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Study Experimental of Temperature Effect of B40 Biodiesel Engine Performance

Dwiki Wisnu [a] and Romy [b]*

[a)] *Student Mechanical Engineering Department, Universitas Riau, Indonesia*
[b)] *Laboratory of Energy Conversion, Mechanical Engineering Department, Universitas Riau, Indonesia*

*Corresponding author: romy@lecturer.unri.ac.id

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ABSTRACT

This paper aims to determine the performance of diesel engine and increase the injection pressure by varying the fuel temperature using biodiesel B40 with a compression ratio of 21:1 and an injection pressure of 150 Bar. The parameters were calculated include, h at the orifice, the volume of fuel used, fuel consumption time, and engine rpm. In the tests carried out, it was found that variations in fuel temperature affect engine performance parameters such as effective shaft power, average effective pressure, thermal efficiency values, air fuel ratio, and specific fuel consumption. The results of the fuel temperature test with variations of 50°C, 55°C, 60°C, 65°C and 70°C. Where for the value of the largest effective shaft power at a temperature of 60°C with a value of 3.7892 kW at a load of 25,000 kg/m^2 and the largest BMEP (Brake Mean Effective Pressure) at a temperature of 70°C with a value of 1275.321 N/m^2, for the value of thermal efficiency, specific fuel consumption, ratio of air and the best fuel at a temperature of 65°C with a thermal efficiency value of 92.333 % at a load of 25,000 kg/m^2, for a better air-fuel ratio with a value of 157,660 at a load of 5,000 kg/m^2, and the smallest specific fuel consumption with value 0.00002291 kg/kJ at a load of 25,000 kg/m^2.

KEYWORDS: *Biodiesel, B40, Temperature, Injection Pressure.*

NOMENCLATURE

A	= The cross-sectional area of the piston (m^2).
$\overline{AFR}$	= Air-fuel ratio mole base.
AFR	= Air fuel ratio mass base.
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 (kJ/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

Increasing technological efficiency in the automotive sector causes fuel oil to still dominate in total energy consumption with an average growth rate of 3.5% per year. Biodiesel is one of the vegetables and animal oils that has been used as a substitute for diesel oil because it has similar properties to diesel oil and is composed of mono alkyl esters of long chain fatty acids [1-3]. The main raw material for biodiesel in Indonesia is palm oil (Crude Palm Oil/CPO), which according to the Palm Oil Plantation Fund Management Agency (BPDPKS) projects crude palm oil production in 2022 to reach 51.01 million tons.

The direct use of 100% biodiesel as fuel will reduce the performance of the diesel engine due to the higher viscosity and density of 100% biodiesel when compared to diesel oil, which makes the injector ejection process less good. So that combustion is not perfect. Therefore, it is needed a treatment on the fuel. The treatment that can be carried out on biodiesel before combustion is by heating the biodiesel to a certain temperature, which will cause a decrease in the viscosity and

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density of the fuel before entering the high-pressure pump. So that the injected into the combustion chamber it will form finer fuel mist grains, which will cause the process of mixing fuel and air.

Khalid *et al*. (2014) [4] using biodiesel-based crude palm oil (B5, B10 and B15) at 40°C, 50°C and 60°C to study on the performance and emissions of diesel engines at three different load conditions, namely 0% load, 50% load and 100% load. A four-stroke four-cylinder, water-cooled, direct-injection engine was used for the experiment. The results show that the maximum performance is produced at 0% load conditions with a heating temperature of 60°C at B10 where torque, flywheel torque and brake power increase by 11.55%, 11.42% and 4.16% respectively compared to diesel fuel. As for emissions, the heating temperature causes a decrease in CO emissions for all load conditions and the maximum reduction recorded is 41.2%. However, the increase in fuel temperature led to higher NOx emissions being produced and the maximum increase recorded was 51.7% [4].

Anis *et al*. (2018) [5] conducted research and efficiency of diesel motors with various mixtures of biodiesel (B0-B30) and preheating temperature of 30°C-70°C at constant injection pressure. The results showed that the pump performance decreased with increasing the percentage of biodiesel. The highest pump capacity and efficiency occurred at a temperature of 50°C, while the highest pump head occurred at a temperature of 70°C. At 60°C and 70°C, the pump experiences excessive vibration. The fuel spray angle also increases as the preheat temperature increases. The widest spray angle occurs at a fuel preheat temperature of 70°C [5].

