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Study Experimental of Diesel Engines Performance by Using Variations of Mesh Filter and Biodiesel B40, B50 as Fuel

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ABSTRACT

Biodiesel is an alternative fuel, which can be used as a substitute for fossil fuels. Biodiesel has different characteristics than fossil fuels, so need study to improve engine performance. One way to improve engine performance by vary the fuel filter mesh. In this study by varied the size of the filter mesh with sizes of 2, 10, and 30 microns. This study used B40 (a ratio 60% diesel and 40% biodiesel) and B50 (a ratio 50% diesel and 50% biodiesel) as fuel. Then, an engine rpm was varied by brake pressure load of 2500 kg/m2, 5000 kg/m2, 7500 kg/m2, 10000 kg/m2, and 12500 kg/m2. As results, the optimal mesh size used for B40 was 2 microns and 30 microns for B50 fuel. From the comparison of engine performance results, the fuel filter mesh used in B40 fuel has better engine performance results compared to B50.

KEYWORDS: *B40, B50, Biodiesel, Fuel Filter.*

NOMENCLATURE

A	= The cross-sectional area of the piston (m^2).
$\overline{AFR}$	= Air-fuel ratio mole basis.
AFR	= Air fuel ratio.
b	= Width of brake pad (mm).
$bmep$	= Brake measured effective pressure (N/m^2).
i	= Number of cylinders.
l	= Length of piston stroke (m).
LHV	= Lower heating value (kcal/kg).
m_{air}	= Molar mass of air (kg/mol).
m_{bb}	= Molar mass of fuel (kg/mol).
$\dot{m}_{bb}$	= Fuel flow rate per time (kg/hour).
n	= Speed of diesel engine (rpm).
Ne	= Effective shaft power (watt).
P	= Braking pressure (kg/m^2).
R	= Inner radius of brake (mm).
sfc	= Specific fuel consumption (kg/W.Hour).
T	= Torque (kg.m).
z	= 1 (2 stroke engine) or 2 (4 stroke engine).
$\theta 1$	= Angle of brake pad (°).
$\theta 2$	= Angle of brake pad and hook (°).
μ	= Coefficient of friction.
ηth	= Thermal efficiency (%).

1.0 INTRODUCTION

To reduce usage of diesel fuel, the government of Indonesia has committed to creation and utilization of new and renewable energy sources [1]-[5], with the issuance of Government Regulation No. 1/2006 [6]. The regulates the procurement and use of biodiesel is a national policy in the national energy sector related to biodiesel and Presidential Regulation No. 5 of 2006 concerning the national energy policy, and the Minister of Energy and Mineral Resources Regulation No. 32 of 2008 concerning the supply, utilization and trading of biofuels as other fuels [7]. In 2015 the Minister of Energy and Mineral Resources issued the third amendment of the Minister of Energy and Mineral Resources Regulation no. 32 of 2008, which stipulates a minimum use of 30% biodiesel (biodiesel B30) as a fuel oil mixture for all sectors [10]. This minimum figure may increase in the future, if petroleum resources are decreasing and biodiesel utilization technology has developed in Indonesia.

In the use of biodiesel, there are many problems that occur in diesel engines because biodiesel has a higher or thicker viscosity than diesel fuel, which tends to slow down atomization (the combustion process in the engine). In addition, biodiesel also contains more glycerin (unburnt impurities). One of the engine components in charge of overcoming this problem is the fuel filter [11]-[13]. Fuel filter is a part that functions to filter water and impurities contained in the fuel. However, if the fuel filter is clogged, the resistance in the fuel flow in the line will increase [14]-[15]. If this happens, it will reduce the amount of fuel sent to the combustion chamber due

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to the engine rotates at high speed or at heavy loads. The engine requires a large amount of fuel, at this time the power from the engine decreases due to lack of fuel supply [15]-[16]. The magnitude of changes in the properties that occur in biodiesel and its mixtures is in line with the increased risk of contaminant formation in the oil. This can increase the possibility of blockages on the surface of the filter media. The higher the ratio of biodiesel blend used in engine operation, the greater the possibility of filter blockage [16].

