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Research Article

Performance of a Single Cylinder Diesel Engine Fueled by 40% Biodiesel Blend with Excess Air System

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Abstract

In recent years, advances in science and technology have changed human lifestyles and increased global energy consumption. The global innovative search for alternative fuels from renewable sources such as biomass has become important, such as biodiesel. The use of biodiesel in diesel engines requires changes in air supply. Proper air supply is needed to obtain optimal engine performance. The purpose of this study was to determine the effect of using an excess air system on engine performance and exhaust emissions in diesel engines with a mixture of dexlite and biodiesel fuels. The research method used is experimental research and the parameters in this study include the use of an excess air system of 10 L / m, 20 L / m and a load of 300, 400, 500 Watt with biodiesel fuel (B40). The results of this study with the presence of an excess air system can increase combustion efficiency, thus increasing engine engine powerand torque with the most efficient engine power and torque, namely 4.87 KW at a load of 500 watts and 3.101 Nm at a load of 500 watts with excess air of 20 L/m. Fuel consumption also decreases with the presence of an excess air system at 10 L/m load 300 with a value of 0.16 kg/hour. The excess air system can also reduce CO and HC exhaust emissions with excess air of 20 L/m and a load of 300 watts, namely a CO value of 0.02%, an HC value of 18.2 ppm. So the use of excess air is effective in improving engine performance and emissions.

Keywords: *Excess Air, Biodiesel, Diesel Engine, Engine Performance, Emissions.*

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INTRODUCTION

In recent years advances in science and technology have changed human lifestyles and increased global energy consumption. The increasing demand for fossil fuels has led to the rapid depletion of conventional fossil fuel reserves[1]. This also increases the greenhouse gas content in the atmosphere due to the burning of fossil fuels, which poses serious concerns for the ecosystem. The global innovative search for alternative fuels from renewable sources such as biomass has become important[2]. Fossil fuels such as coal, gas and crude oil are the world's main energy sources [3]. This dependence on fossil fuels has caused environmental problems such as air pollution and climate change. The negative impacts of air pollution, which have an impact on human health and socio-economic costs, have encouraged researchers to look for the potential of replacing fossil fuels with renewable energy [4].

Biodiesel is an alternative fuel produced from renewable resources, such as vegetable oil or animal fat. Biodiesel is similar to conventional diesel fuel (petrodiesel) and can be used as a substitute or fuel mixture in diesel engines without requiring significant engine modifications. Blends of biodiesel and conventional diesel produce similar or slightly lower engine power than pure diesel. The lower heating value of biodiesel increases fuel consumption, resulting in higher SFC at higher blends [5]. Biodiesel is environmentally friendly because it reduces greenhouse gas emissions compared to fossil fuels, thus helping reduce pollution and the impact of climate change. In addition, biodiesel is a renewable energy source derived from renewable raw materials, such as vegetable oil and waste oil, which contributes to reducing dependence on fossil fuels[6]. The use of biodiesel has a significant influence on engine performance and emissions. Biodiesel can affect power, torque and exhaust emissions such as CO and HC[7]. The use of biodiesel can reduce exhaust emissions compared to conventional diesel, and has the potential to increase engine efficiency[8]. However, these effects can vary depending on the operational conditions of the machine, the type of biodiesel used, and the biodiesel production process itself[9]. In this context, the aim of adding biodiesel mixtures is one of the promising alternatives that has the potential to replace conventional fuel [10]. The weakness in previous research is that it is still not optimal for improving engine performance because the compression pressure in the combustion chamber is still standard and there has been no increase. One way to increase it is by adding air intake (Excess Air).

