Vol. 15 No. 1 (2024) 1-9

Jurnal Riset
Teknologi Pencegahan Pencemaran
Industri

Journal homepage: https://www.jrtppi.id

Optimization of Injection Pressure and Fuel Temperature in a Diesel Engine Using Biodiesel B40

Romy*, Suwitno, Yogie Rinaldi Ginting, Zikri Mahendra, Ferdinandus Extranta Sembiring
Department of Mechanical Engineering, Universitas Riau, Pekanbaru, Indonesia

ARTICLE INFO

Article history:
Received November 18, 2023
Received in revised form March 01, 2024
Accepted April 15, 2024
Available online May 31, 2024

Keywords:
Biodiesel
Engine Performance
Temperature
Injection Pressure
Taguchi Method

ABSTRACT

Biodiesel is an alternative fuel substitute for diesel engines produced from vegetable or animal oil through the transesterification reaction process between fatty acid, methanol, and catalyst. However, in its use in diesel engines, there is a decrease in engine performance. This is partly due to the higher viscosity value compared to diesel. Some ways to improve engine performance using biodiesel include adjusting injection pressure and increasing fuel inlet temperature. This study aimed to determine the effect of adding injection pressure and fuel inlet temperature on the performance of diesel engines using B40, such as power, thermal efficiency, sfc, and AFR. This study used a 1-cylinder diesel engine with constant rotation, using five variations of injection pressure 110-150 bar with a 10-bar interval, and five variations of fuel inlet temperature 30˚C-70˚C with a 10˚C intervals, and five loads from 5,000 kg/m^2 to 25,000 kg/m^2 with a 5000 kg/m^2 interval. Testing and data processing were done using the Taguchi method. The results showed that the best diesel engine performance occurred at an injection pressure of 150 bar and a fuel temperature of 60˚C. The predicted performance value achieved under optimal conditions is a power of 2.9 kW at a load of 25000 kg/m^2, thermal efficiency of 69.92% at a load of 25000 kg/m^2, sfc of 3 x10^{-5} kg/kJ at a load of 25000 kg/m^2, and AFR of 169.23 at a load of 5000 kg/m^2. Temperature significantly affects engine performance power, sfc, thermal efficiency, and AFR compared to injection pressure.

1. INTRODUCTION

The Indonesian government's program in the utilization of biofuels started in 2006 with the issuance of Presidential Regulation No. 5/2006 regarding the utilization of biofuels target in 2025 of 5% of the national energy mix. In 2015, the government issued ESDM Regulation No. 12/2015 on mandatory utilization of biofuels, replacing two previous KESDM regulations. As a baseline, the use of biodiesel as a substitute for diesel oil has been considered according to the target mix of biodiesel with diesel oil as stated in ESDM Regulation No. 12/2015, namely 20% for the period 2016-2025 and increased by 30% for 2026-2050. However, in 2019 the government accelerated the use of biodiesel with the implementation of 30% biodiesel (B30) in diesel fuel types starting January 1, 2020. And, the use of this percentage of biodiesel is expected to continue to increase with the use of B40, B50 and so on gradually.

Biodiesel itself has different properties from diesel fuel (diesel), including higher viscosity (Ahmad et al., 2019; Arumugam & Ponnusami, 2019; Keera et al., 2018; Mohadesi et al., 2020), lower calorific value (Pugazhendhi et al., 2020; Rabie et al., 2019; Ramos et al., 2019), more solid contamination (Bondioli et al., 2015; Komariah et al., 2018) and lower cetane number (Keera et al., 2018; Rabie et al., 2019). This biodiesel quality results in a decrease in the performance of diesel engines when using biodiesel fuel, especially if the concentration of biodiesel mixture in diesel is getting higher (Asokan et al., 2019; Buyukkaya, 2010; Dabi & Saha, 2019; Ge et al., 2020) So it is necessary to conduct a study on the use of biodiesel fuel as a gradual diesel mixture, such as testing the use of B40, B50 to B100 fuel by modifying the engine to improve diesel engine performance.

---

*Correspondence author.
E-mail: romy@lecturer.unri.ac.id (Romy)

doi: https://10.21771/jrtppi.2024.v15.no.1.p1-9

Accreditation number: (Ristekdikti) 158/E/KPT/2021

Modifications to diesel engines are one of the efforts that can be made to improve diesel engine performance due to the use of biodiesel fuel mixtures. Among the modifications that can be made to diesel engines to improve performance are adjusting injection pressure (Wang et al., 2020; Yesilyurt, 2019) and fuel temperature (Czechlowski et al., 2020; Geng, 2020; Suardi et al., 2023)

Modification of injection pressure successfully improved the performance of diesel engines using B20 fuel, whereby increasing the injection pressure up to 240 bar produced the best BTE and the smallest exhaust gas emissions from the injection pressure variations of 180, 210 and 240 bar used (Kumar et al., 2019) . Another study used B20, B40 and B100 biodiesel from Roselle Oil, where the injection pressure varied at 180, 200, 220, 240 and 260 bar. As a result, the best performance was produced when using B20 and an injection pressure of 220 bar produced the smallest exhaust gas emissions compared to other variables (Shrivastava & Verma, 2020).