Soni (2019) [17] conducted a research on the optimization of biodiesel filter media size and configuration for longer service intervals. In this study, two filters with a size of 25 microns and 10 microns were used. The result is that the 25 microns filter configuration has 8 hours of treatment with the filter a differential pressure (DP) of 20 kPa while a 10 microns filter provides 11 hours of treatment with a DP of 26 kPa which has a 25% better treatment value. In this study, it can be seen that the larger the mesh size of the fuel filter, the greater the differential pressure that occurs, which will affect the pressure of the fuel flow to the combustion chamber [17].

Nufus (2019) [18] conducted a study on the study of the combustion quality of the use of fuel filters in diesel engines. The test was carried out in engine speed from 1100 to 1700 rpm, by opening the throttle % to 60% from 30% using 3 electromagnet filters. The three filters are made of 5,000 coils of wire with core diameters of 44 mm, 28.5 mm and 17.5 mm. In this study, the results showed that the best fuel filter is the first filter with a rotation of 1700 revolutions per minute (rpm) and the valve opening is kept constant by 40%, which can save fuel up to 33%. Another test carried out by making a constant rotation of 1500 rpm and a valve opening of 60% resulted in the best filter but the first filter saves fuel reaching 36%, so from several tests it shows that the greater the load is given and the greater the engine speed, the greater the difference. The significant difference between standard engines compared to diesel engines using filters [18].

Therefore, it is still a challenge to research fuel filter mesh implementation and test the effect of biodiesel on filtering ability to improve engine performance. The purpose of this study is to obtain the most optimal filter circuit for use in engines using biodiesel fuels (B40 and B50).

2.0 METHODOLOGY

This research adopted the experimental method to investigate the performance for diesel engines using B40 and B50 with variations in the fuel filter mesh. The test was carried out by operating the engine at 900 rpm, using biodiesel B40 and B50 by varying the fuel filter mesh 2 micron, 10 micron, 30 micron and giving a load from 2500 kg/m^2 to 12500 kg/m^2. The test flowchart can be seen in Figure 1. The test setup used in this study can be seen in Figure 2. The data specification for test equipment used in this study, it can be seen in Table 1 and 2.

