

## Effects of bio-oil - diesel blends: the performance and emissions of diesel engines with intake manifold variations

**Farid Majedi\***, Agus Choirul Arifin, Alfi Tranggono Agus Salim, Agus Ma'ruf Prasetya  
Department of Automotive engineering, Faculty of Engineering, Madiun State Polytechnic, Indonesia

### Abstract

Alternative fuels such as vegetable oil, biodiesel, and bio-oil are potential alternatives for diesel engines. Bio-oil is one of the products of the decomposition process of chemical and organic matter by adding heating process without oxygen is called rapid pyrolysis. Bio-oil in the pyrolysis process is made from Brem waste. Brem is a typical food from the district of Madiun, Indonesia. This research is important because the switch from petroleum-sourced fuel to Bio-Oil oil cannot be automatically applied to diesel engines. Spray quality and combustion process, type and quality of fuel, and engine design and condition are some of the important parameters affecting diesel engine performance. Research data is very important because it can determine the intake manifold and the best bio-oil-diesel blends to be used in the operation of diesel engines with bio-oil-diesel blends. The research uses three variations of the intake manifold form. Variations of research with lamp loading of 650, 1300, 1950 and 2600 watts determine specific power and fuel consumption. Use an opacity smoke meter to determine the opacity of diesel engine exhaust gases. The fuel used is pure diesel fuel and Bio-Oil fuel B10, B15, and B20 resulting from the pyrolysis of Brem waste with a fuel volume of 25 ml for each research variable. The results of testing the intake manifold variation and the bio-oil-diesel blended are the intake manifold variation 1 with a fuel mixture variation of 20 % Bio-Oil - 80% pure diesel (B20), which has the best results both electric power, specific fuel consumption and opacity.

### Keywords:

Bio-oil;  
Engine performance;  
Exhaust gas opacity;  
Intake manifolds;

### Article History:

Received: December 14, 2021  
Revised: January 27, 2022  
Accepted: February 13, 2022  
Published: October 5, 2022

### Corresponding Author:

Farid Majedi,  
Department of Automotive  
engineering, Faculty of  
Engineering, Politeknik Negeri  
Madiun, Indonesia  
Email: [farid@pnm.ac.id](mailto:farid@pnm.ac.id)

This is an open access article under the [CC BY-NC](https://creativecommons.org/licenses/by-nc/4.0/) license



### INTRODUCTION

Power and energy are the main research topics in research on petroleum fuels [1, 2, 3]. The energy policy of governments around the world is to develop alternative renewable fuels for internal combustion engines and diesel engines [4] due to the scarcity of petroleum and global warming. Alternative fuels, such as vegetable oil, biodiesel, and bio-oil, are potential alternative fuels for diesel engines [5][6]. Brem waste oil is one of the products of the decomposition process of chemical organic matter by adding a heating process without oxygen is called rapid pyrolysis, where biomass undergoes chemical breakdown

into gas [7, 8, 9]. Biomass in the pyrolysis process is made from Brem waste. Brem is a typical food from the district of Madiun, Indonesia. Brem is produced with the basic ingredients of white/black sticky rice through a stages fermentation process. From the processing of Brem, this will be left behind by the Brem waste that is waste or waste. Brem waste uses fodder, organic fertilizer, bioethanol etc. Waste carbohydrate content Brem 14.7% and protein 9.5% and CO<sub>2</sub> 19.5% [10][11].

One alternative to solve the energy supply problem is the development of Brem waste oil. The fuel is made from vegetable oil converted

into a fuel mixture in diesel oil [12]. This study uses a diesel engine (or compression ignition engine, CI) as a research tool. Diesel oil from crude oil or biodiesel or a mixture of both can be used in CI engines having specific characteristics [13, 14, 15]. The switch from petroleum-sourced fuel to Bio-Oil oil cannot be automatically applied to diesel engines [1]. Spray quality and combustion process [16][17], type and quality of fuel [4, 18, 19, 20, 21], as well as engine design and condition [22], are some of the critical parameters that affect the diesel engine performance. The viscosity of Bio-Oil oil is greater than that of diesel oil, so it is necessary to regulate the supply of sufficient air to create complete combustion in the combustion chamber, influenced by variations in the Intake Manifold. The supply of air to the combustion chamber can also be varied to obtain the right setting with the fuel used [23]

The viscosity of Brem waste oil is thicker than that of diesel oil. For this reason, the research uses three variations of the intake manifold form. Variations of research with lamp loading of 650, 1300, 1950 and 2600 watts determine specific power and fuel consumption. To determine the opacity of diesel engine exhaust gases, use an opacity smoke meter. The fuel used is pure diesel fuel and Brem waste oil fuel B10, B15, and B20 resulting from the pyrolysis of Brem waste with a fuel volume of 25 ml for each research variable.