Previous researchers increased air pressure in the intake manifold using a turbocharger to increase the volume of air entering the combustion chamber[11]. The addition of a turbocharger system not only improves diesel engine performance, but also fuel efficiency, reduces emissions, and provides benefits in other aspects such as engine responsiveness and reliability[12]. The combustion process in a diesel engine is influenced by air temperature and volume, fuel composition, and turbulence in the combustion chamber [13]. The increased air pressure produced by the turbocharger also increases the temperature of the incoming air in the intake manifold, so that the temperature in the combustion chamber increases[14]. This decrease in temperature makes the air molecules denser so that the volume of air entering the combustion chamber increases and the temperature in the combustion chamber decreases. However, lowering the engine temperature can reduce performance because combustion is less than optimal, which affects the engine power produced. In addition, at low temperatures, the engine may have difficulty maintaining consistent performance, especially under high loads or rapid acceleration. Although harmful emissions can be reduced, the effectiveness of the emission control system can also be affected, affecting the overall performance of the system. [15]. The aim of previous research was to analyze the effect of different turbocharger pressure ratios on diesel engine performance using Diesel-RK software. The diesel engine studied is the 4D56 2.5L type which uses a single turbocharger with a maximum engine power of 136 PS at 4000 rpm, and a maximum torque of 324 Nm at 2000 rpm so that it can increase engine performance optimally [16].

The aim of this research is to determine the effect of adding excess air on engine performance and exhaust emissions in diesel engines fueled by a mixture of dexlite and biodiesel.

METHODS AND ANALYSIS

The research method used is experimental research, namely conducting direct observations to determine the causal relationship with one or more treatment groups. The air pressure produced by an electric blower is lower than a turbocharger, but with the addition of an electric blower to a diesel engine, it is hoped that it can solve the problem of compression failure caused by wear and tear that occurs in engines, with long operating levels like the MDX type diesel engine. -170 F which is used as a medium for this research. Test machine specifications can be seen in Table 1.

Table 1. Specifications for the MDX-170F Diesel Engine

Specification	Detail
Model	Matsumoto MDX 170 F
Machine Type	Diesel, 4 Stroke, Direct Injection
Cylinder Capacity	418 cc
Diameter x Step	85 mm x 66 mm
Maximum Power	7 HP / 3600 rpm
Cooling System	Air Conditioning
System Start	Manual (Rope Pull)
Tank Capacity	3,5 Liter
Lubrication System	Penangan Pompa Oli
Oil Capacity	1,65 Liter
Machine Weight	45 Kg
Machine Dimensions	490 mm x 425 mm x 510 mm
Fuel Consumption	275 g/kWh
Maximum Torque	16 Nm / 2500 rpm
Application	Generator, Air Pump, Heavy Equipment

Table 2. Composition of fuel mixtures

No	Fuel	Presentation
1	D60B40	Dexlite 60% + Biodiesel 40%

Table 3. Research Variables

Independent Variable	Dependent Variable
Excess Air: 10 and 20 L/m	Torque, Power, Exhaust Emissions
Load: 300, 400, 500 Watts	

Table 4. Dexlite Fuel Specifications

Parameter	Specification	Unit
Cetane Number	Min. 51	-
Sulfur Content	Max. 1,200	ppm
Density at 15°C	820 - 860	kg/m^3
Viscosity at 40°C	2.0 - 4.5	cSt
Flash Point	Min. 52	°C
Distillation (T90)	Max. 370	°C
Air Content	Max. 200	ppm
Ash Content	Max. 0.01	% mass
Carbon Residue	Max. 0.05	% mass