Baridhono (2018) [6] conducted a test to determine the effect of the compression ratio on the performance of a diesel engine using a mixture of biodiesel fuels B0, B10, B20 and B30 where the variations in the compression ratio of the diesel engine are 15.5, 17.5 and 19.5 with engine speed varying from 1600 to 2400 rpm with 200 rpm intervals. The results showed that the use of B20 biodiesel fuel at the highest compression ratio of 19.5 produced 5.26% torque, 5.24% effective power and 6.99% higher effective thermal efficiency, but the effective fuel consumption (SFCe) was 1.28% higher than ordinary diesel. Where the best performance of diesel fuel is obtained at a compression ratio of 19.5 with a torque value of 0.399 kgf.m, an effective power of 1.337 PS, an SFCe value of 0.234 kg/PS. Hour and an effective thermal efficiency of 24.156% [6].

Simanihuruk *et al.* (2019) [7] conducted tests with the fuel mixture used Bio-solar (B20) 95% with 5% ethanol, Bio-solar (B20) 90% with 10% ethanol and Bio diesel (B20) 85% with 15% ethanol in 1000 ml with temperature variations of 50°C, 60°C and 70°C and load variations of 1000 watts, 2000 watts and 3000 watts. The results showed that the performance of the Dong Feng diesel engine using an electric generator with 95% biodiesel and 5% ethanol in 1000 ml increased the effective power, torque and brake mean effective pressure by 5.88% compared to using only biodiesel. The best temperature effect is found in a mixture of 95% biodiesel fuel and 5% ethanol with a temperature of 60°C an increase of 5.06%, this is because the fuel flow rate is faster into the combustion chamber and the viscosity of the fuel is getting lower due to heating of the fuel [7].

Dinesha & Mohanan [8] conducted an experimental investigation on a four-stroke single cylinder engine to assess the performance and emission characteristics of a blend of B40 and B20 biodiesel heated at 60, 75, 90, and 110 degrees Celsius in a shell and tube heat exchanger using waste heat from exhaust gas. Their investigation yielded a considerable improvement in the performance and emission characteristics of the B40 mixture preheated to 110°C, with a maximum gain in brake thermal efficiency of 8.97% over the B20 combination at 75% load [8].

Therefore, this paper aims to determine the performance of diesel engine and increase the injection pressure by varying the fuel temperature using biodiesel B40, injection pressure of 150 Bar to calculated include: h at the orifice, the volume of fuel used, fuel consumption time, and engine rpm. The variations in fuel temperature affect engine performance parameters such as effective shaft power, average effective pressure, thermal efficiency values, air fuel ratio, and specific fuel consumption would be analyzed.

2.0 METODHOLOGY

2.1 Research Flowchart

The research flow chart for a diesel engine using B40 with temperature variations with an injection pressure of 150 bar can be seen in Figure 1. The test was carried out by operating the engine at 900 rpm, using biodiesel B40 by varying the fuel temperature 50°C, 55°C, 60°C, 65°C, 70°C, and loading from 5000 kg/m^2 to 28000 kg/m^2.

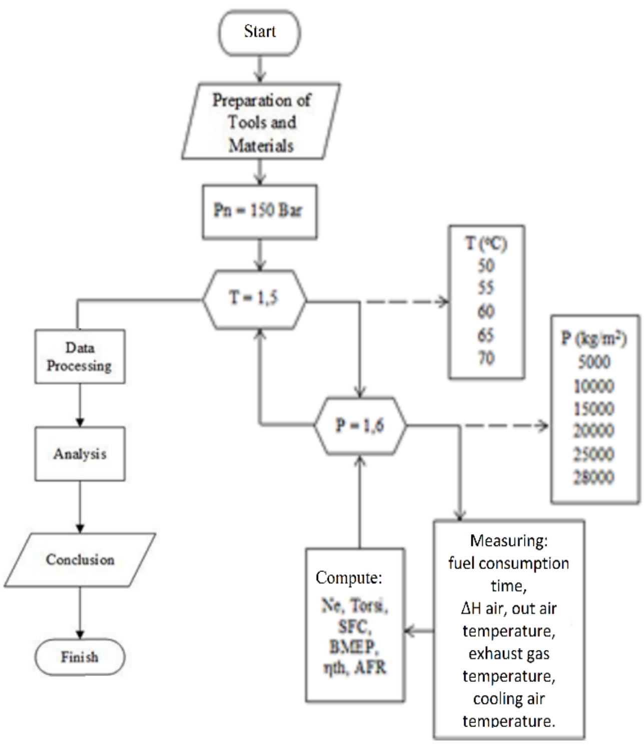

Figure 1: Research flowchart

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2.2 Test Setup

The test setup was used in this study can be seen in Figure 2.