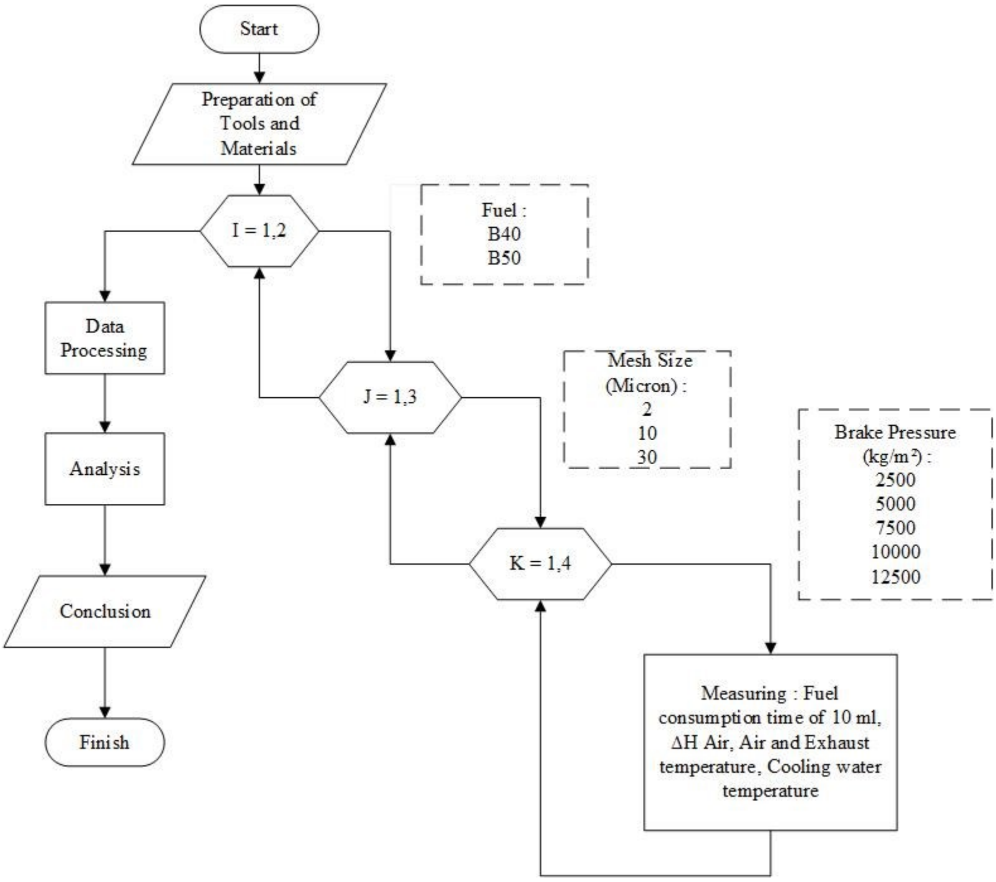

Figure 1: Test flowchart

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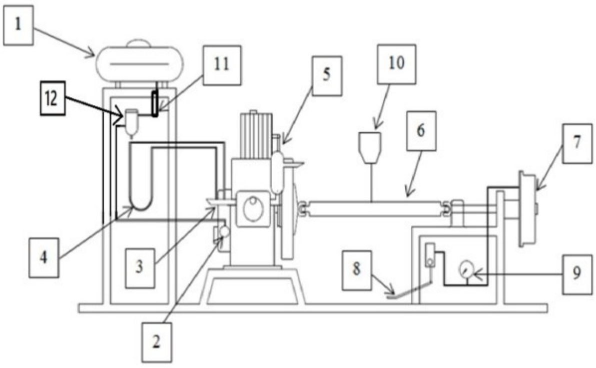

1. Fuel Tank
2. Injector Pump
3. Orifice Plate
4. Differential Manometer
5. Engine
6. Propeller Shaft
7. Drum Brake
8. Brake Pedal
9. Pressure Gauge
10. Tachometer
11. Measuring Tube
12. Fuel Filter

Figure 2: Test Setup

Table 1: The engine specifications

Model	R100 CDi
Brand	Ratna
Type	4 Steps
Combustion System	Live combustion chamber
Number of Cylinders	1 Cylinder
Diameter X Step Length	85 x 90 mm
Cylinder Volume	510 cc
Compression Comparison	21:1
Maximum Power/RPM	10 HP/2200 rpm
Average Power	9 HP/2200 rpm
Oil Capacity	2.5 Liter
Cooling System	Condenser
Governor System	Mechanical
How to turn on	Crank
Oil Type	SAE 40 Diesel Engine
Rotation Direction	Counter clockwise
Bruto	98 kg

Table 2: The dynamometer specifications

Type of dynamometer	drum brake
Brake canvas width	3 cm
Coefficient of friction (μ)	0.4
Inside radius (mm)	12.5 cm
Brake Length(mm)	27 cm
Brake canvas angle (°)	30°
Brake and hook blade angle (°)	110°

The diesel engine performance parameters are below:

1. Torque (*T*)

Torque is a measure of the engine's ability to produce work. In the tests carried out, where the rotation of the engine, which was channeled from the shaft would experience a load in the form of braking with a drum break. The equation was used [19]:

$$T = 2 \times \mu \times P \times b \times r^2 \times (Cos\ 1 - Cos\ 2) \quad (1)$$