## MATERIAL AND METHODS

### Material

This study uses pure diesel fuel and bio-oil-diesel blends. bio-oil-diesel blends consist of 10% Brem waste oil + 90% diesel oil (B10), 15% Brem waste oil + 85% diesel oil (B15) and 20% Brem waste oil + 80% diesel oil (B15). This material is used as a test sample. The test material (pure diesel and bio-oil-diesel blends) as much as 25 ml using a variation of the intake manifold was tested on a diesel engine to determine the electric power, Specific Fuel Consumption (SFC) and Opacity (OPC).

### Method

The research was conducted with a Dongfeng S195 diesel engine loaded with a 2600-watt lamp. Some are assembling and installing the load light socket to the diesel engine. The engine speed is set to 1500 rpm, measured by a tachometer. Experiments were carried out experimentally with standard intake

manifolds with B0, B10, B15, and B20; variation of the intake manifold 1 with B0, B10, B15, and B20; Variation of the intake manifold 2 with B0, B10, B15, B20.

The experiment was carried out at a constant engine speed of 1500 rpm with variations in lamp loads of 650, 1300, 1950 and 2600 watts connected to an electric motor that was rotated by the engine. Each variation of injector pressure was tested three times for 5 minutes, and the results were averaged. The measuring cup is used to measure fuel consumption in a certain period and is measured with a stopwatch. Finally, diesel engine gas emissions are calculated by smoke meter opacity. The engine specifications are presented in Table 1.

The experimental setup is presented in Figure 1. In addition, the variations intake manifold tested on a diesel can be seen in Figure 2.

### Analysis

Calculating output power and SFC using (1) and (2). The output power- $P_e$  (Watt) from a single-cylinder engine is calculated using (1).

$$P_e = V \times I \quad (1)$$

Where,  $V$  and  $I$  are the output voltage (Volt) and current (A) generated from the engine. A Comparison of fuel consumption to useful energy is SFC [g/kWh]. To produce 1 kWh of electrical energy obtained from grams of fuel is needed. For the CI engine, it can be calculated using (2) [24]:

$$SFC = \frac{\dot{m} \times 10^3}{P_e} \quad (2)$$

Where  $\dot{m}$  are the mass flow rate of blended diesel-bio-oil (kg/s)

Table 1. The engine specifications

Model	:	S 195
Type	:	4 Strokes
Combustion system	:	Direct Injection
Number of cylinders	:	One cylinder
Diameter x stroke	:	95 x 119 mm
Cylinder volume	:	0,815 L
Compression ratio	:	17:1
Maximum Power	:	9,6941 kW/2200 rpm
Oil Capacity	:	3,5 L
Cooling system	:	Water with hoper
Lubrication system	:	Pressure / splash
Starting system	:	Crank

