Biodiesel Production from POME (Palm Oil Mill Effluent) and Effects on Diesel Engine Performance

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(Received: 30 September 2022 / Revised: 17 December 2022 / Accepted: 17 December 2022)

***Abstract* - one way to reduce the scarcity of fuel oil is to make environmentally friendly alternative fuels such as biodiesel. The utilization of biodiesel can be a new energy source and also help reduce the excessive use of fuel, especially diesel and diesel oil in Indonesia. In Indonesia, the amount of palm oil will reach 49.7 tons by 2021, and this data is up 2.9% from the previous year. Palm fruit is processed into CPO. More palm oil processing will produce waste called POME (Palm Oil Mill Effluent). The diesel engine transesterification method is suitable for the manufacture of biodiesel. The amount of base on the catalyst's surface affects the catalyst's activity. So that the higher the base value on the catalyst, the higher the yield of biodiesel that will be produced. The biodiesel produced will be tested on a 4-stroke diesel engine with a B5 and B10 blending composition. The study's results showed that the density and viscosity values for B5 were 5.8 cSt and 810 Kg/m3 and for B10 were 6.3 cSt and 860 Kg/m3. As for engine performance, power, torque, and SFC for B5 fuel at 4000-watt load conditions and 1000 Rpm, engine speeds are 1.18 Kw, 11.28 Nm, and 256.8 gr/Kw. B10 at 4000-watt load condition and 1000 Rpm engine speed is 1.16 Kw, 11.12 Nm, and 269.2 gr/Kw.**

Keywords-biodiesel, POME, density, viscosity, engine performance.

I. INTRODUCTION

Biodiesel is a renewable fuel that is processed from vegetable oils, animal fats and can also be recycled from waste oil [1]. Not only renewable, but this fuel is also very environmentally friendly whose manufacturing process is through chemical modification, namely the reaction between vegetable oil and methanol assisted by an alkaline catalyst (NaOH, KOH, or sodium methylate) to produce a mixture of fatty acid methyl esters which can later be used as fuel. combustion engine compression ignition [2][3]. Biodiesel is becoming a very popular fuel throughout the world because it is more environmentally friendly, has very low emission levels compared to fossil fuels, is non-toxic, biodegradable, and non-flammable [4][5].

Many studies have discussed related to biodiesel raw materials and one of the most frequently used materials is palm oil [6]. In the production of palm oil, it cannot be separated from residual waste, this residual waste is commonly referred to as Palm acid oil (PAO) which is residual oil from palm oil effluent (POME) mills [7][8]. In every CPO (Crude Palm Oil) processing plant, it has not been widely used so that it is disposed of to the environment and tends to pollute the environment. The amount of waste oil that is quite large in palm oil processing is a potential source of raw material to be used as biodiesel which is cheap and the use of its needs does not compete with basic human needs [8].

The content contained in the palm oil waste in the fermentation process obtained nitrogen levels with 7% bentonite nitrogen at 167 ppm, phosphorus levels in bentonite 3% with phosphorus at 20.1 ppm, and the highest K element was obtained in the provision of 3% bentonite at 742 ppm. Biodiesel production is obtained from used oil using the lipase enzyme biocatalyst method with a 96% yield achieved [9].

Research related to the use of Biodiesel in engines also has an impact not only on engine performance, but it is necessary to conduct a more in-depth study related to the effects of these fuels on engine life and emissions. Previously, the use of Biodiesel (B30) showed that there was an aluminum metal content of 19.8%, an iron content of 0.75%, and a chromium content in diesel engine lubricating oil, in addition, to an increase in piston ring clearance and wear on the journal was also found. bearings [10].

Other studies focused more on the level of exhaust emissions in engines that use biodiesel. One of the requirements for a good fuel is that it has a low emission value. A study stated that the addition of methanol to diesel fuel oil can reduce engine exhaust emissions [11]. Further research states that the addition of methanol is

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also able to reduce hydrocarbon levels and carbon emissions. Monoxide because the fuel burns completely [12].