2. Effective shaft power (*Ne*)

Effective shaft power is the power generated net at the motor shaft output. The equation was used to calculate the effective shaft power [20]:

$$N = \left(\frac{T \times 2 \times \pi \times n}{60}\right) \quad (2)$$

3. Brake measured effective pressure (*bmep*)

The combustion process of the air-fuel mixture produces pressure that acts on the piston to revealing stroke. The amount of this pressure varied throughout the piston stroke. If it took a constant value pressure that acts on the piston and produces the same work, then the pressure to be work per cycle per piston stroke volume. The theoretical average effective pressure acting along the stroke volume of the piston to produce a power equal to the effective power. Hence, the bmep can be formulated in below equation [2]:

$$bmep = \frac{Ne \times z \times 60}{A \times l \times n \times i} \quad (3)$$

4. Specific fuel consumption (sfc)

The specific fuel consumption (sfc) is the amount of fuel used by the engine to produce an effective shaft power of 1(Kg/kW.s) [21].

$$sfc = \frac{\dot{m}bb}{Ne} \quad (4)$$

To find the value of the mass flow rate of fuel ($\dot{m}bb$) can be formulated as:

$$\dot{m}bb = \frac{vbb \times \rho bb}{t} \quad (5)$$

5. Thermal efficiency (ηth)

Thermal efficiency is a measure of the use of heat energy stored in the fuel to be converted into effective power by an internal combustion engine. The equation was used to calculate the thermal efficiency [22]:

$$\eta th = \frac{Ne}{\dot{m}bb \times LHV} \times 100\% \quad (6)$$

6. Air fuel ratio (AFR)

Air fuel ratio is the ratio between the masses of air and fuel at a point of view. The AFR can be formulated in equation [23]:

$$AFR = \frac{\dot{m}u}{\dot{m}bb} \quad (7)$$

3.0 RESULTS AND DISCUSSION

3.1 Torque

Based on the data obtained from the test was obtained the torque value on the engine. The following was an example of calculating torque at a loading of 2,500 kg/m^2 using a 2 micron filter with μ = 0.4, b = 0.025 m, r = 0.125 m, θ1 = 30°, and θ2 = 110° was the dynamometer specification data (Table 2). The results of the torque on the tests were carried out, it can be seen in Table 3. Then, it was plotted into a graph of the relationship between torque and loading as seen in Figure 3. It can be seen in Figure 4, which has a linear function as the load increased,

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the torque would also increase. In other words, the greater the load given, the greater the torque produced.

$$T = 2 \times \mu \times P \times b \times r^2 \times (\cos \theta 1 - \cos \theta 2)$$
$$T = 2 \times 0.4 \times 2{,}500\ kg/m^2 \times 0.025\ m \times (0{,}.25\ m)^2 \times (\cos 30^o - \cos 110^o)$$
$$T = 0{,}818\ kg.m$$
$$T = 8{,}025\ Nm.$$

Table 3: Torque rest results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 μm)	8.025	16.050	24.075	32.100	40.125
2	B40 (10 μm)	8.025	16.050	24.075	32.100	40.125
3	B40 (30 μm)	8.025	16.050	24.075	32.100	40.125
4	B50 (2 μm)	8.025	16.050	24.075	32.100	40.125
5	B50 (10 μm)	8.025	16.050	24.075	32.100	40.125
6	B50 (30 μm)	8.025	16.050	24.075	32.100	40.125

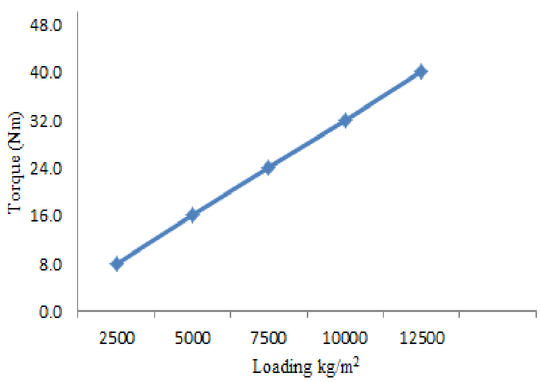

Figure 3: Graph of torque versus loading

The torque value from the test was calculated using equation (1) where both the coefficient of friction, angle cos $\theta 1$, cos $\theta 2$, width of brake pad, and drum radius were the specifications of the dynamometer used and the braking value given was the same for each loading. This causes the torque results for each test carried out to be the same. It was due to the calculation of the braking torque performed by the dynamometer.