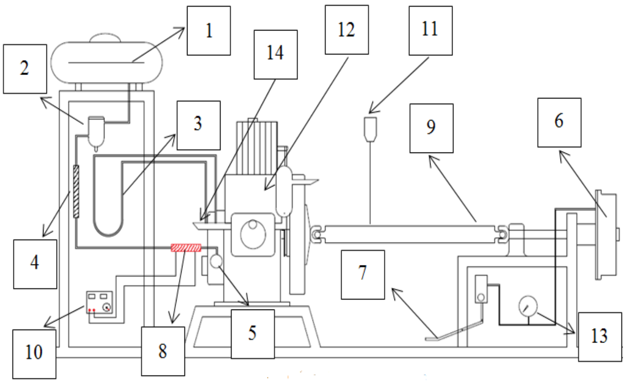

Figure 2: Test Setup

1. Fuel Tank	8. Heater
2. Filter	9. Profeller Shaft
3. Manometer U	10. Power Supply
4. Measuring Tube	11. Tachometer
5. Injector Pump	12. Engine
6. Drum brake	13. Pressure Gauge
7. Brake pedal	14. Orifice

The specifications of the test equipment in this study, it can be seen in Table 1. In Table 2 is depicted the dynamometer specifications.

Tabel 1: 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

Tabel 2 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°

2.3 Diesel Engine Achievement

1. Torque

Torque is a measure of the engine's ability to produce work. The torque generated by the motor is then transmitted to the drive wheels if it is in a vehicle and to the generator set it is passed on to rotate the generator. In the test to be carried out, where the rotation of the motor, which is channeled from the shaft will experience a load in the form of braking with a drum break. Therefore the torque can be formulated in equation [9]:

$$T = \mu .\ P.\ b.\ r^2 .\ (Cos\theta 1 - Cos\theta 2) \qquad (1)$$

Tabel 3: Friction coefficient of various materials in brakes

Friction Material	Coefficient of Friction (M)
Cast iron	0.08-0.12
Bronze	0.10-0.20
Wood	0.10-0.35
Weave	0.35-0.60
Mold/ Paste	0.20-0.45
Sintered Alloy	0.20-.0.45

2. Effective Shaft Power

Effective shaft power is used to drive the load, the shaft power itself is generated by the power indicator which is the combustion gas power that drives the piston, the shaft power price is expressed in Watts, speed per minute and torque in N.m. Then, the power can be formulated in the equation [10]:

$$Ne = \frac{T.2.\pi.n}{60} \qquad (2)$$

3. Brake Measured Effective Pressure (BMEP)

The combustion process of the air-fuel mixture produces pressure that acts on the piston so that it does the work stroke. The amount of this pressure varies throughout the piston stroke. If we take a constant value pressure acting on the piston and produce the same work, then the pressure is said to be work per cycle per piston stroke volume [11]. The theoretical average effective pressure acting along the stroke volume of the piston so as to produce a power equal to the effective power [12]:

$$BMEP = \frac{Ne\ .\ z\ .\ 60}{A\ .\ l\ .\ n\ .\ i} \qquad (3)$$

4. Specific Fuel Consumption (SFC)

Specific fuel consumption is the amount of fuel used by the engine to produce an effective power of 1 (one) hp for 1 (one) hour. If in the test data is obtained regarding the use of fuel Q (ml) in s (seconds) and the power generated is (hp) then the fuel consumption per hour of fuel is the amount of specific fuel consumption [12]:

$$SFC = \frac{\dot{m}_{bb}}{Ne} \ (kg/kW.hour) \qquad (4)$$

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 [13]. Where Q is the lower heating value (LHV) or the lower heat of combustion of the fuel [kJ/kg fuel. The calorific value is the maximum amount of heat energy released by a fuel through a complete combustion reaction per unit mass or volume of fuel [14]. Theoretically written in the

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equation [15]:

$$\eta th = \frac{Effective\ Power\ generated}{\dot{m}\ fuel\ .\ Q\ fuel} \times 100\% \quad (5)$$

6. Air Fuel Ratio (AFR)
 The ratio between the masses of air and fuel at a given point of view. Symbolically, AFR is calculated in the equation [16]:

$$AFR = \frac{\dot{m}\ air}{\dot{m}\ fuel} \quad (6)$$

3.0 RESULT AND DISCUSSION

3.1 Torque

Torque is a measure of the engine's ability to produce work. In the test to be carried out, where the rotation of the motor, which is channeled from the shaft have a load in the form of braking with a drum break. To calculate the torque with a value of P = 5000 kg/m², = 0.2, the value of b = 0.025 m, r = 0.125 m, 1 = 30°, and 2 = 110° which is the dynamometer specification (Tabel 2) data using Eq (1).