For the performance of the engine itself, many studies have been carried out related to the modification of the fuel used, ranging from the performance of dual fuel engines such as modification of CNG fuel injection timing on engine performance [13], modification of Biodiesel fuel mixture from microalgal [14], modification of fuel Biodiesel mixture from animal oil [15], corn oil biodiesel [16], all of which studies show a relatively better performance value in terms of reducing emissions, reducing SFC, increasing thermal efficiency, but in terms of power and torque the engine is still better with this fuel diesel oil fuel.

A good quality diesel engine fuel has criteria that must be met. The rules related to fuel have been set in the Indonesian National Standard (SNI 7182-2015) [17]. One of the advantages of biodiesel compared to Diesel oil is if the cetane number value of diesel oil is around 51, then biodiesel is above that. The calorific value of biodiesel is still below that of diesel oil but considering the urgency of energy needs related to fuel due to a large amount of consumption and the increasing trend of world oil prices, this biodiesel, with its advantages and disadvantages, still has to be developed again [3].

II. Method

This study is a reference from the publication of scientific papers that are related to the title of this research. There are two types of methods used in this study. The first method is the method of making POME (Palm Oil Mill Effluent) biodiesel fuel which is better known as the transesterification method [18], and the experimental method for testing direct fuel in diesel engines to determine engine performance results.

After the test of fuel, properties are complete, and then direct testing is carried out on the diesel engine to test the performance of POME fuel. The machine specifications can be seen in table 1 below.

TABLE 1.
THE SPECIFICATIONS OF ENGINE [19]

Brand/Model	Yanmar TF 85 Series
Type	TF 85MH
No. of Cylinder	1 Cylinder 4 Stroke
Displacement	493 cc
Continuous Power	7.5 Kw/2200 rpm
Compression Ratio	1:18
Specific Fuel Consumption	171 gr/HP h

The test flow can be seen in Figure 1 below:

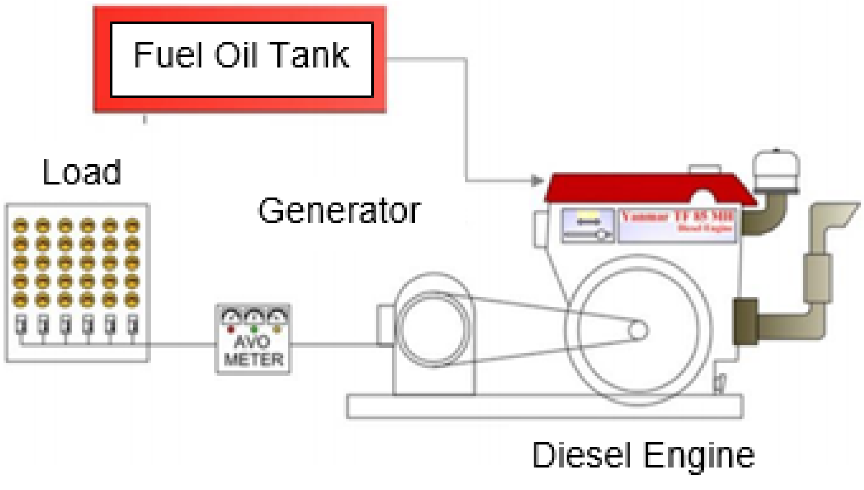


Figure. 1. Experimental System [16]