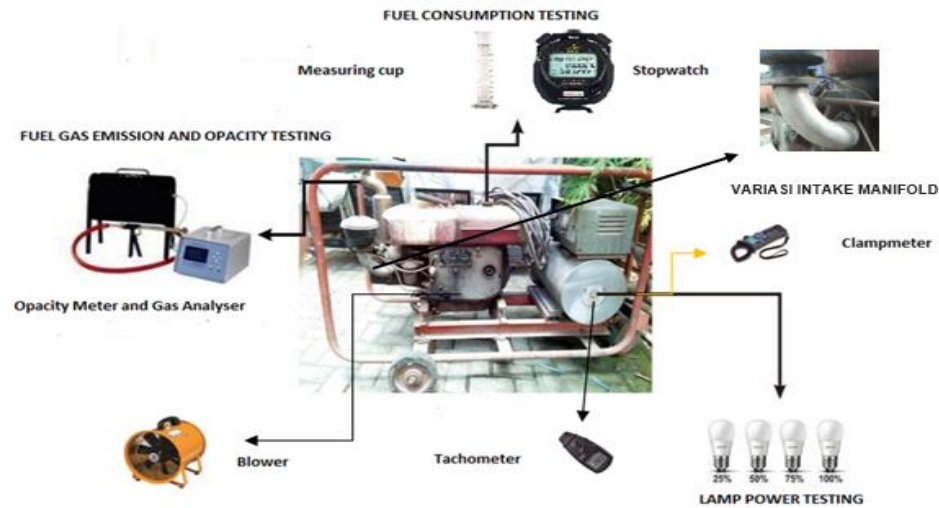


Figure 1. Research apparatus and experiment setup



Intake manifold standart



Intake manifold variations 1



Intake manifold variations 2



Intake manifold variations 3

Figure 2. Variations intake manifold

## RESULTS AND DISCUSSION

### Electrical Power

Figure 3 compares the value of the generator output power produced when the diesel engine uses a standard Intake manifold, variation 1, variation 2, and variation 3.

The maximum electric power generated is 2572 watts, with a fuel mixture variation of 20% bio-oil - 80% pure diesel at 1500 RPM using a standard Intake Manifold. Testing with Intake Manifold variation 1 produces a maximum electric power value of 2555 watts, with a fuel mixture variation of 20% Bio-Oil - 80% pure diesel at 1500 RPM. The maximum value of electric power of 2502 watts is produced using Intake Manifold variation 2, with 100% pure diesel fuel at 1500 RPM. Finally, intake manifold variation 3 produces a maximum electrical power value of 2493 watts, with a fuel mixture variation of 10% Bio-Oil - 90% pure diesel at 1500 RPM.

Figure 3 shows that the maximum electric power value is 2572 watts for variations in the B20 fuel mixture on a standard Intake Manifold with a load lamp of 2600 watts and RPM 1500 for variations in the intake manifold. The maximum electric power value on the intake manifold variation 2 is 2555 watts at the condition of the B20 fuel mixture with a load lamp of 2600 watts and 1500 RPM.

This study increased the value of electric power in all conditions, both pure diesel fuel and bio-oil-diesel, using standard intake manifolds, intake manifold variations 1, intake manifold variations 2, and intake manifold variations 3. The condition follows the general provisions of information that the cause of the generator output power value increasing/decreasing is caused by the size of the load lamp.