Plotnikov conducted tests using diesel fuel and pre-heating the fuel before injecting it into the combustion chamber. From the test results, it was concluded that pre-heating the fuel shortened the initial phase of the combustion process and moderated the load, thus allowing for an increase in the average effective pressure of the diesel engine and increasing engine output power (Plotnikov et al., 2018). Pre-heated biodiesel would perform better performance and exhaust gas emissions compared to biodiesel without heating (Mohod et al., 2014).

Based on the background description the government will set B40 (40% biodiesel and 60% diesel) as diesel engine fuel in Indonesia, but the use of B40 biodiesel will reduce power and torque. To overcome this, research with the addition of biodiesel and fuel heating is expected to further improve diesel engine performance.

The main problem to be solved with this research is what is the injection time, injection pressure and fuel temperature to be used in biosolar B40 to get maximum performance from the diesel engine. The purpose of this research is to utilize and develop alternative energy sources in diesel engines and to get recommendations for operating conditions that produce the best performance from diesel engines. The operating conditions referred to in this study are injection time, pressure and initial heating temperature of biosolar B40 before entering the combustion chamber. The performance in question includes torque, effective power, fuel consumption and thermal efficiency of braking produced.

2. METHODS

The research method used in this study is an experimental research method. The process of data collection and data analysis is carried out based on the Taguchi Method. This research was conducted to determine the optimum variation of injection pressure, fuel inlet temperature and loading on the performance of diesel engines using B40.

The sketch of the test equipment that was used in this research can be seen in Figure 1.

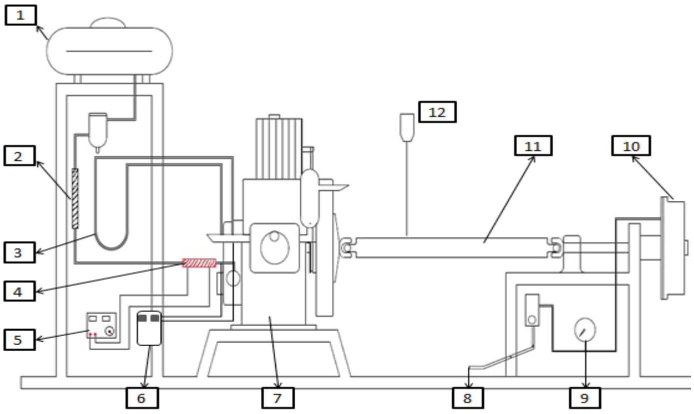

Figure 1. Engine Test Bed

The fuel in the storage tank (1) enters the measuring tube (2) then from the measuring tube, the fuel is heated using a heater (4) where the heater flows with electricity regulated through a power supply (5) then the fuel that has gone through the heater enters the engine (7), the fuel consumption time is measured using a stopwatch while the air enters the engine after passing through a pitot tube that can be measured on a differential manometer (3) and the inlet air temperature and fuel are measured through a thermocouple (6), the load on the engine is done by a drum brake (10) by turning the brake pedal (8) where the pressure given can be seen on the pressure gauge (9), to measure the engine speed using a digital tachometer (12) directed at the shaft (11).

The independent variables in this study are the injection pressure, fuel temperature, and load which are varied.

Table 1. Variables and Levels

No	Variable	Level 1	Level 2	Level 3	Level 4	Level 5
1	Injection pressure (bar)	110	120	130	140	150
2	Fuel temperature (°C)	32	40	50	60	70
3	Load (kg/m^2)	5000	10000	15000	20000	25000

Based on the determined research variables, the number of experiments to be conducted can be determined. Using the Taguchi Method for 3 factors (variables) and 5 levels (levels 1, 2, 3, 4 and 5), the orthogonal matrix used is L25(5^3). And, the results of the orthogonal matrix using the Minitab 19 application can be seen in Table 2.

Table 2. Orthogonal Matrix for Experiments

Experiment	Injection Pressure (bar)	Temperature (°C)	Load (kg/m²)
1	110	32	5000
2	110	40	10000
3	110	50	15000
4	110	60	20000
5	110	70	25000
6	120	32	10000
7	120	40	15000
8	120	50	20000
9	120	60	25000
10	120	70	5000
11	130	32	15000
12	130	40	20000
13	130	50	25000
14	130	60	5000
15	130	70	10000
16	140	32	20000
17	140	40	25000
18	140	50	5000
19	140	60	10000
20	140	70	15000
21	150	32	25000
22	150	40	5000
23	150	50	10000
24	150	60	15000
25	150	70	20000

After obtaining the optimal conditions from the experiment with the orthogonal Array, the S/N ratio of the process for prediction under optimal conditions can be estimated. This is obtained by summing the effects of the highest-ranking factors. The effect of significant factors is their effect on the average experiment. The predicted S/N ratio value under optimal conditions can be calculated with the equation:

$$S/N_{prediction} = \overline{X} + (A_{opt} - \overline{X}) + (B_{opt} - \overline{X}) + \cdots + (n_{opt} - \overline{X}) \quad (1)$$

or

$$S/N_{predictionsi} = (A_{opt} + B_{opt} + \cdots + n_{opt}) - ((n-1)\overline{X}) \quad (2)$$