III. Results and Discussion

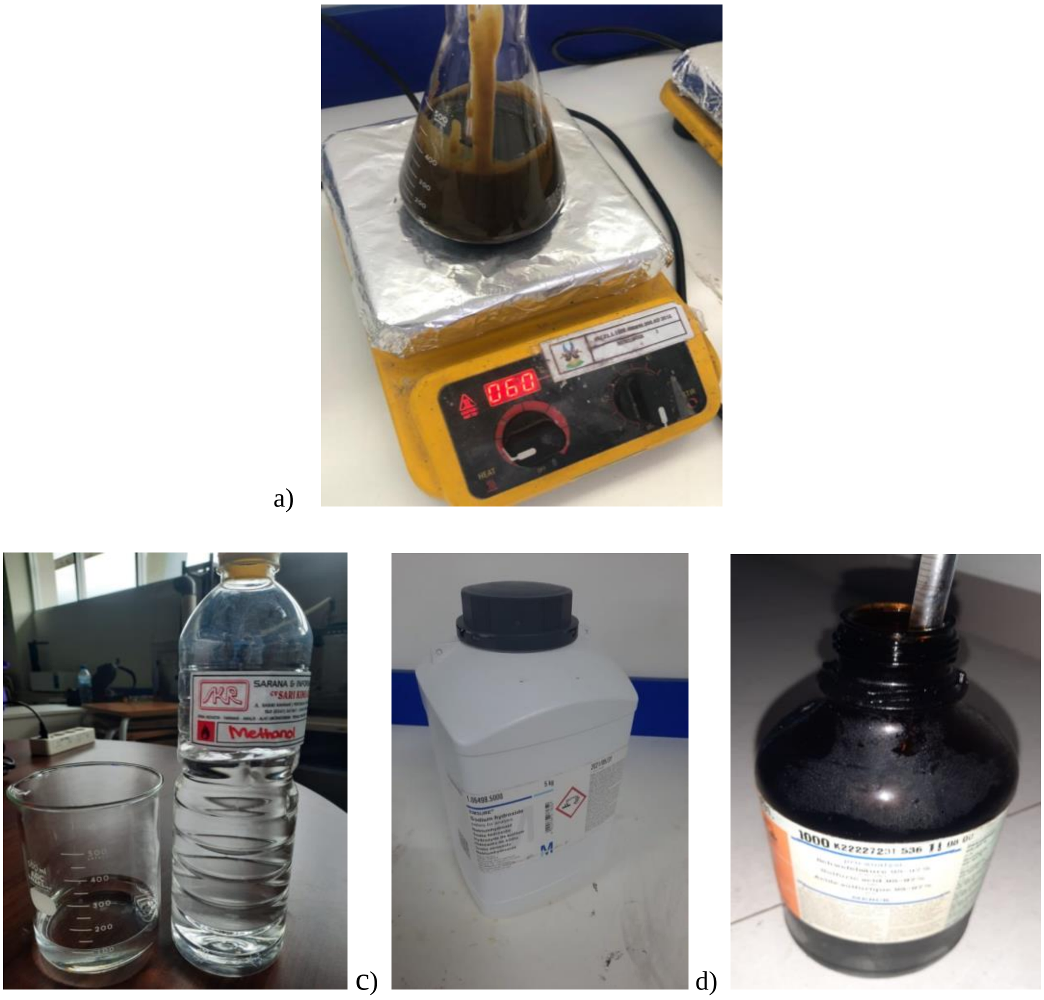
As previously explained, the research process is divided into two parts, namely the manufacture of POME Biodiesel and the testing of Biodiesel on Diesel engines. In this research, the properties of Biodiesel fuel were also tested, namely Viscosity and Density.

A. POME Biodiesel Production Process

The liquid waste from the waste collection pond is still warm because it goes through a heat treatment (heating) process so that it is still in liquid form. If the waste is exposed to room temperature, the waste will turn into a solid form. Therefore, there is a need for a heating process when reused in waste. The heating process is carried out at a temperature of 60ºC using a hot plate. After the liquid waste melts, it is filtered to remove impurities that are still included in the collection in the pond.

The next process is the catalyst and methanol preparation process. The function of the catalyst is to reduce the activation energy of the reaction so that the reaction can take place quickly.