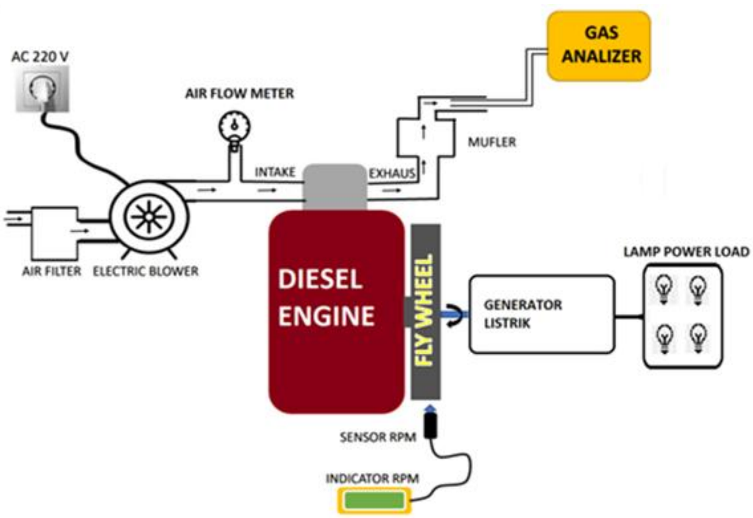

Figure 1. Test Equipment Scheme

Table 5. Electric Blower Specifications

Spesifikasi	**Detail**
Motor Type	Electric Motor (AC)
Power	500 Watt - 2000 Watt
Voltage	220-240V / 50-60Hz
Rotation Speed	2000 - 5000 rpm
Air Capacity	1.5 m^3/min - 5.0 m^3/min

The fuel used in this research was a mixture of 60% dexlite and 40% biodiesel (B40), the composition of the fuel mixture can be seen in Table 2. The variables used in this research are the independent variable and the dependent variable which includes the excess air system and load, both of which have a role that can be controlled according to the variations tested, with the variable of added air in L/m units in this study does refer to the excess air system. Because this study wants to know how variations in the amount of excess air added can affect performance and exhaust emissions. The variables can be seen in Table 3.

The test engine specifications can be seen in Figure 1, namely that there is an additional electric blower before the intake manifold and an electric generator to measure the engine power torque of the diesel engine.

Torque

Torque is a measure of a machine's ability to produce work. Torque is obtained from the product of the tangential force and the arm. Engine torque functions to overcome obstacles while driving. Moment/torque is calculated using the following equation (1):

$$T = m \times g \times l \quad (1)$$

Where T is engine torque (N.m), m is weight (kg), g is earth's gravitational force (m/s^2), and l is torque moment arm length (m).

Power

Engine power can be measured using a dynamometer or electric generator and calculated using the following equation formula (2):

$$Ne = \frac{2\pi NT}{60} \quad (2)$$

Where Ne is engine power (W), N is engine speed (rpm), and T is engine torque (Nm).

Fuel Consumption

When a machine operates, it produces mechanical power. To produce mechanical power, fuel is needed which can provide engine power in the machine. Fuel consumption is the fuel requirements used by the engine during the combustion process. To determine fuel consumption, the following equation (3) is used:

$$SFC = \frac{mf}{ne}$$

$$mf = \frac{v\ x\ p\ fuel}{t} \quad (3)$$

Where *SFC* is Specific fuel consumption (kg/jam.KW), *mf* is amount of fuel per unit time (kg/jam), *v* is volume of fuel used, *p* is specific gravity of the fuel used, *t* is Time required for fuel consumption, and *ne* is engine powergenerated (Kw).

Exhaust Gas Emissions

Exhaust gas emissions are dangerous compounds produced when fuel does not burn completely, therefore it can be said that exhaust gas emissions are exhaust gas from incomplete combustion in motorized vehicles. For emission testing, use a gas analyzer.

RESULTS AND DISCUSSIONS

The results of this research provide a deeper understanding of the effect of adding biodiesel to dexlite fuel on engine performance. Variations in the amount of excess air and engine speed indicate that there is a complex interaction between various variables that influence engine performance. These findings have important implications in the development of alternative fuels and optimization of engine performance.

Engine power

Figure 2 shows the relationship between load (watts) and engine power produced from several excess air systems by using the calculation formula equation 2. The higher the load, the resulting engine power tends to increase, especially at the load (500 Watts), this shows an increase in combustion efficiency. The excess air system also has an effect, where increasing excess air can increase power. Engine power increases as the load increases, in accordance with the working principle of an internal combustion engine, where faster piston movement burns more of the fuel mixture. Comparisons between loads show that B40 blends typically produce higher engine power at a given load, indicating a benefit from the addition of biodiesel. Variations in excess air in the B40 mixture can increase as the load increases as seen in the figure. The highest engine power is 4.87 KW at a load of 500 watts and excess air is 20 L/m and the lowest is 2.65 KW at a load of 300 watts and excess air 0 L/m. In the graph in Figure 2, the addition of biodiesel is not optimal for engine performance, but proper adjustment of the load and excess air is very important to achieve optimal performance. The engine power test results in this research are in accordance with research of Kusuma [17], who reported that a higher load can increase engine power due to a faster combustion process.