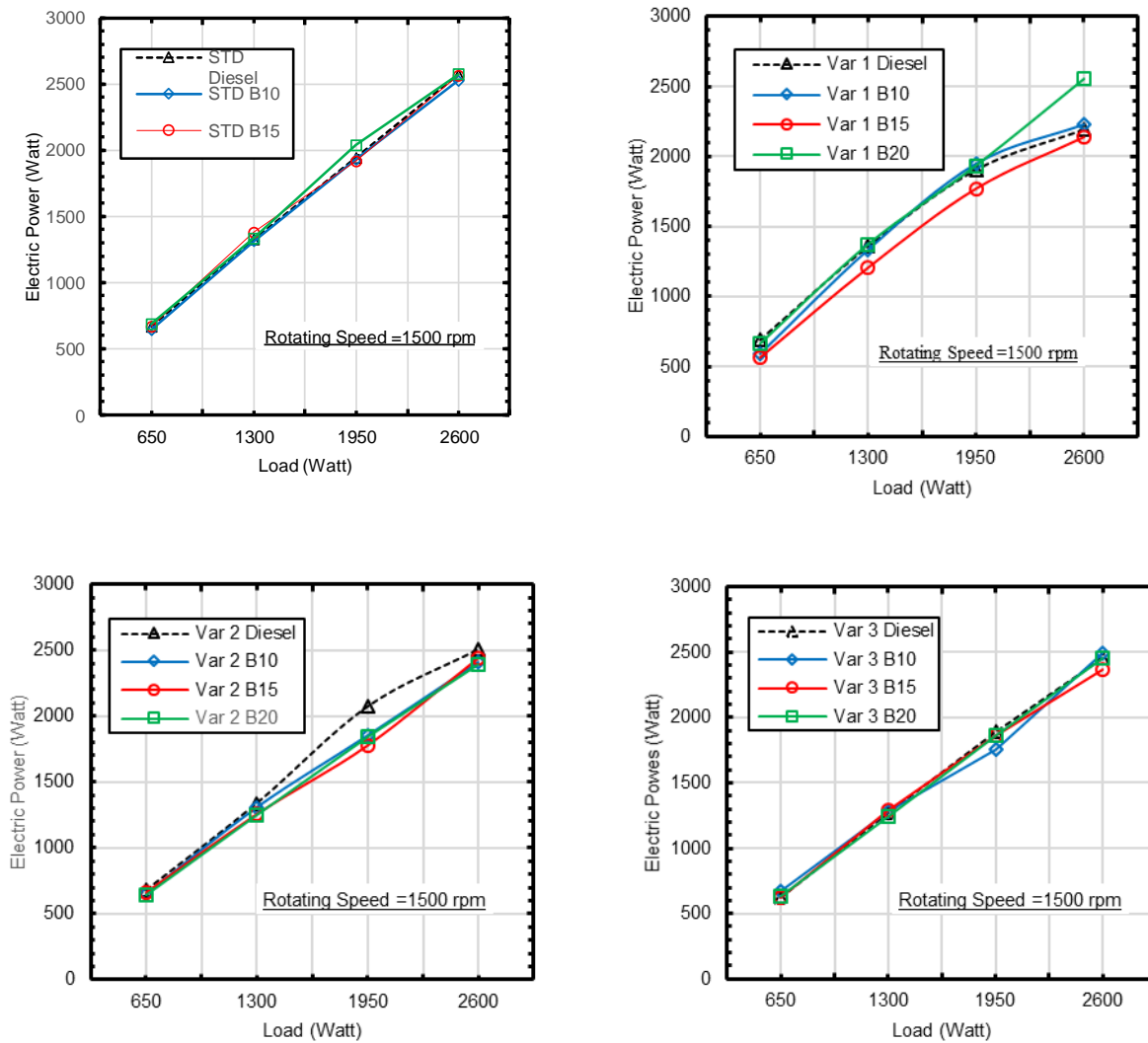


Figure 3 Electrical Power with Variations Intake Manifold

**Specific Fuel Consumption**

Figure 4 compares the SFC values produced when the diesel motor uses the standard intake manifold, variation 1, variation 2, and variation 3.

Tests with a standard intake manifold resulted in a maximum SFC value of 0.262 g/watt on 100% pure diesel fuel at 1500 RPM. In the Intake Manifold variation 1, the maximum SFC value produced is 0.354 g/watt at the condition of the 15% Bio-Oil - 85% pure diesel at 1500 RPM. Tests with Intake Manifold variation 2 resulted in a maximum SFC value of 0,308 g/watt on 15% Bio-Oil -85% pure diesel fuel at 1500 RPM.

In the Intake Manifold variation 1, the maximum SFC value produced is 0.342 g/watt at

the condition of the 10% Bio-Oil - 90% pure diesel at 1500 RPM.

This study decreased the value of specific fuel consumptions in all conditions, pure diesel fuel and bio-oil-diesel, using standard intake manifolds, intake manifold variations 1, intake manifold variations 2, and intake manifold variations 3. The cause of the increase/decrease in the value of specific fuel consumption is the large lamp load. The greater the lamp load on the generator, the more fuel is injected into the combustion chamber to maintain the stability of the diesel engine rotation because when the light load increases, the generator rotation load increases heavy, and the diesel engine speed is reduced.