Meanwhile, the function of methanol is as a solvent that has the lowest molecular weight. Besides, that methanol was chosen because it is cheaper and stable. The catalyst was mixed with methanol using a magnetic bar until well mixed. Then put into a reactor containing waste. The use of methanol is carried out as a catalyst solvent and (H2SO4) in the catalysis process. The amount of methanol used is a ratio of 1:2 from the number of samples used, or as much as 100 ml from the amount of oil palm, which is 200 ml.



a) b) c) d)

Figure. 2. a) Dilution process using Hot Plate b) Methanol. c) KOH catalyst. d) Sulfuric Acid H2S04

KOH catalyst was chosen as a catalyst to speed up the reaction rate. The amount of catalyst used was 4 grams which were then dissolved in Methanol using a magnetic bar at a speed of 600 rpm until the catalyst dissolved, while for sulfuric acid, it was almost the same as KOH catalyst, except that sulfuric acid was harder if Compared to KOH, care must be taken when using it. The sulfuric acid used was 10 ml which was then dissolved in 100 ml of Methanol.

After the catalyst reactor is dissolved by Methanol, then the resulting solution is put into a reactor containing liquid waste. The mixture was then put into a glass baker and then heated at a temperature of 60ºC at a speed of 50 rpm for 1 hour until evenly mixed. After the catalyst mixture, Methanol and sulfuric acid were mixed, and the liquid waste had been liquefied, all ingredients were mixed until evenly mixed for 1 hour at a constant speed of 50 rpm. After mixing evenly then, enter the filtering stage.

The filtering process serves to separate POME and Methanol. The filtering process lasts for 12 hours until two layers are formed. The liquid from the precipitate will form 2 layers, namely the top layer of glycerol and the bottom layer, namely methyl ester. Once separated, the bottom layer (methyl ester) is taken and then separated in another reactor, and pure biodiesel is obtained.

a) b)

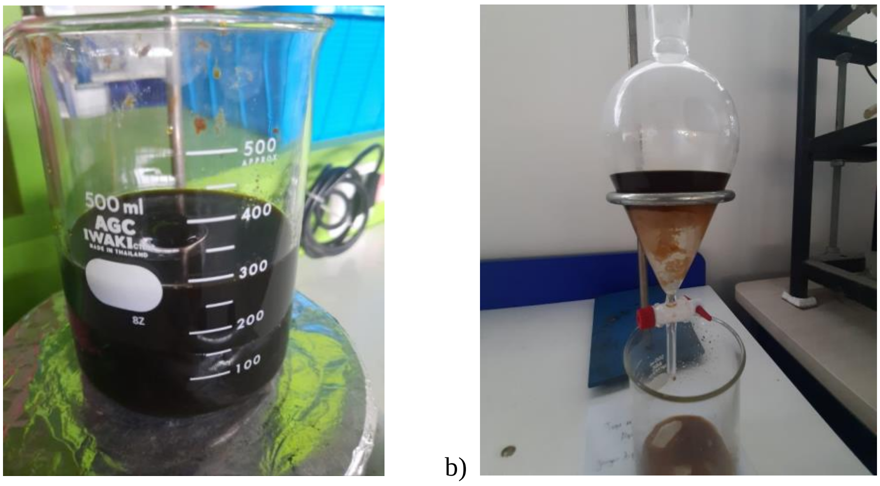


Figure. 3. a) Mixing Process of Catalyst, Methanol and Liquid Waste. b) Screening Process to produce Biodiesel

B. B5 and B10 . Viscosity and Density Testing

It is crucial to test the properties of mixed biodiesel before using it directly on the test machine. Parameter properties that are tested are only viscosity and density, for the samples of the fuel used are B5 and B10. This test is important to do to find out whether this biodiesel is included in the fuel quality standards set by the Indonesian National Standard (SNI 7182-2015), as shown in the following table out whether this biodiesel is included in the fuel quality standards set by the Indonesian National Standard (SNI). 7182-2015) as shown in the following table