Where:

$\overline{X}$ = mean factor X

A_{opt} = optimal mean factor A

B_{opt} = optimal mean factor B

n_{opt} = optimal mean factor n

n = number of factors

The S/N ratio is defined as the logarithm of the average square deviation from the target value. The signal-to-noise ratio is a transformation result of several data so that its value represents the quality of variation presentation. The S/N ratio value can be calculated based on the quality characteristics of a response, so the optimum value is the highest S/N ratio value. The characteristics used in this study are two, namely:

a. The bigger the better is used for power parameters, thermal efficiency, and AFR. The use of the calculation of the S/N ratio, the bigger the better means the optimum value chosen is the largest response value, as a result, the larger the value of the data, the larger the S/N ratio value. Where the Y value in Equation 3 is the parameter to be observed, namely power, thermal efficiency, and AFR.

$$S/N = -10 \log(1/Y^2) \quad (3)$$

b. The smaller the better is used for the sfc parameter. The use of the calculation of the S/N ratio, the smaller the better means the optimum value chosen is the smallest response value, as a result, the smaller the value of the data, the larger the S/N ratio value. Where the Y value in Equation 4 is the parameter to be observed, namely sfc.

$$S/N = -10 \log(Y^2) \quad (4)$$

The dependent variable in this study is the value of effective shaft power (Ne), thermal efficiency (η_{th}), specific fuel consumption (sfc), air-fuel ratio (AFR). The controlled variable in this study is the diesel engine compression ratio of 21:1, B40, and idle engine rotation. The mass flow rate of air in the pipe can be measured by a U manometer, which in this study the fluid used is kerosene measured with a density of 800 kg/m³. The v_{air} value is obtained by measuring the inlet air temperature, which is then calculated based on the air stoichiometry table. Using the Bernoulli equation, the airflow velocity is calculated using Equation 5.

$$V_{air} = \sqrt{2g\Delta h\left(\frac{\rho_m}{\rho_{air}} - 1\right)} \quad (5)$$

In the orifice, there is a correction factor which is called the discharge coefficient (cd). The cd value used is 0.716 is a value that has been tested on this measuring instrument. And, the value A is the cross-sectional area of the orifice of 1.256 x 10^{-3} m².

$$\dot{m}_{air} = \rho_{air} \,.\, v_{air} \,.\, A \,.\, cd \quad (6)$$

The mass flow rate of fuel can be calculated using Equation 7. The B40 density used has a value of 853.6 kg/m^3, while t is the time consumption of 1 ml of fuel (V_{fuel}).

$$\dot{m}_{fuel} = \frac{V_{fuel} \cdot \varrho_{fuel}}{t} \quad (7)$$

Torque is a measure of the engine's ability to produce work. In the tests conducted, the rotation of the engine that is channelled from the shaft experiences a braking load with a drum brake. To calculate torque, Equation 8 is used, the value of $\mu = 0.39$, $b = 0.012$ m, $r = 0.125$ m, $\theta 1 = 40^o$, and $\theta 2 = 105^o$ which are data specifications of the drum brake. While P is the braking load given.

$$T = 2. \mu. P. b.r^2. (\text{Cos } \theta 1 - \text{Cos } \theta 2) \quad (8)$$

Effective shaft power is called the power produced net at the engine shaft output. The price of shaft power is expressed in Watts, the equation used to calculate effective shaft power is in Equation 9.

$$Ne = (T.2.\pi.n)/60 \quad (9)$$

The sfc value states how much fuel is used by the engine to produce effective shaft power in (kg/kJ), which also means an indication of engine efficiency in producing fuel combustion power. In the calculation using Equation 10, where $\dot{m}_{fuel}$ has been calculated before, and the effective shaft power has also been obtained in the previous equation. An example of the calculation of sfc is:

$$sfc = \frac{\dot{m}_{fuel}}{Ne} \quad (10)$$

Thermal efficiency is a measure of the utilization of heat energy stored in fuel that is converted into effective shaft power by the engine. For effective thermal efficiency of diesel engines, it is written in Equation 11 and the calorific value is measured using a bomb calorimeter.

$$\eta_{th} = \frac{Ne}{\dot{m}_{fuel} \cdot LHV} \times 100\% \quad (11)$$

The air-fuel ratio is a comparison between the mass of air and fuel at a point of view. AFR is calculated using Equation 12 as follows;

$$AFR = \frac{\dot{m}_{udara}}{\dot{m}_{bb}} \quad (12)$$

3. RESULT AND DISCUSSION

3.1 Shaft Power

With the power value obtained from equation 9, the average shaft power of each variation of injection pressure and fuel temperature can be calculated. Then the data is displayed in a response table as in Table 1:

Table 1. Effective Shaft Power Response Test

Level	Shaft Power (kW)	
	Injection Pressure	**Fuel Temperature**
1	1,849	1,844
2	1,852	1,850
3	1,855	1,856
4	1,858	1,864
5	1,861	1,862
Delta	0,012	0,020
Rank	2	1

From Table 1, the deviation in shaft power from the results of fuel temperature variation is greater than the difference in shaft power from injection pressure variation. Therefore, the factor that has a greater influence on shaft power is the variation in fuel temperature. Next, based on the values obtained in Table 1, a graph can be created as shown in Figure 2:

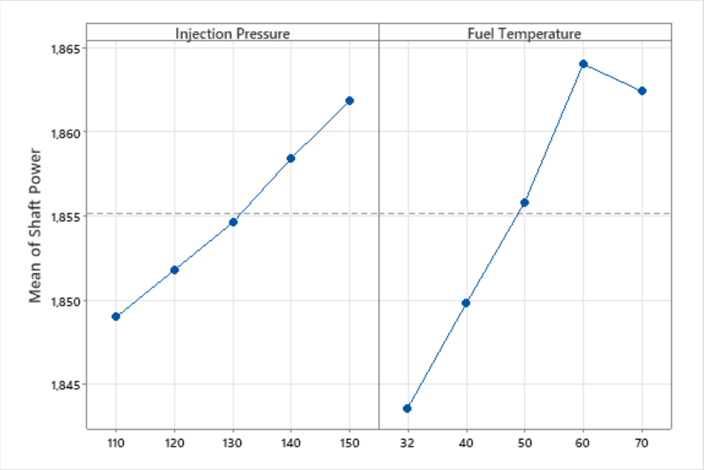

Figure 2. Effect of Injection Pressure and Fuel Inlet Temperature on Average Shaft Power

Figure 2 shows that as the injection pressure increases from 110 bar to 150 bar, the average power value continues to increase. The largest average power value is obtained at an injection pressure of 150 bar. The average power value in temperature variation also increases from 30˚C to 60˚C, but at a temperature of 70˚C there is a decrease in power. So, the maximum power is obtained at a fuel inlet temperature of 60˚C.

Based on the S/N ratio power value obtained from Equation 3, the average S/N ratio value for each level can be obtained in the variation of injection pressure and fuel temperature for the response of the S/N ratio of injection pressure and for the response of the S/N ratio of fuel temperature. The data is then displayed in a response table as in Table 2.

Table 2. Response of S/N Ratio of Shaft Power

Level	Response of S/N Ratio of Shaft Power	
	Injection Pressure	**Fuel Temperature**
1	4,282	4,261
2	4,311	4,321
3	4,352	4,357
4	4,372	4,392
5	4,375	4,361
Delta	0,094	0,131
Rank	2	1

From Table 2, the difference in the S/N ratio from the results of fuel temperature variation is greater than the difference in the S/N ratio from injection pressure variation. Therefore, the factor that has a greater influence on shaft power is the variation in fuel temperature. Next, based on the S/N ratio values obtained in Table 2, a graph can be created as shown in Figure 3.

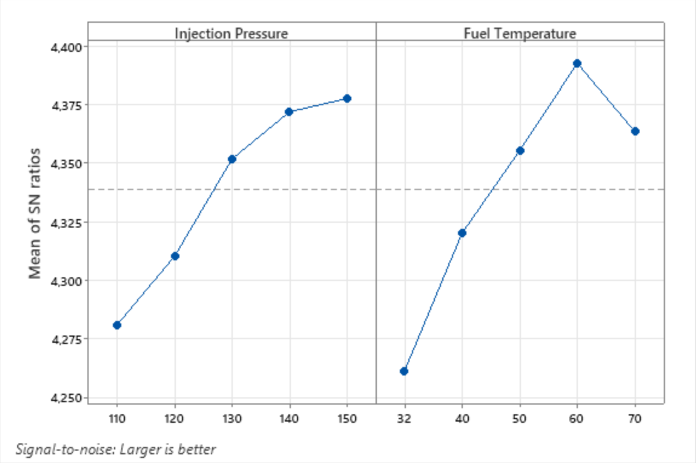

Figure 3. Effect of Pressure and Temperature on the Average Shaft Power S/N Ratio

In Figure 3, as the injection pressure increases from 110 bar to 150 bar, the S/N power ratio continues to increase. The highest value occurs at an injection pressure of 150 bar. The S/N ratio value in temperature variation also increases from 30°C to 60°C, but at a temperature of 70°C there is a decrease. So, the maximum power is obtained at a fuel inlet temperature of 60°C. Based on the S/N ratio, to get the best power is an injection pressure of 150 bar and, fuel inlet temperature of 60°C at a load of 25,000 kg/m².