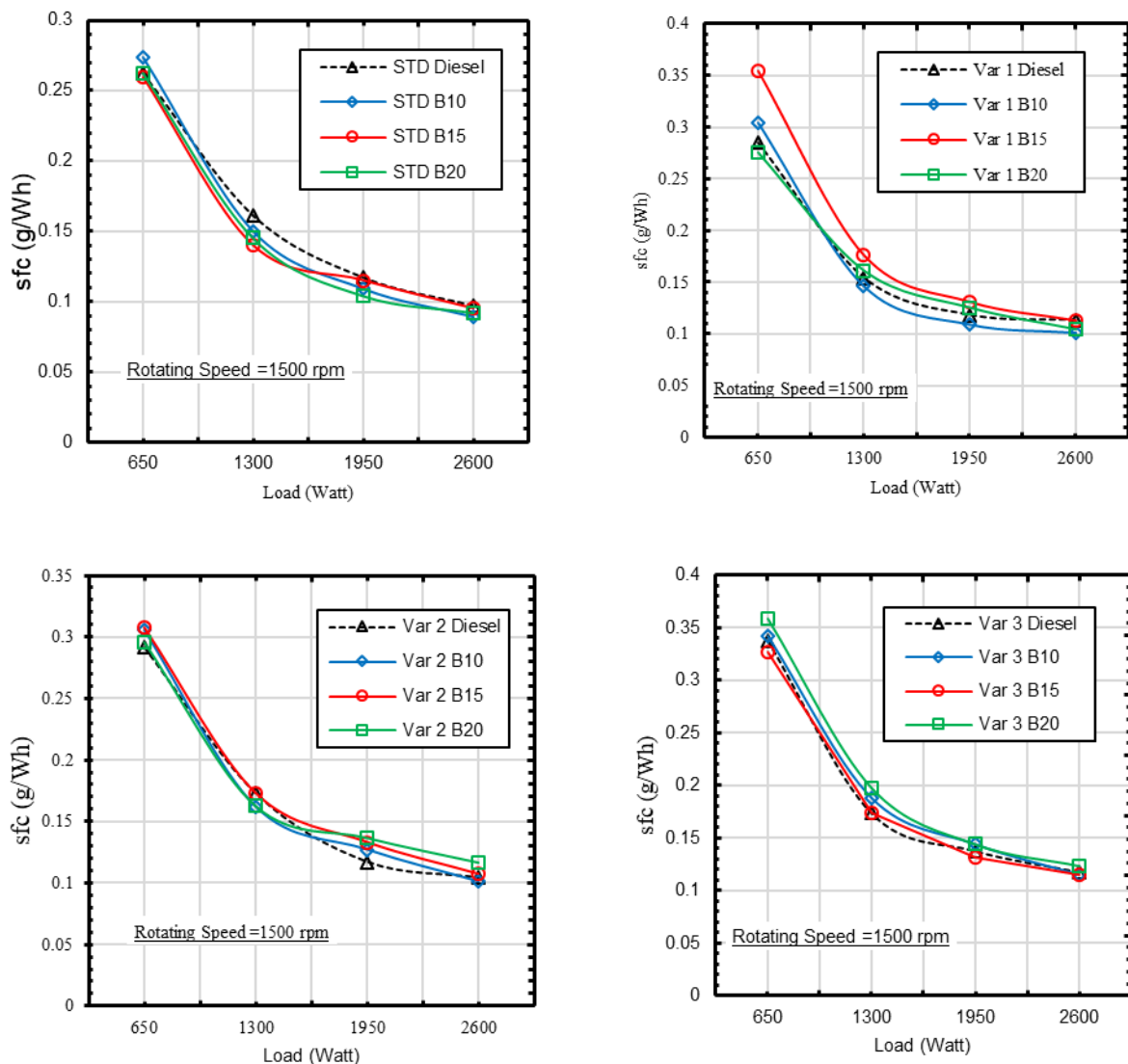


Figure 4. SFC with Variations Intake Manifold

Figure 4 shows the best specific fuel consumption value using a mixture of bio-oil-diesel in the condition using the intake manifold variation 2 with 20% bio-oil - 80% pure diesel. This condition is almost the same as using a standard intake manifold.

### Opacity

Figure 5 compares the exhaust gas opacity values when a diesel motor uses a standard intake manifold, variation 1, variation 2, and variation 3.

Tests with a standard intake manifold resulted in a minimum opacity value of 3,9% on 15% bio-oil -85% pure diesel fuel at 1500 RPM. In the Intake Manifold variation 1, the minimum opacity value produced is 3,6% at the condition

of the 10% Bio-Oil - 90% pure diesel at 1500 RPM.

Tests with Intake Manifold variation 2 resulted in a minimum opacity value of 0,3,1% on 20% Bio-Oil -80% pure diesel fuel at 1500 RPM. In the Intake Manifold variation 1, the minimum opacity value produced is 2,5% at the condition of the 15% Bio-Oil - 85% pure diesel at 1500 RPM.