TABLE 1.
BIODIESEL SPECIFICATION IN INDONESIA (SNI 7182-2015) [18]

Parameter Test	Unit	Limit
Kinematic Viscosity at 40^0C	cSt	2.3 - 6.0
Density at 40^0C	Kg/m^3	850 - 890

fuel is then tested using a viscometer and hydrometer for B5 and B10 fuel, which can be seen in table 2. From the standard fuel reference above, the biodiesel Based on the results of the viscosity and density in table 2 for B5 the viscosity is still included in the SNI standard, but for B10 it has exceeded the SNI standard. For Density B5, it is not included in the SNI standard, but for B10, it is included in the SNI standard

TABLE 2.
VISCOSITY AND DENSITY TEST RESULTS

Parameter Test	Fuel	Unit	Limit
Kinematic Viscosity	B5	cSt	5.8
Density	B5	Kg/m^3	810
Kinematic Viscosity	B10	cSt	6.3
Density	B10	Kg/m^3	860

C. Diesel engine performance testing process

After testing the viscosity and density to measure the characteristics of biodiesel, it is necessary to conduct direct testing of the engine. In this case, the test is carried out on a YANMAR TF 85 Diesel engine. The way to test biodiesel is to put fuel in the tank and make sure the engine position is clean of fuel. So as not to mix with other fuels. Then turn the crank lever on the diesel engine clockwise at the same time as raising the clutch, after turning it off at the same time as the crank lever and clutch. After turning on, wait a while to turn on the load, in this case, the light. Record the amount of current obtained at each step and calculate the time obtained.

Testing on the engine is carried out in stages, namely with 20 ml of pure diesel and then continued with testing of 20 ml at 5% biodiesel content with 1000 Watt and 2000 Watt loading, then 20 ml at 10% biodiesel content with 1000 Watt, 2000 Watt, 3000 Watt loading. And 4000 Watts. The function of this test is to compare the use of fuel and renewable energy. The loading test is carried out on 40 lamps, each with a power of 100 Watts. This test uses 4000 Watt lamps or 40 lamps. Tests on the machine are carried out in the integrated building for shipping.

a) b)

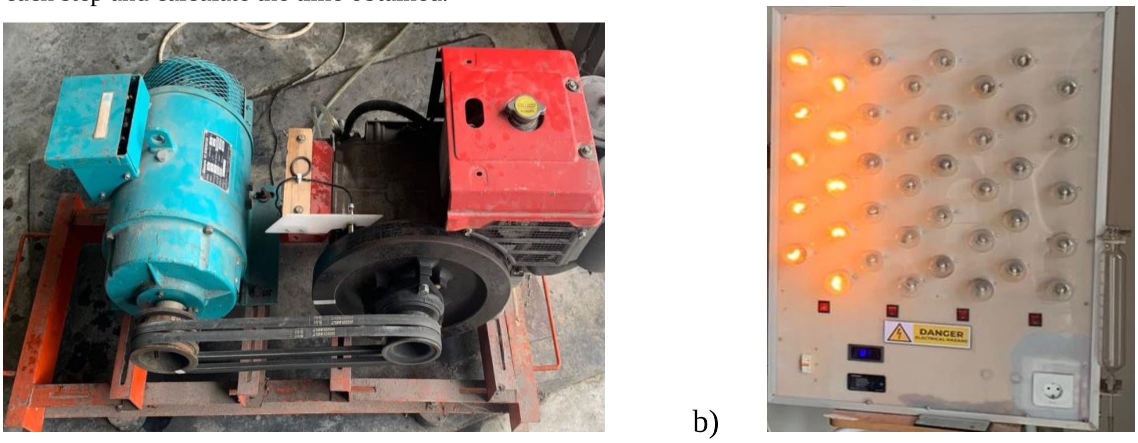


Figure. 5. a) Diesel Engines and Generators. b) Test conditions 2000 watt Lamp Load