3.2 Effective Shaft Power (*Ne*)

Based on the data obtained in the test, which was processed to calculate engine performance. The equation (2) was used to calculate the effective shaft power. The example calculation used data at a loading of 2,500 kg/m^2 standard fogging pressure, with an engine speed of 896.4 rpm, the following were the results:

$$Ne = \frac{T \times 2 \times \pi \times n}{60}$$
$$Ne = \frac{8.0218 Nm \times 2 \times \pi \times 896.4\ rpm}{60}$$
$$Ne = 753\ Watt$$
$$Ne = 0.753\ kW$$

In the same way was done on every other test data. Then the results of the effective shaft power were obtained, which can be seen in Table 4.

Table 4: Effective shaft power test results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 μm)	0.753	1.486	2.204	2.917	3.602
2	B40 (10 μm)	0.744	1.457	2.165	2.803	3.476
3	B40 (30 μm)	0.734	1.445	2.123	2.775	3.354
4	B50 (2 μm)	0.744	1.470	2.177	2.860	3.479
5	B50 (10 μm)	0.749	1.498	2.206	2.931	3.638
6	B50 (30 μm)	0.727	1.434	2.127	2.755	3.346

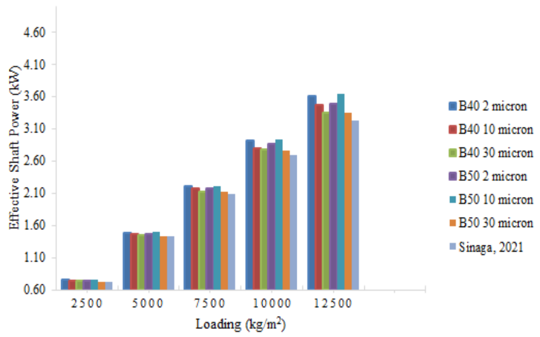

Figure 4: Graph of effective shaft power versus loading

The obtaining data was plotted into a graph of the relationship between effective shaft power and loading. The graph of the effective shaft power against loading can be seen in Figure 4. In Figure 4 it can be seen that the shaft power graph increases as the load value increases. This is because the increase in the load given is in line with the amount of biodiesel that is injected into the combustion chamber in order to maintain a constant rotation.

The larger the mesh fuel filter, the fuel content sent into the combustion chamber will be easier to inject because the obstacles that affect the injection pressure are properly filtered in the fuel filter, so that the supply of fuel sent to the combustion chamber is fulfilled more quickly. This can be seen in the B40 fuel with 2 microns filter producing a greater average power of 3,602 kW at a load of 12,500 kg/m^2, compared to the 10 microns and 30 microns of filter. Meanwhile, in B50 fuel, the highest shaft power value was produced by 10 microns filter, which was 3,638 kW at a load of 12,500 kg/m^2. This meaning of the 10 microns fuel filter was better at filtering B50 fuel than other mesh sizes. In the smallest filter, which was 2 microns, the filter gradually closes due to impurity, resulting in a shorter filter life, while for the 30 microns filter the impurity was not filtered properly.