Figure 5 shows the best opacity value using a mixture of bio-oil-diesel in the condition using the intake manifold variation 2 with 20% bio-oil - 80% pure diesel. This condition is almost the same as using a standard intake manifold and has met Indonesia's normal flue gas opacity value [25].

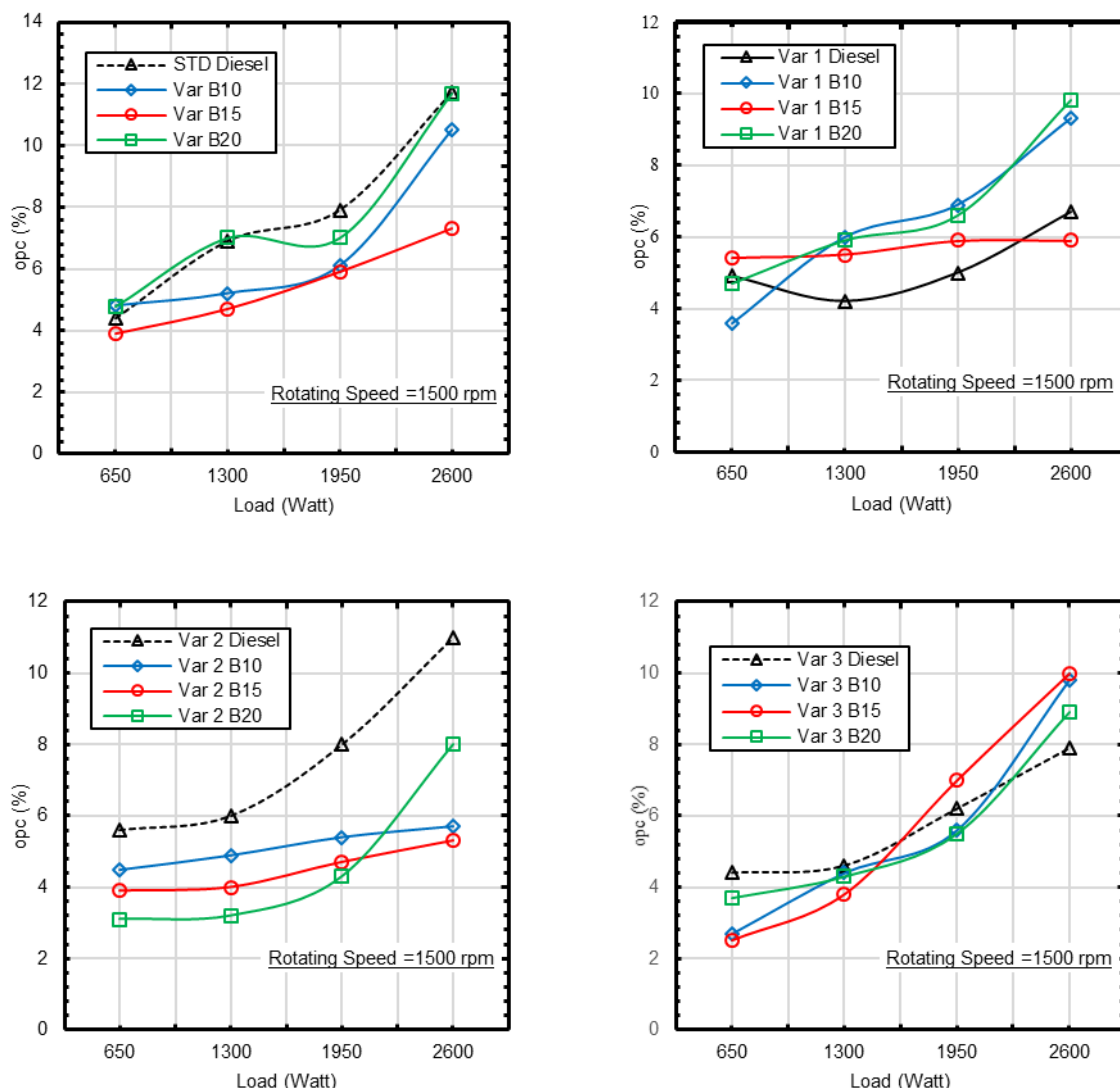


Figure 5. OPC with Variations Intake Manifold

## CONCLUSION

The effect of this study using pure diesel, bio-oil-diesel using standard intake manifolds, intake manifold variations 1, intake manifold variations 2, and intake manifold variations three significantly affect the results of electric power, Specific Fuel Consumption (SFC) and Opacity (OPC). And in this research, the best is taken from electric power, SFC and OPC.