TABLE 3.
MACHINE TEST RESULTS DATA IN FOUR LOAD CONDITIONS

Fuel	Load (Kw)	Rpm	V (Volts)	A (Amperage)	Time(s)
Diesel Oil	1	1000	136	3.21	335
	2		130	5.05	289
	3		119	8.96	224
	4		107	11.3	209
B5	1	1000	107	2.84	383
	2		111	5.78	377
	3		114	8.8	189
	4		105	11.2	201
B10	1	1000	124	3.06	356
	2		128	6.23	266
	3		116	8.85	196
	4		174	11.1	194

1. Torque comparison analysis, SFC vs Load

Based on the test data above, the torque and SFC of the engine can be calculated, while the fuel sample taken is B10 at a load of 4 Kw.

$$P = 2\ (\pi n/60)\ T \quad (1)$$

Where:

P = Power (W)
n = engine speed (Rpm)
T = Torque generated (Nm)

So to get the torque value, the equation is:

$$T = (n/2)\ (P/1000) \quad (2)$$

With the above equation, it can be calculated torque as follows:

$$T = (1000/2)\ 3.14\ (2.41/1000)$$
$$T = 3.79\ \text{Nm}$$

Calculation of SFC generated in diesel engines with the following equation:

SFC = (3600 mBB) / (P s) (3)

Where:
SFC = Specific Fuel Consumption (gr/kWh)
mBB = Fuel flow rate (kg/hour)
P = Power generated (kW)
S = Fuel consumption time (s)

With the above equation, it can be calculated SFC as follows:

SFC = (3600 x 0.029) / (2.41 x 194)
= 0.2266 Kg/kWh

The calculation results of Torque, Power, and SFC from three samples of fuel in four variations of the complete load can be seen in table 4 below.

TABLE 4.
DATA RESULT OF CALCULATION OF TORQUE, POWER AND SFC AT RPM 1000

Fuel	Load	Ne (kW)	SFC Kg/kW.h	Torque (Nm)
Diesel Oil	1	0,546	0,5806	0,857
	2	0,821	0,4476	1,288
	3	1,333	0,3555	2,092
	4	1,511	0,3360	2,373
B5	1	0,380	0,7296	0.596
	2	0,802	0,3511	1,259
	3	1,254	0,4478	1969
	4	1,470	0,3592	2,308
B10	1	0,474	0,6286	0.745
	2	0,997	0,4003	1,565
	3	1,283	0,4220	2015
	4	2,414	0,2266	3,790

The performance parameter of the combustion engine that compares fuel consumption vs SFC produced per unit time is the specific fuel consumption (Specific Fuel Consumption). Figure 6 will be presented a graph of SFC vs power for 1000 Rpm rotation in 4 load conditions. From the graph, it can be seen that the use of DO material still has a better power value when compared to B5 and B10 fuel, which is 1.2 kW at a 4000-watt load. Much more efficient and better use when compared to the use of pure biodiesel and other fuel combinations.