T = 2. µ. P. b.r². (Cos θ1- Cos θ2)
T = 2 x 0.2 x 5000 kg/m² . 0,025 m *x* (0,125 m)² *x* (Cos 30° - Cos 110°)
T = 0,94378 kg.m
T = 9,2553 Nm

The results of the torque on the tests carried out are as in Table 4. It can be seen from the graph of the engine torque against loading in Figure 3 braking where the greater the load given, the relationship between loading and torque is linear and the greater the loading, the greater the torque value.

The torque value resulting from the test is calculated using equation 1 where for the coefficient of friction, angle cos 1, cos 2, brake lining width and drum radius are specifications of the dynamometer used for research, while the braking pressure value given is the same for every braking. In this case, the torque value for each test performed is the same because the calculated torque is the braking torque performed by the dynamometer. This means that the torque is only affected by the loading and that is why the torque graph is straight.

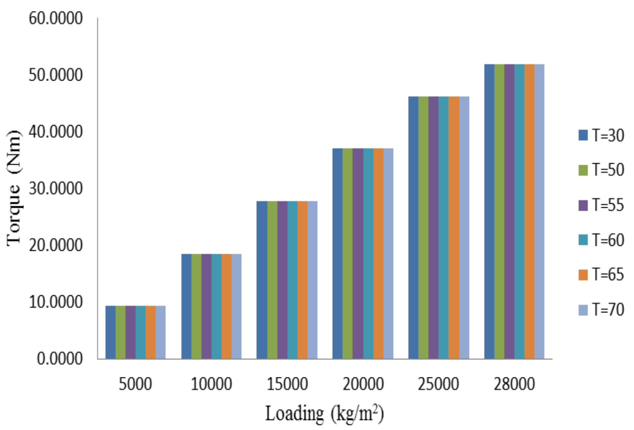

Figure 3: Graph of torque against loading

Tabel 4: Torque the results

T (°C)	Loading (kg/m²)					
	5000	10000	15000	20000	25000	28000
30	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299
50	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299
55	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299
60	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299
65	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299
70	9,2553	18,5107	27,7660	37,0213	46,2767	51,8299

3.2 Effective Shaft Power

Effective shaft power is also referred to as the net power generated at the motor shaft output. The shaft power price is expressed in Watts, while the equation used to calculate the effective shaft power is in Equation 2 with the torque that has been calculated previously, and the engine speed is 885.8 rpm, then the example calculation is.

$$Ne = \frac{T.2.\pi.n}{60}$$

$$Ne = \frac{9{,}2553\ \frac{N}{m}\ x\ 2\ x\ 3{,}14\ x\ 885{,}8\ rpm}{60}$$

$$Ne = 0{,}8581\ \text{kW}$$

The results of the effective shaft power in the tests carried out are as in Table 5. The data obtained is then plotted into a graph of the relationship between the effective power of the shaft and the load. The graph of the effective power of the shaft against loading can be seen in Figure 4.

In Figure 4, it can be seen that the graph of the effective power increases along with the increase in the load value, but when it exceeds the load of 25,000 kg/m² the graph decreases as in the graph above. This is because the greater the load, the greater the effective power, but the power will reach its optimal point at a load of 25,000 kg/m². After reaching the optimal point by adding the load will result in the effective power not increasing but decreasing. This is because the effective power is directly proportional to the load (P) and the engine speed (n) the greater the load, the smaller the value (n) so that the effective power will have maximum power.

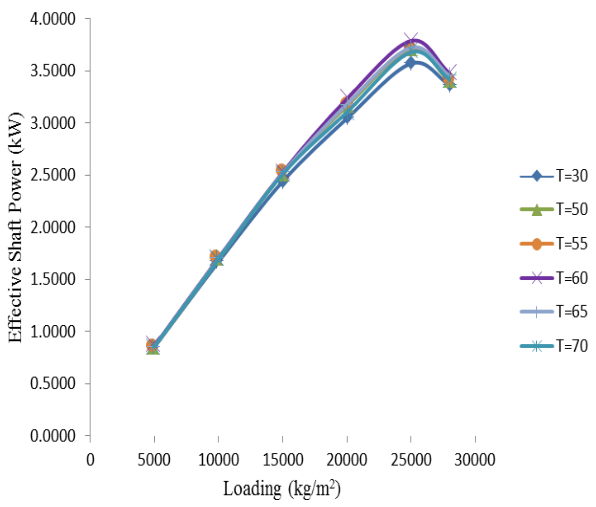

Figure 4: Graph of effective shaft power against loading

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Tabel 5: Effective shaft power test results