Torque

The results of this research show a torque graph that presents the relationship between the amount of excess air, the load of the lamp, and the amount of torque produced by using the calculation formula equation 1. The more air given to the combustion process, the greater the torque produced. In the graph in Figure 3, a 300 watt load with excess air of 0 L/m obtains a torque of 1.69 Nm. The more air supply that enters, the torque value increases. The highest torque value is 3,101 Nm at a load of 500 rpm with excess air of 20 L/m. Increasing excess air can increase torque at low and high loads with the B40 mixture proven to increase engine torque performance. The torque test results in this study are in accordance with research of Warkhade [18], which states that the addition of biodiesel increases torque, but there is an optimal point at each rpm and torque increases with the addition of excess air.

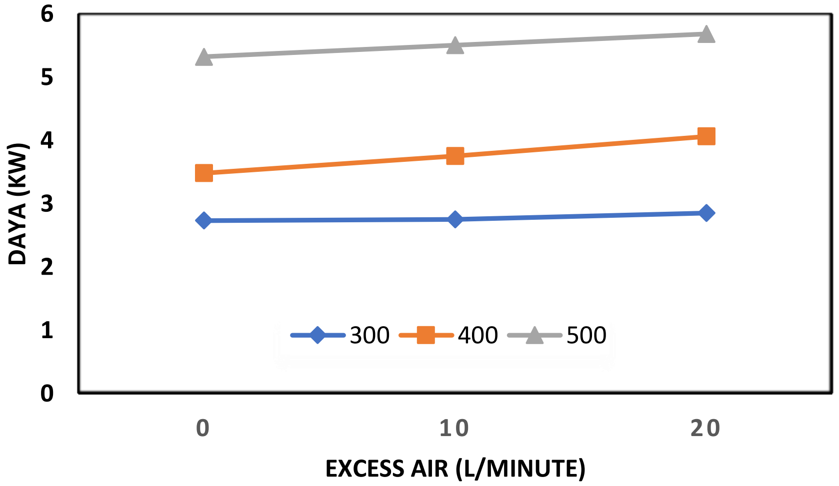

Figure 2. Effect of Excess Air on Engine power with Biodiesel Fuel (B40)

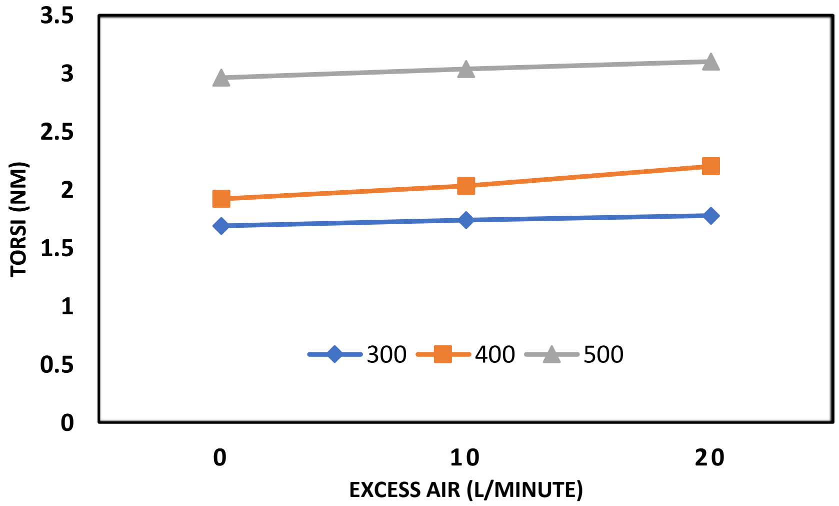

Figure 3. Effect of Excess Air on Torque with Biodiesel Fuel (B40)