Based on the effect of injection pressure that can be seen in Figure 2 and Figure 3 where the injection pressure increases from 110 bar to 150 bar, the power continues to increase, the highest power is achieved at an injection pressure of 150 bar. The results obtained are also by the research conducted by Sinaga (Sinaga et al., 2021), who conducted tests with variations in injection pressure from 110 bar to 150 bar, the results obtained that the highest power was achieved at an injection pressure of 150 bar. The increase in effective shaft power of the engine occurs because the greater the injection pressure will make the fuel spray into the combustion chamber finer (Alifuddin., 2020) so that the mixing between air and fuel is better. As a result, combustion in the combustion chamber is more optimal which produces greater combustion heat energy. This heat energy will push the piston and rotate the engine shaft, so the greater the heat energy will add to the effective shaft power of the engine.

The effect of fuel inlet temperature can be seen in Figure 2 and Figure 3 whereas the fuel inlet temperature increases, the effective shaft power increases from a fuel inlet temperature of 30°C to 60°C, but at a temperature of 70°C there is a decrease in power. The highest effective shaft power is achieved at a fuel inlet temperature of 60°C. The increase in power is due to the increase in fuel temperature which will reduce the viscosity and density of the fuel (Murni, 2010). The decrease in viscosity and density will improve the quality of fuel spray in the combustion chamber (Anis et al., 2018), as a result, making combustion more perfect, but the increase is only up to a temperature of 60°C. At a temperature of 70°C there is a decrease in engine performance because the fuel temperature is already approaching the flash point of the fuel. The fuel used is biosolar B40 consisting of 40% Biodiesel and 60% diesel, where the flash point of biodiesel is 100°C and diesel is 80°C. So, the flash point of biosolar B40 is between 80-100°C, if the fuel is heated to 70°C the fuel is already approaching its flash point (Murni, 2010). So, when sprayed into the combustion chamber the fuel immediately burns before mixing with air in the combustion chamber, as a result, the heat energy produced is not maximal.

Based on the effective shaft power S/N ratio value obtained, the best power can be obtained with a variation of injection pressure of 150 bar, fuel inlet temperature of 60°C and a load of 25000 kg/m². Then the prediction of the power value at optimal conditions is made with the data of the average S/N ratio value of effective shaft power in Table 2. Where pressure is factor A, fuel inlet temperature is factor B, and load is factor C. Then with Equation 2, the prediction of the optimum power value is made based on the optimum S/N ratio value:

$$S/N_{prediction} = A_5 + B_4 + C_5 - 2S/N_{mean}$$
$$= 4.375 + 4.392 + 9.156 - 2(4.339)$$
$$= 9.248$$

The prediction of the S/N ratio value at optimum variation is 9.248, and Equation 3 can be used to calculate the optimum power value:

$$S/N = -10 \text{ Log } (1/Y^2)$$
$$9{,}248 = -10 \text{ Log } (1/Y^2)$$
$$Y = \sqrt{1/10^{-0{,}924}}$$
$$Ne = 2{,}9 \text{ kW}$$

Based on the prediction value obtained, the best effective shaft power is obtained at a variation of injection pressure of 150 bar, fuel inlet temperature of 60°C, and a load of 25000 kg/m² with an effective shaft power value of 2.9 kW. The optimum power obtained in the study is greater than the power under standard conditions (injection pressure 110 bar and fuel temperature 32°C), where under standard conditions the largest power generated is 2.65 kW. With a larger optimum power, it indicates better diesel engine performance because there is an increase in power generated.

3.2 Thermal efficiency analysis

Using the same method as in the calculation of effective shaft power, the result has been obtained that the difference in the S/N ratio from fuel temperature variation is greater than the difference in the S/N ratio from injection pressure variation, so the factor that has a greater influence on thermal efficiency is the variation in fuel temperature. Next, based on the values obtained, a graph has been created as shown in Figure 4.

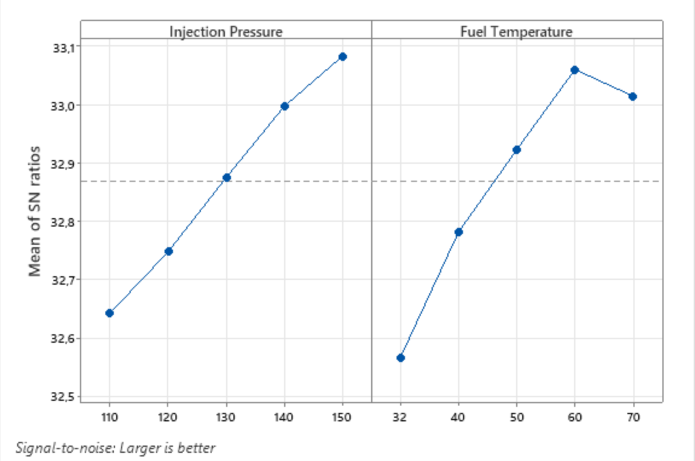

Figure 4. Effect of Pressure and Temperature on the S/N Ratio of Thermal Efficiency

Based on Figure 4, as the injection pressure increases from 110 bar to 150 bar, the S/N ratio of thermal efficiency continues to increase. The highest value occurs at an injection pressure of 150 bar. The average power value in temperature variation also increases from 30°C to 60°C, but at a temperature of 70°C there is a decrease. So, the maximum power is obtained at a fuel inlet temperature of 60°C. Based on the S/N ratio, to get the best thermal efficiency is with an injection pressure of 150 bar, fuel inlet temperature of 60°C and a load of 25,000 kg/m².