T	Loading (kg/m²)					
(°C)	5000	10000	15000	20000	25000	28000
30	0,8531	1,6711	2,4415	3,0441	3,5717	3,3678
50	0,8581	1,6957	2,5173	3,1642	3,7049	3,3998
55	0,8588	1,7026	2,5217	3,1770	3,7160	3,4133
60	0,8630	1,7092	2,5287	3,2324	3,7892	3,4757
65	0,8588	1,7032	2,5211	3,1801	3,7228	3,4540
70	0,8565	1,6955	2,5115	3,1042	3,6802	3,4187

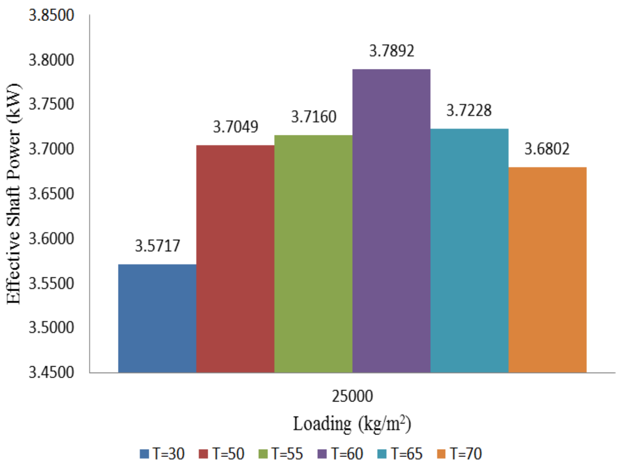

Figure 5: Optimal effective power at loading 25,000 kg/m²

The effect on heating the fuel temperature with an injection pressure of 150 bar can be seen in Figure 5 where the heating of the fuel with a temperature of 60°C increases and the power generated is also higher. It can be seen in table 5 that the 60°C temperature produces a greater effective power of 3.7892 kW at a load of 25,000 kg/m² compared to a temperature of 65°C at 3.7228 kW and 70°C at 3.6802 kW.

3.3 Brake Measured Effective Pressure (BMEP)

The equation used to calculate the BMEP is equation 3 with the value of the effective shaft power that has been obtained previously, the value of A is calculated using the formula for the area of a circle with the values of d = 0.085 m and L = 0.09 m in the engine specifications (Table 1). The example of the calculation and the results can be seen Table 6.

$$BMEP = \frac{Ne\,.\,z\,.\,60}{A\,.\,l\,.\,n\,.\,i}$$

$$BMEP = \frac{0{,}8581\ \text{kW} \times 2 \times 60}{\left(\frac{\pi}{4}\,.\ 0{,}085\text{m}\right) \times 0.09\ \text{m} \times 885.8\ \text{rpm} \times 1}$$

$$BMEP = 227{,}736\ \text{N/m}^2$$

Tabel 6: The BMEP test results

T	Loading (kg/m²)					
(°C)	5000	10000	15000	20000	25000	28000
30	227,736	455,472	683,208	910,944	1138,680	1275,321
50	227,736	455,472	683,208	910,944	1138,680	1275,321
55	227,736	455,472	683,208	910,944	1138,680	1275,321
60	227,736	455,472	683,208	910,944	1138,680	1275,321
65	227,736	455,472	683,208	910,944	1138,680	1275,321
70	227,736	455,472	683,208	910,944	1138,680	1275,321

The data obtained is then plotted into a graph of the relationship between BMEP and load. The graph of the effective power of the shaft against loading can be seen in Figure 6.