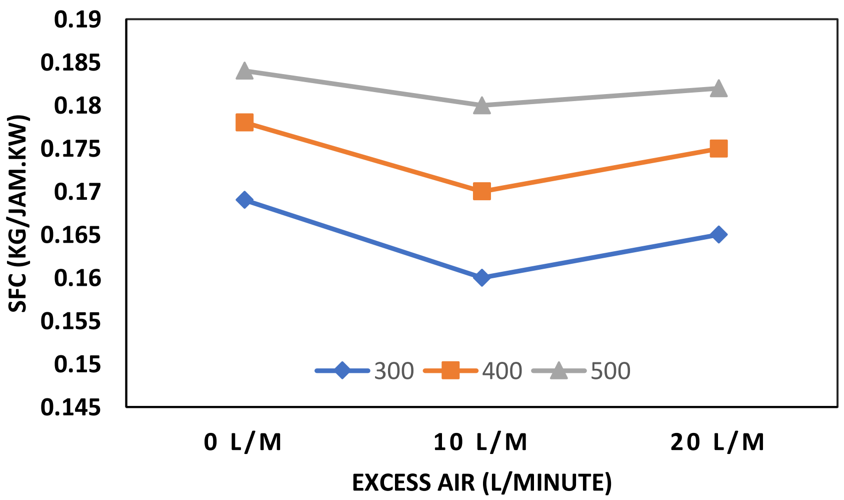

Figure 4. Effect of Excess Air on Fuel Consumption with Biodiesel Fuel (B40)

Fuel Consumption

It can be seen in the graph in Figure 4 that the SFC value increases with increasing load (W) by using the calculation formula equation 3, this fuel has the highest SFC, namely at excess air 0 L/m, load of 500 with a value of 0.184 kg/hour.kW, the lowest value is at excess air 10 L/m load 300 with a value of 0.16 kg/hour.kW. This result is in accordance with research that fuel with a high calorific value and low viscosity can increase the oxidation rate in the combustion process. A low BSFC value at full load indicates better engine performance. The smaller the BSFC value, the more effective the use of fuel energy to produce better production and engine performance. Apart from that, the excess air system also has an effect, where increasing excess air generally increases engine powerup to a certain point, although excess air can reduce efficiency [19].

Emission

The loads used for CO measurements are 300, 400 and 500 Watts by looking at the results from the gas analyzer. This causes an increase in engine load, so that the fuel mixture ratio becomes richer, as per the results of research conducted by Gad [20]. The addition of an electric blower can also reduce CO. The use of electric blowers can also affect carbon monoxide (CO) and hydrocarbon (HC) emissions in some cases [21]. In the graph in Figure 5, the fuel with the highest CO content is 0.06% at a load of 500 watts with excess air of 0 L/m, the lowest CO value is 0.02% at a load of 300 watts with excess air of 20 L/m. Biodiesel has an oxidation rate. which is better than diesel oil, burning biodiesel produces a lot of CO compounds because biodiesel contains oxygen and this process can help minimize CO emissions. then a mixture of B40 fuel and the addition of excess air of 20 L/m will be better for reducing CO.

HC emissions for each fuel show different results, but each change in engine speed shows the same trend line. This result is the same as Hariyadi & Jelita's research [16]. In the graph in Figure 6, B40 fuel with excess air of 0 L/m produces the highest HC emissions, namely 21.5 ppm at a load of 500 watts. The addition of excess air of 20 L/m shows a reduction in HC emissions. The lowest HC emissions were obtained at excess air of 20 L/m with a load of 300 watts, namely 18.2 ppm. This is because adding air will increase compression in the combustion chamber. The addition of biodiesel also changes the stoichiometry of the fuel mixture so that in this study D60B40 fuel with the addition of excess air produced lower HC emissions [22].