$$S/N_{prediction} = A5 + B4 + C5 - 2\ (S/N_{mean})$$
$$= 33.08 + 33.07 + 36.48 - 2(32.87)$$
$$= 36.89$$

The S/N ratio value at optimum variation is 39.89, so Equation 3 can be used to calculate the optimum power value:

$$S/N = -10 \text{ Log } (1/Y^2)$$
$$36.89 = -10 \text{ Log } (1/Y^2)$$
$$Y = \sqrt{1/10^{-3{,}689}}$$
$$\eta_{th} = 69.93\ \%$$

Based on the prediction value obtained, the optimal thermal efficiency is obtained at a variation of injection pressure of 150 bar, fuel inlet temperature of 60°C, and a load of 25000 kg/m² with a value of 69.93%. The optimum efficiency obtained in the study is greater than the power under standard conditions (injection pressure 110 bar and fuel temperature 32°C), where under standard conditions the efficiency produced is 58.02%. The increase in efficiency with increasing injection pressure and fuel temperature indicates better diesel engine performance because there is an increase in efficiency produced.

3.3 sfc analysis

Next, based on the values obtained, a graph can be created as shown in Figure 5.

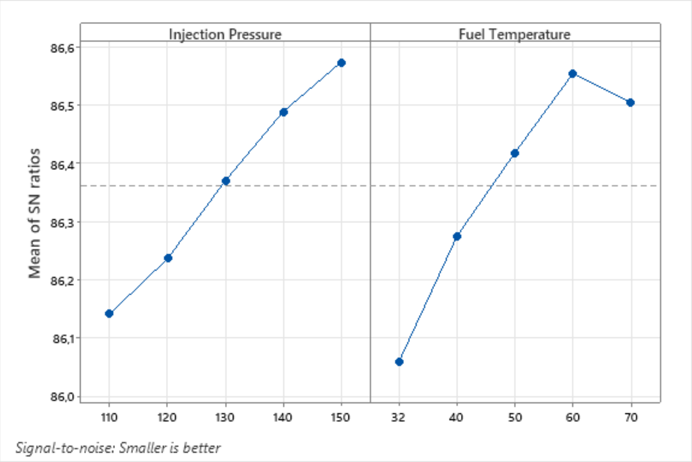

Figure 5. Effect of Injection Pressure and Fuel Inlet Temperature on the S/N Ratio of sfc

Based on Figure 5, as the injection pressure increases from 110 bar to 150 bar, the S/N sfc ratio continues to increase. The highest value occurs at an injection pressure of 150 bar. The average power value in temperature variation also increases from 30°C to 60°C, but at a temperature of 70°C there is a decrease. So, the maximum power is obtained at a fuel inlet temperature of 60°C. Based on the S/N ratio, to get the best sfc is an injection pressure of 150 bar, fuel inlet temperature of 60°C and a load of 25,000 kg/m².

$$S/N_{prediction} = A_5 + B_4 + C_5 – 2(S/N_{mean})$$
$$= 86.59 + 86.56 + 89.98 – 2(86.36)$$
$$= 90.4$$

The S/N ratio value at optimum variation is 90.4, so Equation 4 can be used to calculate the optimum sfc value:

$$S/N = -10 \text{ Log } (Y^2)$$
$$90.4 = -10 \text{ Log } (Y^2)$$
$$Y = \sqrt{10^{-904}}$$
$$sfc = 3.00 \text{ x } 10^{-5} \text{ kg/kJ}$$

So, the best sfc prediction value is obtained at a variation of injection pressure of 150 bar, fuel inlet temperature of 60°C, and a load of 25000 kg/m² with a power value of 3.00 x 10-5 kg/kJ. The sfc value obtained in the study is lower than the sfc under standard conditions (injection pressure 110 bar and fuel temperature 32°C), where under standard conditions the lowest sfc produced is 3.69x10-5 kg/kJ. A decrease in the sfc value, it indicates better diesel engine performance by increasing the injection pressure to 150 bar and the fuel temperature to 60°C because there is a decrease in the sfc value produced.

3.4 AFR analysis

Next, based on the values obtained, a graph has been created as shown in Figure 6.