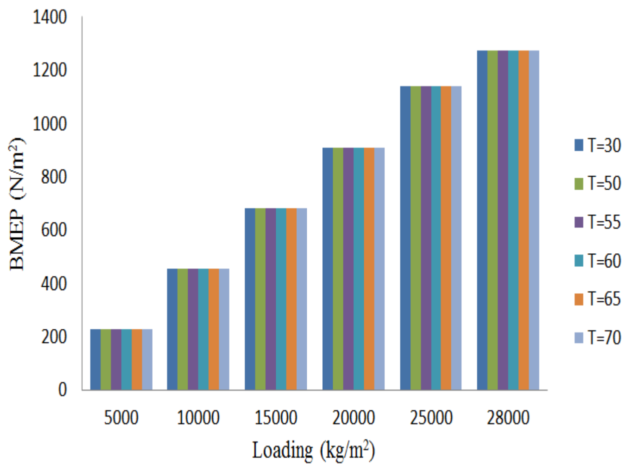

Figure 6: The BEMP graph against load

The graph shows that the Brake Measured Effective Pressure (BMEP) appears to grow with increasing loading, and the relationship between loading and torque is linear because BMEP is impacted by power and engine speed (n). Because power is influenced by torque and engine speed (n), and BMEP is influenced by torque, the BMEP graph is linear.

3.4 Specific Fuel Consumption (SFC)

Specific fuel consumption is the amount of fuel needed by the engine to produce 1 (kg/kJ) effective shaft power, which also indicates the engine's efficiency in creating fuel combustion power. Equation 4 is used in the calculation of heat energy stored in the fuel to be converted into effective power by an internal combustion engine. Table 7 shows the SFC calculation and the outcomes of the SFC in the tests performed.

Table 7: The SFC test results

T	Loading (kg/m²)					
(°C)	5000	10000	15000	20000	25000	28000
30	0,00009007	0,00004893	0,00003431	0,00002964	0,00002704	0,00003039
50	0,00008834	0,00004709	0,00003289	0,00002879	0,00002645	0,00003003
55	0,00008651	0,00004566	0,00003249	0,00002747	0,00002489	0,00002807
60	0,00008578	0,00004511	0,00003191	0,00002665	0,00002384	0,00002766
65	0,00008496	0,00004435	0,00003164	0,00002578	0,00002291	0,00002716
70	0,00008658	0,00004569	0,00003243	0,00002699	0,00002386	0,00002841

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

$$SFC = \frac{0{,}0000758\ kg/s}{0{,}8581\ \text{kW}}$$

$$SFC = 0{,}00008834\ \text{kg/kJ}$$

The data obtained is then plotted into a graph of the relationship between SFC and load. The graph of the effective power of the shaft against loading can be seen in Figure 7. In Figure 7, it can be seen where the greater the loading the result is that the SFC value will decrease, but to reach the optimum value at a loading of 25,000 kg/m² and increase again with

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increasing loading. This indicates that the rotation of 25,000 kg/m^2 states that the more energy from the fuel that is converted for each kW, the greater and the consumption of fuel will also be shorter.

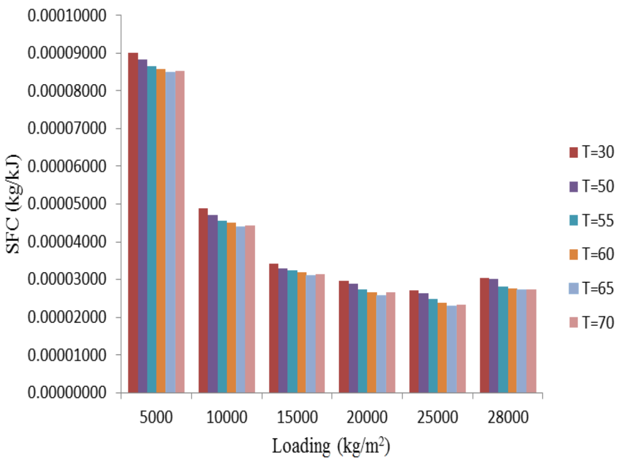

Figure 7: The SFC graph against load

Figure 8 also shows the effect of injection pressure and the effect of variations in B40 biodiesel fuel, it can be seen that the best SFC value is at a temperature of 65°C with a smaller SFC value, it occurs throughout the load. This is because heating the fuel reduces its viscosity, which, when sprayed into the combustion chamber, generates finer granules with more homogenous mixing of fuel and air, making the combustion chamber more combustible. However, if the fuel temperature remains high, the fuel burns quickly, shortening the ignition time (ignition delay), and the combustion process is too fast long before standard circumstances. This results in a loss since it increases fuel consumption time and results in more inefficient fuel usage as fuel temperature rises.