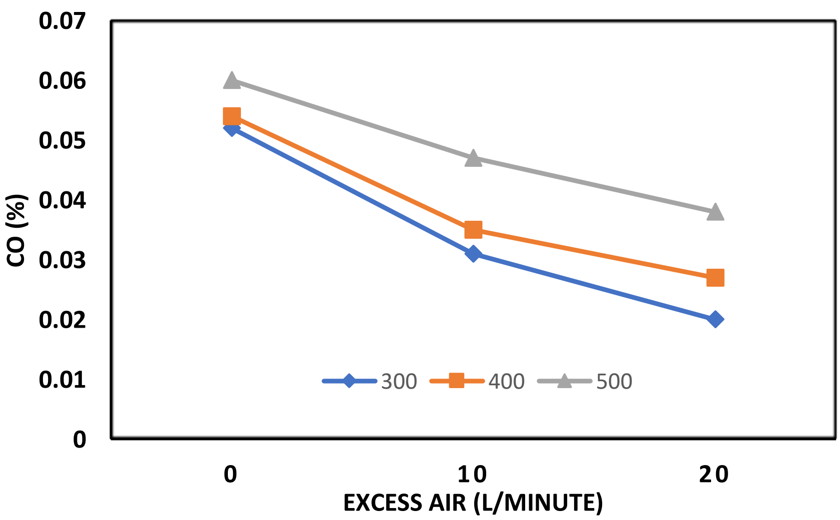

Figure 5. Effect of Excess Air on CO Emissions with Biodiesel Fuel (B40)

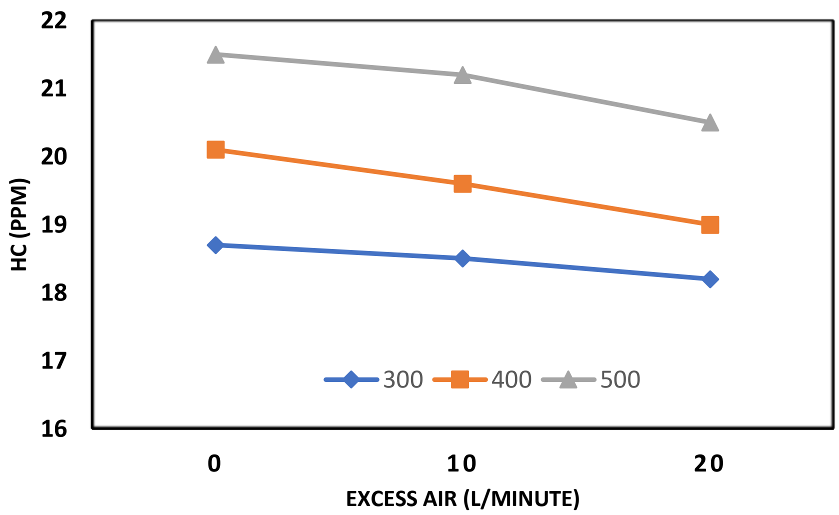

Figure 6. Effect of Excess Air on HC Emissions with Biodiesel Fuel (B40)

CONCLUSIONS

The results of the research that has been carried out show that the mixture of B40 composition and the excess air system can improve engine performance and exhaust emissions efficiency, with appropriate settings for the load.

The scope for future research is that the variables include adding a biodiesel mixture, adding air can also be increased, using other engines instead of engine one cylinder.

1. In the torque engine power results, it can be seen that the greater the load and excess air, the torque engine power increases, because engine power increases along with the increase in light load, in accordance with the working principle of internal combustion engines, where faster piston movements burn more fuel mixture. and adding excess air can help increase combustion compression in the engine.
2. The results of fuel consumption with the excess air system have the effect of reducing fuel consumption at 10 L/m and increasing at 20 L/m, because increasing excess air can reduce consumption to a certain point, excess air can increase fuel consumption making it less efficient.
3. In terms of CO, HC emissions, the use of excess air can reduce CO, HC emissions because excess air increases the fuel-to-air mixture ratio, which can lead to more complete combustion. More complete combustion can reduce hydrocarbon (HC) and carbon monoxide (CO) emissions.