3.3 Brake Measured Effective Pressure (*bmep*)

By using equation (3) and with the effective shaft power value that has been obtained previously, the value of A was calculated using the formula for the area of a circle with the

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values of d = 0.085 m and l = 0.09 m in the engine specifications in Table 1. The example of brake measured effective pressure (bmep) calculations are as following:

$$bmep = \frac{Ne \times z \times 60}{A \times l \times n \times i}$$

$$bmep = \frac{0.75363kW \times 2 \times 60}{\left(\frac{\pi}{4} \times 0.085m\right) \times 0.09m \times 896.4rpm \times 1}$$

$$bmep = 147.058\ N/m^2$$

The results of the bmep on the tests were carried out, as be seen in Table 5. The data obtained is then plotted into a graph of the relationship between bmep and loading. The graph of the bmep against loading can be seen in Figure 5. It can be seen in Figure 5, the larger mesh size of fuel filter, the higher the bemp value. This happens because the greater the value of the mesh fuel filter, the resistance that affected the pressure of the fuel flow to the combustion chamber was filtered properly so, this causes an increase in the capacity of the fuel sent to the combustion chamber.

Table 5: Brake measured effective pressure test results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 μm)	147.058	294.181	441.060	588.182	735.196
2	B40 (10 μm)	147.089	294.161	441.122	588.161	735.283
3	B40 (30 μm)	147.088	294.010	441.191	588.208	735.239
4	B50 (2 μm)	147.105	294.039	441.154	588.275	735.207
5	B50 (10 μm)	147.064	294.095	441.107	588.227	735.173
6	B50 (30 μm)	146.981	294.165	441.028	588.098	735.235

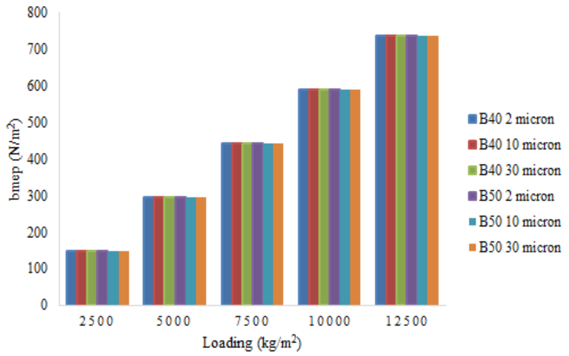

Figure 5: Graph of bmep versus loading

In B50 fuel the filter size of 2 microns produces the highest bmep value, while on B40 fuel the highest bmep value occurred at a filter size of 10 micron. This happens because the higher the level of bio in the fuel, the higher the level of impurities contained in it. Therefore, the smaller the size of the micron filter, the better at filtering the impurities contained in the fuel so that, by filtering the impurities, the amount of fuel sent to the combustion chamber increases and causes the engine bmep to increase. In B40 fuel, the filter size of 10 micron has the best bmep value because the difference in the level of impurity contained in B40 was not as much as B50 fuel.

3.4 Specific Fuel Consumption (*sfc*)

In order to calculate the specific fuel consumption (sfc), it is necessary to first calculate the mass flow rate of the fuel. Based on the data ρbb was obtained 853.6 kg/m^3, the fuel consumption time was 129 seconds (loading 2,500 kg/m^2 for B40 fuel with 2 microns filter), and the fuel volume was 0.00001 m^3, then the rate value of mass flow of fuel using equation (5):

$$\dot{m}_{bb} = \frac{V_{bb} \times \rho_{bb}}{t}$$

$$\dot{m}_{bb} = \frac{0.00001m^3 \times 853.6\ kg/m^3}{129\ s}$$

$$\dot{m}_{bb} = 0.0000662\ kg/s$$

Furthermore, to calculate the specific fuel consumption can be done using equation (4):

$$sfc = \frac{\dot{m}bb}{Ne}$$

$$sfc = \frac{0.0000662\ kg/s}{0.753\ kW}$$

$$sfc = 0.0000879\ kg/kJ$$

In the same way as for each variation of the mesh filter, the sfc value can be seen in Table 6. The obtaining data was plotted into a graph of the relationship between sfc and loading. The graph of sfc against loading can be seen in Figure 6. It can be seen in Figure 6, the sfc graph increased as the loading value increased. This was due to the increase in the load given in line with the amount of biodiesel that was injected into the combustion chamber in order to maintain a constant rotation.