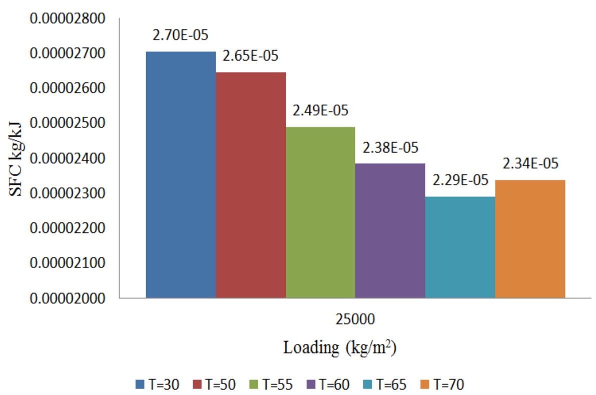

Figure 8: Optimal SFC Graph At 25,000 kg/m^2 loading

3.5 Thermal Efficiency (ηth)

By using equation (5) with the effective shaft power and ṁbb value that has been obtained previously, the examples of calculations and the results of the Thermal Efficiency in the tests carried out are as in Table 8.

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

$$\eta th = \frac{0.8581 \text{ kW}}{0{,}0000758 \ kg/s \times 47281{,}97 \text{ kJ/kg}} \times 100\%$$

$$\eta th = 23{,}980\ \%$$

Table 8: The thermal efficiency test results

T	Loading (kg/m^2)					
(°C)	5000	10000	15000	20000	25000	28000
30	23,482	43,226	61,642	71,351	78,230	69,592
50	23,940	44,912	64,306	64,306	79,955	70,421
55	24,448	46,320	65,104	76,986	84,983	75,354
60	24,655	46,881	66,287	79,370	88,721	76,473
65	24,895	47,687	66,838	82,025	92,333	77,878
70	24,427	46,293	65,215	78,374	88,631	74,457

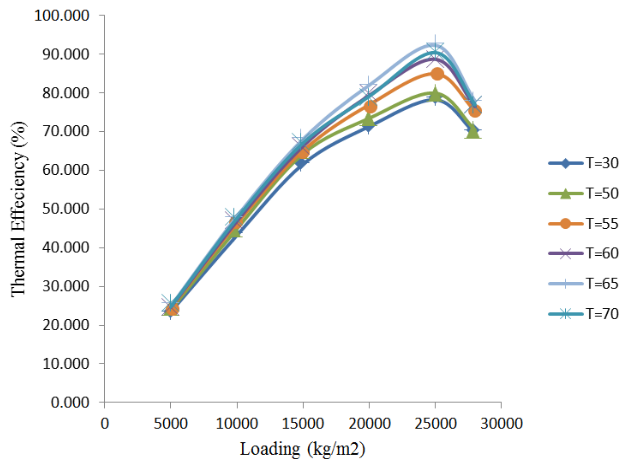

Figure 9: Thermal efficiency graph against load

The data obtained is then plotted into a graph of the relationship between thermal efficiency and load. The graph of the effective power of the shaft against loading can be seen in Figure 9. In Figure 9, it can be seen where it increases with increasing loading, the greater the efficiency and will experience a peak at 25,000 kg/m^2 loading and decreases after a given load of more than 25,000 kg/m^2.

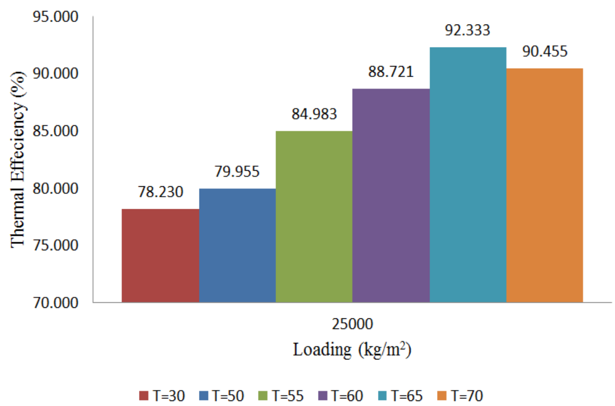

Figure 10: Graph of optimal thermal efficiency at 25,000 kg/m^2 loading

In Figure 10, it can be seen that the best efficiency value occurs at a loading of 25,000 kg/m^2 and at a temperature variation of 65°C compared to a temperature variation of 60°C.

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This is because with the increase in fuel temperature which results in a decrease in the viscosity of the fuel which, when injected with high pressure into the combustion chamber, forms finer mist grains where the mixing of fuel and air is more homogeneous, resulting in a more complete combustion in the combustion chamber. Complete combustion will increase the heat generated in the combustion chamber. This increase in heat can increase the pressure in the engine combustion chamber. The thermal efficiency of the diesel engine will increase and for a temperature of 60°C it consumes more fuel (wasteful) than at a temperature of 65°C. But for the best effective power at a temperature of 60°C because the power produced requires a large amount of power and results in more fuel consumption (wasteful) than at a temperature of 65°C to produce the same power.