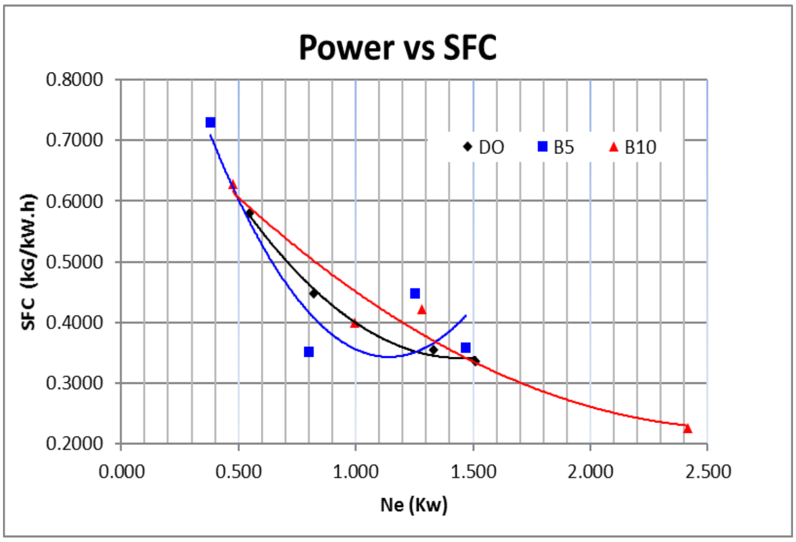


Figure. 6. SFC vs Power Graph at 1000 rpm

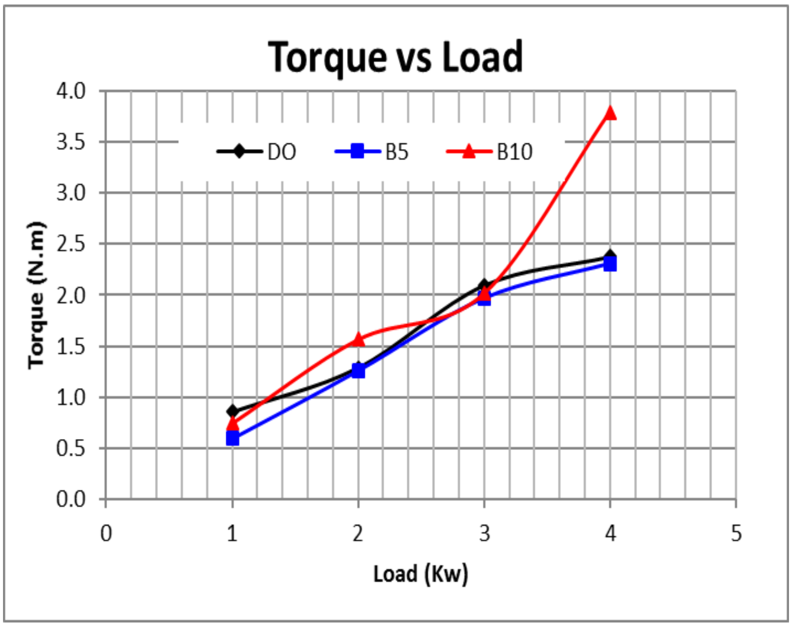


Figure. 7. Torque vs Load Graph at 1000 rpm

From the data obtained in the graph above, it can be seen that the load increases and the torque value also increase. The graph shows that the Torque B10 at a load of 4 KW is higher than the torque of other fuels. The higher the torque also means the power produced is also higher.

IV. Conclusion

Research has been carried out on Biodiesel Production based on Palm Oil Mill Effluent (POME), which will then be used in diesel engines. In the process of making this fuel, several experiments were carried out until the results were quite good. In the first experiment, liquid waste changed to solid during the filtering process. In the second experiment, liquid waste turned into lumps caused by a mixture of N-Hexene, and in the third experiment, liquid waste could turn into biodiesel due to the addition of H2SO4 (Sulfuric Acid) in a ratio of 10 ml. There is also the addition of chemical liquids such as Methanol, Catalyst, KoH, Sulfuric Acid, and Aquades. On the other hand, to test the characteristics of biodiesel, testing is carried out. The tests carried out are Density, Viscosity and Test on the machine.

In fuel testing, there are two tests carried out, namely properties and performance. To test the properties using the Density and Viscosity test. from density testing, the results obtained at B5% are 0.81 gr/cm3, while at B10% are 0.86 gr/cm3, and for Viscosity, the results obtained are poise for 5% biodiesel content 5.8 cSt and for 10% biodiesel content 6.3 cSt. The test results, when compared with SNI 7182:2015 data, only B5 with a density of 5.8 cSt meets the requirements. For testing on the engine, the results obtained on pure diesel showed that much fuel consumed in a short time produces a large amount of power while using biodiesel fuel consumed for a long time has lower power.

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