Table 6: Specific fuel consumption test results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 μm)	0.0000879	0.0000475	0.0000337	0.0000268	0.0000226
2	B40 (10 μm)	0.0000883	0.0000480	0.0000343	0.0000269	0.0000227
3	B40 (30 μm)	0.0000881	0.0000484	0.0000344	0.0000270	0.0000233
4	B50 (2 μm)	0.0001148	0.0000611	0.0000426	0.0000364	0.0000336
5	B50 (10 μm)	0.0001018	0.0000559	0.0000387	0.0000310	0.0000283
6	B50 (30 μm)	0.0000995	0.0000532	0.0000375	0.0000310	0.0000266

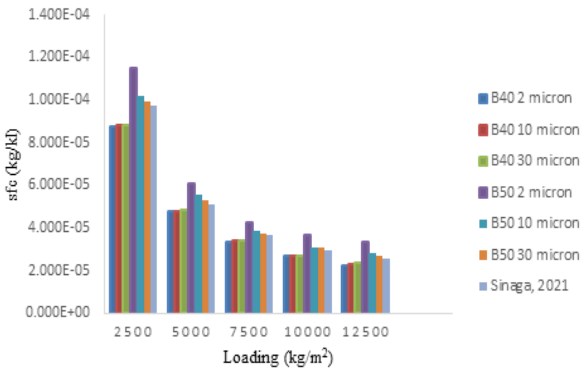

Figure 6: Graph of sfc versus loading

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For B40 fuel, the larger the mesh size of the fuel filter, the smaller the sfc value would be. This is because the larger the mesh size of the fuel filter, the better it would be in filtering the fuel content that can be an obstacle to the flow of fuel into the combustion chamber. The supply of fuel sent to the combustion chamber would be fulfilled more quickly. Whereas in B50 fuel, the smaller the mesh size of the fuel filter, the greater the sfc value obtained. This means that the smaller the mesh size of the fuel filter, the better it would be at filtering the fuel content.

3.5 Thermal Efficiency (ηth)

By using equation (6) with the effective shaft power and $\dot{m}_{bb}$ value that has been obtained previously, the examples of calculations are:

$$\eta th = \frac{Ne}{\dot{m}bb \times LHV} \times 100\%$$

$$\eta th = \frac{0.753\ kW}{0.0000662 \frac{kg}{s} \times 44434.15322\ kJ/kg} \times 100\%$$

$$\eta th = 24.065\ \%$$

The results of the thermal efficiency on the tests are as in Table 7. The obtaining data was plotted into a graph of the relationship between thermal efficiency and loading. The graph of the thermal efficiency against loading can be seen in Figure 7. It can be seen in Figure 7 that the larger mesh size of the fuel filter, the greater the thermal efficiency value obtained. This applies to fuel B40 and B50.

The increasing in thermal efficiency occurred because the larger the mesh size of the fuel filter, the better it would be in filtering the fuel content used, which facilitate the pressure of the fuel flow to be injected into the combustion chamber. The greatest B40 thermal efficiency value occurred in the 2 microns mesh fuel filter with a value of 93.712% at a load of 12.500 kg/m ^{2}. As for B50, the greatest thermal efficiency occurred at 30 microns mesh with a value of 79.586% at a load of 12.500 kg/m ^{2}. The thermal efficiency value of B40 was better than B50. This was due to B40 has a higher heating value than B50, so that the combustion process in B40 was better than B50.

3.6 Air Fuel Ratio (AFR)

By using equation (7) and with $\dot{m}_{bb}$ and $\dot{m}_{air}$ value that has been obtained previously, the examples of AFR calculations are:

$$AFR = \frac{\dot{m}_{Air}}{\dot{m}bb}$$

$$AFR = \frac{0.012199\ kg/s}{0.0000662\ kg/s}$$

$$AFR = 184.353$$

The results of the air fuel ratio on the tests are depicted in Table 8. The obtaining data was plotted into a graph of the relationship between air fuel ratio and loading. The graph of the air fuel ratio against loading can be seen in Figure 8. It can be seen in Figure 8 that the larger mesh size of the fuel filter, the smaller the air fuel ratio value obtained.