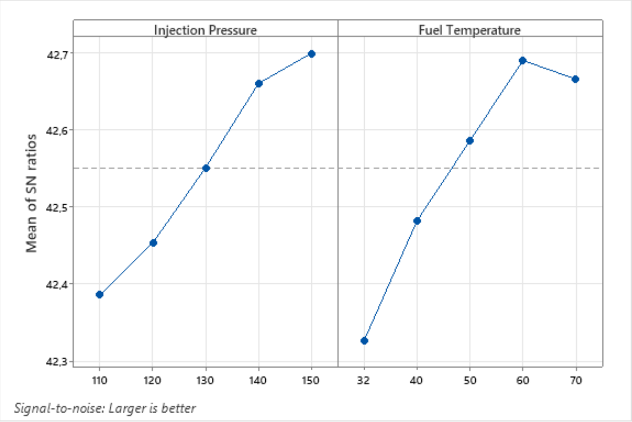

Figure 6. Effect of Injection Pressure and Fuel Inlet Temperature on the S/N Ratio of AFR

Based on Figure 6, as the injection pressure increases, the AFR value will increase so the best AFR is obtained at an injection pressure of 150 bar. For variations in fuel inlet temperature, the AFR value increases from 30°C to 60°C, but at a temperature of 70°C there is a decrease. So, the maximum power is obtained at a fuel inlet temperature of 60°C. Based on the S/N ratio, to get the best AFR is an injection pressure of 150 bar, fuel inlet temperature of 60°C and a load of 25,000 kg/m².

Using Equation 2, the highest AFR value is predicted:

$$S/N_{prediction} = A_5 + B_4 + C_1 – 2\ (S/N)_{mean}$$
$$= 42.7 + 42.69 + 44.28 – 2(42.55)$$
$$= 44.57$$

The S/N ratio value at optimum variation is 44.57, so Equation 3 can be used:

$$S/N = -10 \text{ Log } (1/Y^2)$$
$$44.57 = -10 \text{ Log } (1/Y^2)$$
$$Y = \sqrt{1/10^{-4,457}}$$
$$AFR = 169{,}23$$

Based on the prediction value obtained, the optimal AFR is obtained at a variation of injection pressure of 150 bar, fuel inlet temperature of 60°C, and a load of 5000 kg/m2 with a value of 169.23. The AFR value obtained in the study is greater than the power under standard conditions (injection pressure 110 bar and fuel temperature 32°C), where under standard conditions the AFR produced is 158.24. A larger AFR value indicates better diesel engine performance because the increase in the AFR value indicates that the engine will be more economical because the amount of fuel used in combustion is less or decreases.

4. CONCLUSION

The variable that has a greater impact on the change in engine performance in terms of shaft power, thermal efficiency, sfc, and AFR is fuel temperature. The optimal performance of a diesel engine with B40 biosolar fuel is obtained with a variation of 150 bar injection pressure and 60°C fuel temperature. These findings could be valuable for improving the efficiency and performance of diesel engines using biodiesel fuels.

ACKNOWLEDGEMENT

This research was funded by DIPA LPPM UNIVERSITAS RIAU tahun 2023 dengan Nomor Kontrak: 8266/UN19.5.1.3/AL.04/2023.

REFERENCE

Ahmad, T., Danish, M., Kale, P., Geremew, B., Adeloju, S. B., Nizami, M., & Ayoub, M. (2019). Optimization of process variables for biodiesel production by transesterification of flaxseed oil and produced biodiesel characterizations. *Renewable Energy*, *139*, 1272–1280. https://doi.org/10.1016/j.renene.2019.03.036

Alifuddin, T., Hakim, L., Ilminnafik, N., & ... (2020). Karakteristik Penyemprotan Campuran Diesel-Biodiesel Minyak Nyamplung dan Etanol Dengan Variasi Tekanan Injeksi. In *... Workshop and National ...* (pp. 26–27). Retrieved from https://jurnal.polban.ac.id/proceeding/article/view/2034

Anis, S., Budiandono, G. N., Saputro, D. D., & Zainal, Z. A. (2018). Jurnal Bahan Alam Terbarukan Effect of Biodiesel / Diesel Blend and Temperature on 1-Cylinder Diesel Fuel Injection Pump Performance and Spray Pattern. https://doi.org/10.15294/jbat.v7i2.11891

Arumugam, A., & Ponnusami, V. (2019, February 1). Biodiesel production from Calophyllum inophyllum oil a potential non-edible feedstock: An overview. *Renewable Energy*. Elsevier Ltd. https://doi.org/10.1016/j.renene.2018.07.059

Asokan, M. A., Senthur Prabu, S., Bade, P. K. K., Nekkanti, V. M., & Gutta, S. S. G. (2019). Performance, combustion and emission characteristics of juliflora biodiesel fuelled DI diesel engine. *Energy*, *173*, 883–892. https://doi.org/10.1016/j.energy.2019.02.075

Bondioli, P., Bella, L. Della, Rivolta, G., Faragò, S., Boschi, A., & Beretta, S. (2015). Study of biodiesel solid contaminants by means of Scan Electron Microscosopy (SEM). *Rivista Italiana Delle Sostanze Grasse*, *92*(1), 11–16.

Buyukkaya, E. (2010). Effects of biodiesel on a di diesel engine performance, emission and combustion characteristics. *Fuel*, *89*(10), 3099–3105. https://doi.org/10.1016/j.fuel.2010.05.034

Czechlowski, M., Gracz, W., Marcinkowski, D., & Golimowski, W. (2020). The impact of the temperature of biodiesel from animal fats on nitrogen oxides emissions, *01001*, 1–5.