The use of pyrolysis bio-oil mixed directly with pure diesel requires many factors, the shape of the intake manifold is one of the engine designs factors that significantly affect electrical power, SFC and OPC. The research can be continued for further analysis, with several other factors studied deeper.

## REFERENCES

- [1] S. Rajesh, B. M. Kulkarni, N. R. Banapurmath, and S. Kumarappa, "Effect of injection parameters on performance and emission characteristics of a CRDi diesel engine fuelled with acid oil biodiesel-ethanol blended fuels," *Biofuels*, vol. 9, no. 3, pp. 353–367, 2018, doi: 10.1080/17597269.2016.1271628.
- [2] M. M. Shivashimpi, N. R. Banapurmath, S. A. Alur, and S. V. Khandal, "Effect of Injection Parameters: Injection Timing and Injection Pressure on the Performance of Diesel Engine Fueled with Palm Oil Methyl Ester," *European Journal of Sustainable Development Research*, vol. 3, no. 2, pp. 1–

- 17, 2019, doi: 10.20897/ejosdr/3918
- [3] H. Ambarita, "Performance and emission characteristics of a small diesel engine run in dual-fuel (diesel-biogas) mode," *Case Studies in Thermal Engineering*, vol. 10, pp. 179–191, 2017, doi: 10.1016/j.csite.2017.06.003.
- [4] A. Aziz and Z. Fahmi, "Recondition injector nozzle and its pressure effect on performance parameters of diesel engine Komatsu types SAA12V140E-1," *SINERGI*, Vol. 26, No. 2, pp. 165-172, 2022, doi:10.22441/sinergi.2022.2.005.
- [5] E. K. Karadia and E. A. Nayyar, "Effects of Ethanol-Gasoline blends on Performance and Emissions of Gasoline Engines," *International Research Journal of Engineering and Technology*, vol. 4, no. 1, pp. 1092–1100, 2017
- [6] J. Sriyanto et al., "Effects of Fuel Injection Pressure to Fuel Consumption and Exhaust Gas Emissions of SI Engine," *Journal of Physics: Conference Series*, pp. 1-7, 2019, doi: 10.1088/1742-6596/1273/1/012074.
- [7] V. G. Kamaltdinov, V. A. Markov, I. O. Lysov, A. A. Zherdev, and V. V. Furman, "Experimental studies of fuel injection in a diesel engine with an inclined injector," *Energies*, vol. 12, no. 14, 2019, doi: 10.3390/en12142643.
- [8] A. Afzal et al., "Thermal Performance of Compression Ignition Engine Using High Content Biodiesels: A Comparative Study with Diesel Fuel," *Sustainability*, vol. 13, no. 14, 2021, doi: 10.3390/su13147688
- [9] E. Munarwan and F. Majedi, "Karakteristik Bio-Oil Hasil Pirolisis Limbah Brem Dengan Variasi Temperatur," *Jurnal Teknol. Terpadu (JTT)*, vol. 7, no. 1, pp. 23–28, 2019, doi: 10.32487/jtt.v7i1.552.
- [10] F. Majedi, F. Susanto, and E. Munarwan, "Perubahan kuantitas dan nilai kalor char dengan variasi temperatur pada pirolisis limbah Brem," *Jurnal Teknologi*, vol. 11, no. 2, pp. 91–96, 2019.
- [11] P. V. Rao and D. P. Chary, "Characteristics comparison of Biodiesel-Diesel Blend (B20) Fuel with Alcohol Additives," *International Journal of Advance Engineering Research and Science*, vol. 5, no. 8, pp. 128–132, 2018, doi: 10.22161/ijaers.5.8.17
- [12] R. Jachryandestama, P. Nursetyowati, Sirin F., Bani P., "Risk Analysis In Jakarta's Waste Cooking Oil To Biodiesel Green Supply Chain Using Group Ahp Approach," *SINERGI*, vol. 25, no. 2, pp. 227-236, 2021, doi: 10.22441/sinergi.2021.2.014
- [13] F. Majedi, D. Setiyaningrum, S. M. T. Hidayatullah, and A. Abbas, "Effects of Injection Pressure on Output Power, BTE, SFC and Opacity in a Typical Single-Cylinder Diesel Engine," *Automotive Experience*, vol. 3, no. 1, pp. 20–26, 2020, doi: 10.31603/ae.v3i1.3006
- [14] D. Ayu, R. Aulyana, E. W. Astuti, K. Kusmiyati, and N. Hidayati, "Catalytic Transesterification of Used Cooking Oil to Biodiesel: Effect of Oil-Methanol Molar Ratio and Reaction Time," *Automotive Experience*, vol. 2, no. 3, pp. 73–77, 2019, doi: https://doi.org/10.31603/ae.v2i3.2991
- [15] Y. Tang et al., "Study of Visualization Experiment on the Influence of Injector Nozzle Diameter on Diesel Engine Spray Ignition and Combustion Characteristics," *Energies*, vol. 13, pp. 1-18, 5337, 2020, doi: 10.3390/en13205337
- [16] A. R. Andsaler, A. Khalid, N. S. A. Abdullah, A. Sapit, and N. Jaat, "The effect of nozzle diameter, injection pressure and ambient temperature on spray characteristics in diesel engine," *Journal of Physics: Conference Series*, vol. 822, no. 1, pp. 1–7, 2017, doi: 10.1088/1742-6596/755/1/011001.
- [17] M. Y. Lee, G. S. Lee, C. J. Kim, J. H. Seo, and K. H. Kim, "Macroscopic and microscopic spray characteristics of diesel and gasoline in a constant volume chamber," *Energies*, vol. 11, no. 8, 2018, doi: 10.3390/en11082056.
- [18] N. Kumar and Sidharth, "Performance and Emission Characteristics of Ternary Fuel Blends in Diesel Engines," *Journal of Physics: Conference Series*, vol. 1240, no. 1, 2019, doi: 10.1088/1742-6596/1240/1/012095.
- [19] H. K. Patel and S. Kumar, "A Critical Study on Performance of Diesel Engine using mixture of Diesel and Bio-Diesel as a Working Fuel and Influence of Aluminum Oxide Nanoparticle Additive-A Review," *Research Journal of Engineering and Technology*, vol. 8, no. 3, p. 295, 2017, doi: 10.5958/2321-581x.2017.00050.2.
- [20] Y. P. Asmara, "Simulation of CO2 Corrosion of Carbon Steel in High Pressure and High Temperature Environment (HPHT)," *Journal of Integrated and Advanced Engineering (JIAE)*, vol. 2, no. 1, pp. 63-70, 2022, doi: 10.51662/jiae.v2i1.41
- [21] T. C. Zannis, R. G. Papagiannakis, E. G. Pariotis, and M. I. Kourampas, "Experimental study of di diesel engine operational and environmental behavior using blends of city diesel with glycol ethers