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DECLARATION OF CONFLICTING INTERESTS

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REFERENCES

[1] A. Dwinanda, M. Nurkoyim Kustanto, G. Jatisukamto, and N. Ilminnafik, “Performance and Emission Characteristics of a Diesel Engine Fueled with Calophyllum Inophyllum Biodiesel and Gasoline Additives,” *Int. J. Appl. Sci. Technol. Eng.*, vol. 1, no. 1, pp. 172–179, Feb. 2023, doi: 10.24912/ijaste.v1.i1.172-179.

[2] C.-M. Lai *et al.*, “Performance and emission characteristics of double split injection biodiesel engine with intake air throttling,” *J. Clean. Prod.*, vol. 429, p. 139597, Dec. 2023, doi: 10.1016/j.jclepro.2023.139597.

[3] Y. Gzate, M. Ewnetu, N. Genet, T. Yifter, A. Asratie, and G. Engdaw, “Performance testing of moringa oleifera seed oil biodiesel with additives in diesel engine,” *Heliyon*, vol. 10, no. 4, p. e26293, Feb. 2024, doi: 10.1016/j.heliyon.2024.e26293.

[4] D. S. Zeleke and A. A. Bezabih, “Impact of additives from moringa stenopetela leaf extract and ethanol on the emission characteristics and performance of soybean biodiesel for single cylinder CI engine,” *Heliyon*, vol. 10, no. 6, p. e27619, Mar. 2024, doi: 10.1016/j.heliyon.2024.e27619.

[5] Z. Tosun and H. Aydin, “Combustion, performance and emission analysis of propanol addition on safflower oil biodiesel in a diesel engine,” *Clean. Chem. Eng.*, vol. 3, p. 100041, Sep. 2022, doi: 10.1016/j.clce.2022.100041.

[6] J. Monde, P. I. Kumalasari, D. Aryani, M. Lutfi, and A. Alfandy, “PENGARUH KATALIS SiO2/Al2O3 TERHADAP KARAKTERISTIK BIODIESEL DARI MINYAK JELANTAH,” vol. 6, no. 2, 2022.

[7] T. P. Hariyadi and M. Jelita, “Analisis Potensi dan Evaluasi Emisi Biodiesel dari Palm Oil Mill Effluent,” *J. Al-AZHAR Indones. SERI SAINS DAN Teknol.*, vol. 9, no. 2, p. 115, May 2024, doi: 10.36722/sst.v9i2.2754.

[8] M. Mofijur *et al.*, “Impact of nanoparticle-based fuel additives on biodiesel combustion: An analysis of fuel properties, engine performance, emissions, and combustion characteristics,” *Energy Convers. Manag. X*, vol. 21, p. 100515, Jan. 2024, doi: 10.1016/j.ecmx.2023.100515.

[9] V. Modi *et al.*, “Nanoparticle-enhanced biodiesel blends: A comprehensive review on improving engine performance and emissions,” *Mater. Sci. Energy Technol.*, vol. 7, pp. 257–273, 2024, doi: 10.1016/j.mset.2024.02.001.

[10] C. Adhikesavan, D. Ganesh, and V. Charles Augustin, “Effect of quality of waste cooking oil on the properties of biodiesel, engine performance and emissions,” *Clean. Chem. Eng.*, vol. 4, p. 100070, Dec. 2022, doi: 10.1016/j.clce.2022.100070.

[11] P. Kasprzyk, J. Hunicz, A. Rybak, M. S. Gęca, and M. Mikulski, “Excess Air Ratio Management in a Diesel Engine with Exhaust Backpressure Compensation,” *Sensors*, vol. 20, no. 22, p. 6701, Nov. 2020, doi: 10.3390/s20226701.