Table 7: Thermal efficiency test results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 µm)	24.065	44.536	62.810	78.778	93.712
2	B40 (10 µm)	23.957	44.031	61.690	78.480	93.007
3	B40 (30 µm)	23.999	43.691	61.536	78.378	90.579
4	B50 (2 µm)	18.426	34.607	49.622	58.097	62.927
5	B50 (10 µm)	20.782	37.857	54.661	68.258	74.820
6	B50 (30 µm)	21.264	39.783	56.403	68.270	79.586

Table 8: Air fuel ratio test results

No.	Filter	Loading (kg/m^2)				
		2500	5000	7500	10000	12500
1	B40 (2 µm)	184.353	172.778	164.480	139.278	134.167
2	B40 (10 µm)	185.718	174.349	164.409	144.439	138.101
3	B40 (30 µm)	188.868	155.889	149.610	145.717	139.326
4	B50 (2 µm)	127.717	121.279	117.500	90.697	80.708
5	B50 (10 µm)	143.111	130.378	127.822	120.111	91.847
6	B50 (30 µm)	150.778	143.111	136.598	110.697	106.136

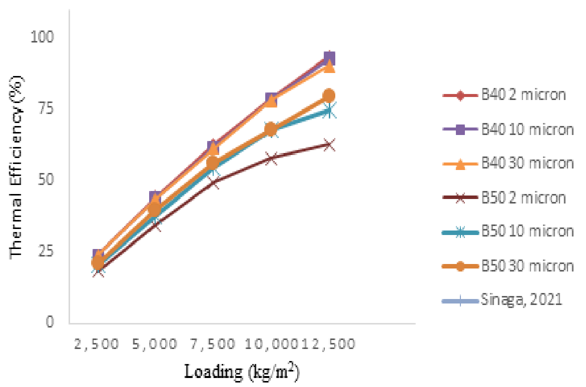

Figure 7: Graph of thermal efficiency versus loading

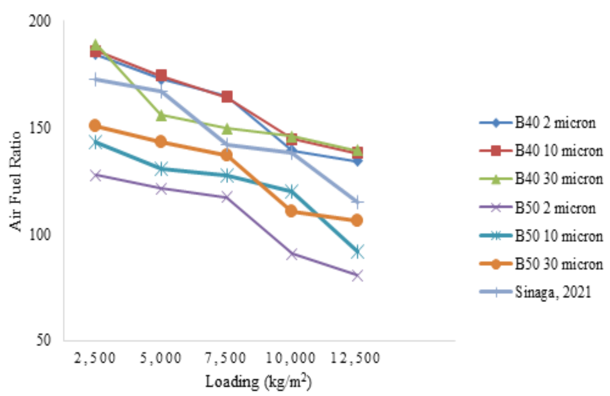

Figure 8: Graph of air fuel ratio versus loading

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This happened because the larger size of the fuel filter mesh, the lower the fuel flow rate and the greater the air fuel ratio value obtained. The largest AFR B40 value occurred in the 30 microns mesh fuel filter with a value of 139.326 at a load of 12.500 kg/m^2. The results for B50, the largest AFR also occurred at 30 microns mesh with a value of 106.136 at a load of 12.500 kg/m^2.

4.0 CONCLUSION

The purpose of this study is to obtain the most optimal filter circuit for use in engines when using biodiesel fuels (B40 and B50). The fuel filter mesh is varied the size of 2, 10, and 30 microns. From the results of engine performance, the optimal mesh size used for B40 fuel is 2 microns. As for the B50 fuel is 30 microns. From the comparison of engine performance results obtained through research, the fuel filter mesh used in B40 (a ratio 60% diesel and 40% biodiesel) fuel has better engine performance results compared to B50 (a ratio 50% diesel and 50% biodiesel).

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