- and RME," *Energies*, vol. 12, no. 8, 2019, doi: 10.3390/en12081547.
- [22] X. Zhu et al., "High-Speed Imaging of Spray Formation and Combustion in an Optical Engine: Effects of Injector Aging and TPGME as a Fuel Additive," *Energies*, vol. 13, pp. 1-26, 3105, 2020, doi: 10.3390/en13123105
- [23] J. Monieta and L. Kasyk, "Optimization of Design and Technology of Injector Nozzles in Terms of Minimizing Energy Losses on Friction in Compression Ignition Engines," *Applied Sciences*, vol. 11, no. 6, p. 1–16,7341, 2021, doi: 0.3390/app11167341
- [24] H. Ambarita, "Performance and emission characteristics of a small diesel engine run in dual-fuel (diesel-biogas) mode," *Case Studies in Thermal Engineering*, vol. 10, no. February 2017, pp. 179–191, 2017, doi: 10.1016/j.csite.2017.06.003.
- [25] NN, "Peraturan Menteri (Permen) LHK No. 20/Setjen/Kum.1/3/2017 tanggal 10 Maret 2017 tentang Baku Mutu Emisi Gas Buang Kendaraan Bermotor Tipe Baru Kategori M, N, dan O.," *Ministry of Environment and Forestry*, 2017.