[12] Safiullah, S. C. Ray, K. Nishida, V. G. McDonell, A. Ahmed, and Y. Ogata, “Evaluation of multi-hole diesel injectors spray under evaporating conditions: Effects of adjacent spray plumes on the macroscopic and mixture characteristics of target spray,” *Proc. Inst. Mech. Eng. Part J. Automob. Eng.*, vol. 237, no. 14, pp. 3559–3571, Dec. 2023, doi: 10.1177/09544070221133880.

[13] N. Padilla, S. Subaer, and M. Muris, “ANALISIS PENGGUNAAN BAHAN BAKAR HIGH SPEED DIESEL (HSD) DAN MARINE FUEL OIL (MFO) TERHADAP PARAMETER TITIK UTAMA SIKLUS KERJA DAN PERFORMA MESIN DIESEL MITSUBISHI MAN TYPE 18V52/55A,” *J. Sains Dan Pendidik. Fis.*, vol. 15, no. 1, Sep. 2019, doi: 10.35580/jspf.v15i1.9402.

[14] Department of Mechanical Engineering, National Institute of Technology Silchar, Silchar 788010, Assam, India, B. P. Pattanaik, J. Jena, Department of Mechanical Engineering, Gandhi Institute for Education and Technology, Bhubaneswar, Khurda 752060, Odisha, India, R. D. Misra, and Department of Mechanical Engineering, National Institute of Technology Silchar, Silchar 788010, Assam, India, “The effect of oxygen content in soapnut biodiesel-diesel blends on performance of a diesel engine,” *Int. J. Automot. Mech. Eng.*, vol. 14, no. 3, pp. 4574–4588, Sep. 2017, doi: 10.15282/ijame.14.3.2017.14.0361.

[15] R. Vishnu Varthan and D. Senthil Kumar, "Emission Characteristics of Turbocharged Single Cylinder Diesel Engine," *Indian J. Sci. Technol.*, vol. 9, no. 17, May 2016, doi: 10.17485/ijst/2016/v9i17/93158.

[16] Y. M. Pell and M. M. Dwinanto, "Pengaruh Rasio Tekanan Kompresor Turbocharger Terhadap Kinerja Mesin Diesel dan Emisi NOX," vol. 24, no. 4, 2022.

[17] S. T. Kusuma, "TORSI DAN DAYA MESIN DIESEL 2.5L BERBAHAN BAKAR BIODIESEL CAMPURAN MINYAK KELAPA SAWIT".

[18] G. Warkhade and A. Babu, "Impact of supercharging and compression ratio on performance characteristics in a single cylinder DICI engine," *Int. J. Heat Technol.*, vol. 36, no. 3, pp. 955–961, Sep. 2018, doi: 10.18280/ijht.360323.

[19] B. V. Subhanandh, N. Abilash, and P. Saji Raveendran, "Investigation of emission and performance analysis of honne oil in VCR diesel engine," *J. Phys. Conf. Ser.*, vol. 2054, no. 1, p. 012065, Oct. 2021, doi: 10.1088/1742-6596/2054/1/012065.

[20] M. S. Gad, R. El-Araby, K. A. Abed, N. N. El-Ibiari, A. K. El Morsi, and G. I. El-Diwani, "Performance and emissions characteristics of C.I. engine fueled with palm oil/palm oil methyl ester blended with diesel fuel," *Egypt. J. Pet.*, vol. 27, no. 2, pp. 215–219, Jun. 2018, doi: 10.1016/j.ejpe.2017.05.009.

[21] C. Chen *et al.*, "Sustainability and challenges in biodiesel production from waste cooking oil: An advanced bibliometric analysis," *Energy Rep.*, vol. 7, pp. 4022–4034, Nov. 2021, doi: 10.1016/j.egyr.2021.06.084.

[22] R. S. Kuware and D. A. V. Kolhe, "Effect of Hydroxy (HHO) Gas Addition on Performance and Exhaust Emissions in Spark Ignition (SI) Engine," vol. 3, 2016.