15, and B20) which is 48 while for B5 fuel mixture (diesel fuel = 95%: biodiesel = 5%) has the highest cetane number which is 51.1. As shown in Figure 4, because of the oxygen content contained in biodiesel [4].

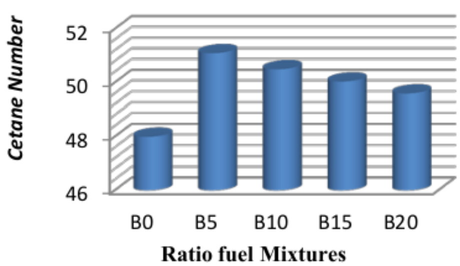

Figure 4. RatioSolar and Biodiesel Mixtures againts to Cetane Number

From the results of this study, can be compared the using of diesel fuel and B5, B10, B15, B20 against to achievement performance on diesel engine and from the ratio of fuel use above obtaining the expected data and processed through the calculations to obtain the data table and the performance curve as shown below.

From Figure 5, shown the relationship between engine revolution (rpm) and effective power (Ne). In Figure 5 shows that generally the form of graphs for fuel B0 - B20 is almost the same. It also shown that the higher engine revolution of the effective power, the higher effective power at constant torque. It cause of the flash point on B5 smaller than the flash point on the B10, B15 and B20, ignition in diesel engines more easily so it does not need high compression for the combustion process. Maximum effective power is obtained at 2500 rpm at the torque of 4.8 Nm is 1.26 kw. This value is similar for all ratio fuel mixtures.

Table 3. Effective power against to the engine revolution at the various fuel mixture

Ratio	Engine revolution (rpm)	Effective power (Ne) at Constant torque			
		3 Nm	3.6 Nm	4.2 Nm	4.8 Nm
B0-B20	1500	0.47	0.57	0.66	0.75
	1750	0.55	0.66	0.77	0.88
	2000	0.63	0.75	0.88	1.0
	2250	0.71	0.85	0.99	1.13
	2500	0.79	0.94	1.1	1.26

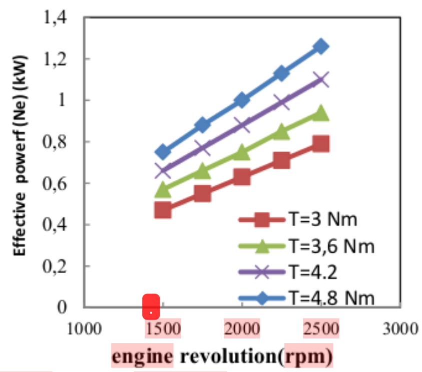

Figure 5. Graph of engine revolution (n) against to effective power (Ne)

In Figure 6, shows that the specific fuel consumption for B0, B5, B10, B15 and B20 almost coincides starting at engine revolution 1500 rpm to 2000 rpm At 2000 rpm engine revolution showing the lowest specific fuel consumption of 0.34 kg/kWh for B5 fuel, cause of B5 fuel having viscosity and specific gravity within limits permitted in Table 2 such as diesel fuel, its viscosity 2.9 cSt and specific gravity 0.8529 kg/m^3 higher than diesel fuel and has a higher cetane number than diesel fuel thus affecting the combustion process.

Table 4. Specific fuel consumption against to engine revolution

Engine Revolution n(rpm)	Specific fuel consumption (kg/kwh)				
	B0 (solar)	B5	B10	B15	B20
1500	0.33	0.36	0.35	0.36	0.35
1750	0.35	0.35	0.36	0.36	0.36
2000	0.39	0.34	0,35	0.35	0.36
2250	0.37	0.35	0.36	0.39	0.37
2500	0.36	0.38	0.37	0.37	0.39

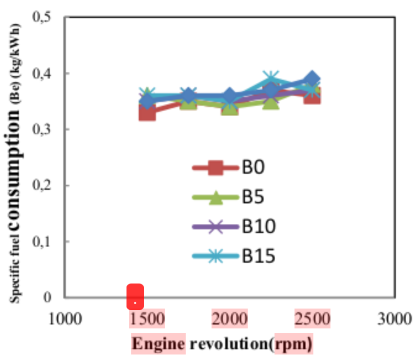

Figure 6. Graph of engine revolution(n) against to specific fuel consumption (kg/kWh).

In Figure 7, shows the relationship between the ratio of the fuel mixture and the engine revolution against to thermal efficiency. At the engine revolution 1500 rpm to 2000 rpm, occurs increasing and crushing of ther al efficiency for B0 and B5 fuels, but between both of fuel mixture ratio, the highest thermal efficiency is on B5 which is 24.02% as shown in Table 5 cause of B5 fuel has a higher cetane number than other fuels (B0, B10, B15 and B20) and the viscosity is also higher than B0 therefore work generated diesel engine increase [1]. After engine revolution 2000 rpm, it will decrease to 2500 rpm.

Table 5. The relationship between engine revolution and thermal efficiency at the various fuel mixtures

Engine Revolution n (rpm)	Thermal Efficiency (%) B0 (solar)	B5	B10	B15	B20
1500	22.17	22.41	23.15	22.55	23.2
1750	23.31	23.53	22.33	22.41	22.78
2000	23.74	24.02	23.38	22.98	22.62
2250	22.17	23.19	22.33	21.03	21.74
2500	22.2	21.45	22.17	21.75	21.06

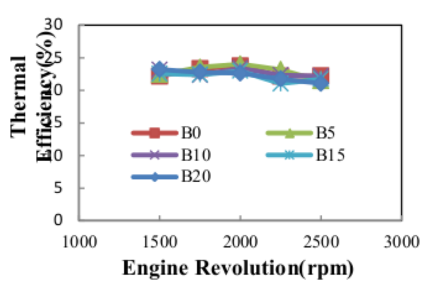

Figure 7. Graph of engine revolution (n) against to thermal efficiency (%)

4. CONCLUSIONS

According to analysis data above can be concluded that :

1. The highest heating value is B5 biodiesel that is 44 355 kJ/kg but relatively lower 0.27% of B0.
2. The highest cetane number is B5 biodiesel that is 51.1.
3. Flash point of B5 biodiesel is relatively similar to the flash point of B0 (diesel) that is 59°C.
4. The lowest specific fuel consumption of B5 biodiesel occured in operating conditions 2000 rpm and a torque 4.8 Nm is 0.34 kg/kWh or 12.82% relatively lower than diesel (B0).
5. The highest thermal efficiency of B5 biodiesel occured in operating conditions 2000 rpm and torsi 4.8 Nm is 24.02% or 16% relatively higher than diesel (B0).
6. Based on the conclusions above, concluded that B5 biodiesel is the most suitable as an alternative to diesel fuel.

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