Dabi, M., & Saha, U. K. (2019, December 1). Application potential of vegetable oils as alternative to diesel fuels in compression ignition engines: A review. *Journal of the Energy Institute*. Elsevier B.V. https://doi.org/10.1016/j.joei.2019.01.003

Ge, J. C., Kim, H. Y., Yoon, S. K., & Choi, N. J. (2020). Optimization of palm oil biodiesel blends and engine operating parameters to improve performance and PM morphology in a common rail direct injection diesel engine. *Fuel*, *260*. https://doi.org/10.1016/j.fuel.2019.116326

Geng, L. (2020). Numerical simulation of the influence of fuel temperature and injection parameters on biodiesel spray characteristics, (July 2019), 312–326. https://doi.org/10.1002/ese3.429

Keera, S. T., El Sabagh, S. M., & Taman, A. R. (2018). Castor oil biodiesel production and optimization. *Egyptian Journal of Petroleum*, *27*(4), 979–984. https://doi.org/10.1016/j.ejpe.2018.02.007

Komariah, L. N., Hadiah, F., Aprianjaya, F., & Nevriadi, F. (2018). Biodiesel effects on fuel filter; Assessment of clogging characteristics. *Journal of Physics: Conference Series*, *1095*(1), 0–10. https://doi.org/10.1088/1742-6596/1095/1/012017

Kumar, S., Dinesha, P., & Rosen, M. A. (2019). Effect of injection pressure on the combustion, performance and emission characteristics of a biodiesel engine with cerium oxide nanoparticle additive. *Energy*, *185*, 1163–1173. https://doi.org/10.1016/j.energy.2019.07.124

Mohadesi, M., Aghel, B., Maleki, M., & Ansari, A. (2020). The use of KOH/Clinoptilolite catalyst in pilot of microreactor for biodiesel production from waste cooking oil. *Fuel*, *263*. https://doi.org/10.1016/j.fuel.2019.116659

Mohod, R, T., Bhansali, S, S., Moghe, S. M., & Kathoke, T. B. (2014). Preheating of Biodiesel for the Improvement of the Performance Characteristics of Di Engine : A Review. *International Journal of Engineering Research and General Science*, *2*(4), 747–753. https://doi.org/10.12691/ajme-6-2-4

Plotnikov, S. A., Kartashevich, A. N., & Buzikov, S. V. (2018). Analysis of pre-heated fuel combustion and heat-emission dynamics in a diesel engine. In *Journal of Physics: Conference Series* (Vol. 944). Institute of Physics Publishing. https://doi.org/10.1088/1742-6596/944/1/012089

Pugazhendhi, A., Alagumalai, A., Mathimani, T., & Atabani, A. E. (2020). Optimization, kinetic and thermodynamic studies on sustainable biodiesel production from waste cooking oil: An Indian perspective. *Fuel*, *273*. https://doi.org/10.1016/j.fuel.2020.117725

Rabie, A. M., Shaban, M., Abukhadra, M. R., Hosny, R., Ahmed, S. A., & Negm, N. A. (2019). Diatomite supported by CaO/MgO nanocomposite as heterogeneous catalyst for biodiesel production from waste cooking oil. *Journal of Molecular Liquids*, *279*, 224–231. https://doi.org/10.1016/j.molliq.2019.01.096

Ramos, M., Dias, A. P. S., Puna, J. F., Gomes, J., & Bordado, J. C. (2019, November 20). Biodiesel production processes and sustainable raw materials. *Energies*. MDPI AG. https://doi.org/10.3390/en12234408

Shrivastava, P., & Verma, T. N. (2020). Effect of fuel injection pressure on the characteristics of CI engine fuelled with biodiesel from Roselle oil. *Fuel*, *265*. https://doi.org/10.1016/j.fuel.2019.117005

Sinaga, W. V., Romy, & Helwani, Z. (2021). Kaji Eksperimental Penggunaan Biosolar B40 Terhadap Unjuk Kerja Mesin Dengan Menggunakan Variasi Tekanan Pengabutan Pada Nosel. *Jom FTEKNIK*, *8*(1), 1–6. Retrieved from https://jom.unri.ac.id/index.php/JOMFTEKNIK/article/view/29352

Suardi, S., Setiawan, W., Nugraha, A. M., Alamsyah, A., & Ikhwani, R. J. (2023). Evaluation of Diesel Engine Performance Using Biodiesel from Cooking Oil Waste (WCO). *Jurnal Riset Teknologi Pencegahan Pencemaran Industri*, *14*(1), 29–39. https://doi.org/10.21771/jrtppi.2023.v14.no1.p29-39

Wang, S., Karthickeyan, V., Sivakumar, E., & Lakshmikandan, M. (2020). Experimental investigation on pumpkin seed oil methyl ester blend in diesel engine with various injection pressure, injection timing and compression ratio. *Fuel*, *264*. https://doi.org/10.1016/j.fuel.2019.116868

Yesilyurt, M. K. (2019). The effects of the fuel injection pressure on the performance and emission characteristics of a diesel engine fuelled with waste cooking oil biodiesel-diesel blends. *Renewable Energy*, *132*, 649–666. https://doi.org/10.1016/j.renene.2018.08.024