3.6 Air Fuel Ratio (AFR)

Air Fuel Ratio is calculated using Equation 6 with the previously obtained values of bb, and air. An example of the calculation and the results of the AFR in the tests carried out are as in Table 9.

Table 9: The AFR test results

T	Loading (kg/m²)					
(°C)	5000	10000	15000	20000	25000	28000
30	150,130	140,983	121,338	112,627	88,949	64,981
50	152,357	144,359	123,050	111,776	87,799	65,276
55	155,086	148,129	123,811	116,456	92,873	69,422
60	155,626	149,343	125,712	118,004	95,087	69,097
65	157,660	152,244	127,096	123,651	100,472	70,750
70	155,176	148,570	124,627	121,198	97,626	68,397

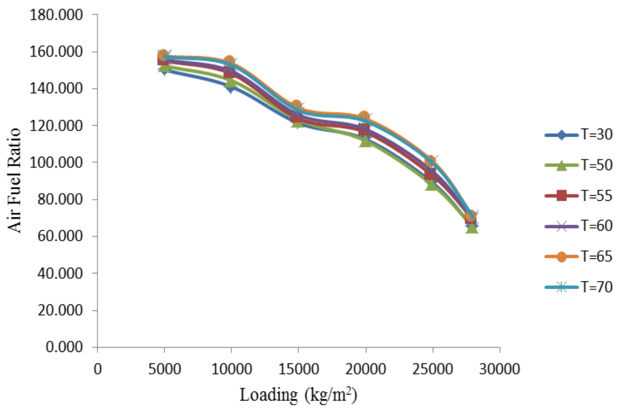

Figure 11: The AFR graph against load

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

$$AFR = \frac{0.01155\ kg/s}{0.000758\ kg/s}$$

$$AFR = 152{,}357$$

The data obtained is then plotted into a graph of the relationship between AFR and load. The graph of the effective power of the shaft against loading can be seen in Figure 11. It can be seen in Figure 11, the greater the load, the AFR value decreases. The value of AFR will be better if the value of the mass flow rate of fuel is smaller. Therefore, to get the best AFR value, that is by getting a large AFR value which decreases with increasing load because the fuel consumption is getting bigger.

In Figure 12 the effect of injection pressure and temperature on the air and fuel ratio where the highest AFR value occurs at a temperature of 65°C. This happens because the fuel temperature reaches 65°C the viscosity of the fuel will decrease resulting in finer granules and the combustion process will be better, then the mass flow rate of the fuel will be small.

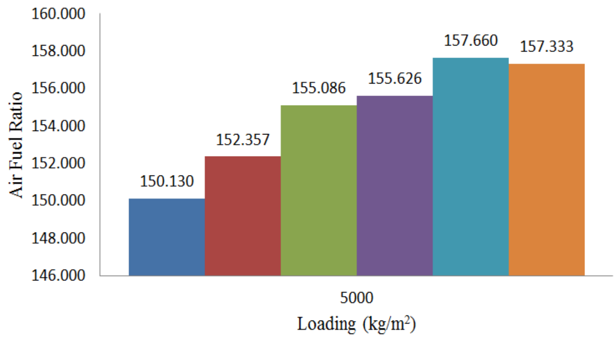

Figure 22: Highest Graph of AFR Against Loading 5,000 kg/m²

4.0 CONCLUSION

Based calculating and analyzing the parameters, the torque value is 51.8299 Nm, and the largest effective power value at a temperature of 60°C is 3.7892 kW at a load of 25,000 kg/m². The largest average effective pressure (BMEP) is 1275,321 N/m². The lowest value of fuel consumption (SFC) is at a temperature of 65oC at a loading of 25,000 kg/m², which is 0.00002291 kg/kJ. For the best thermal efficiency value occurs at a temperature of 65°C with a loading of 25,000 kg/m², which is 92.333%. The highest air and fuel ratio (AFR) occurs at a temperature of 65°C with a loading of 5000 kg/m², which is 157,660.

For the optimal temperature for biodiesel B40 fuel with an injection pressure of 150 bar, namely at a temperature of 65°C where the efficiency value increases with increasing loading and for the SFC value it decreases with increasing load, due to the increase in fuel temperature which causes the viscosity of the fuel to decrease. The sprayed into the combustion chamber, it would be form finer granules where the mixing of fuel and air was more homogeneous, resulting in more complete combustion in the combustion chamber and making fuel consumption more efficient.

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