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THE FFECT OF ETHANOL AND WATER FUEL MIXTURE IN DIRECT INJECTION DIESEL ENGINE ON POWER AND SPECIFIC FUEL CONSUMPTION

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ABSTRACT

The increasing use of fossil energy is causing a national and global energy crisis. To reduce dependence on fossil energy, planned actions are being taken to replace fossil energy with alternative energy sources, one of the alternative fuels that can be burned is ethanol or ethyl alcohol. This research aims to identify the effect of using a mixture of ethanol and water fuel, by controlling the ethanol content and the effect of engine speed on power and specific fuel consumption in direct injection engines, as well as identifying the interaction between ethanol content and engine speed. This research uses an experimental method by testing a direct injection engine connected to an electric generator to determine power and SFC by testing variations in ethanol content and engine speed. For the load in this test, 3 so is 250 Watt lamps are used. The result was that when testing the direct injection engine using a 93% ethanol fuel mixture it produced a power of 0.115 kW at 1300 rpm, while in the 96% ethanol test the power obtained was 0.118 kW at the same engine speed. For an ethanol content of 99% at 1900 engine speed, the highest power is obtained, reaching 2,326 kW, this indicates that the higher the ethanol content used, the greater the power produced. However, the SFC value has decreased. As in testing 93% ethanol content at 1300 engine speed, the SFC obtained was 2.2997 L/kWh. At 99% ethanol content, SFC experienced a minimum decrease of 0.6418 /kWh. At low ethanol levels, the water content tends to be high which causes the combustion process to be incomplete.

Keywords: Ethanol, Alternatives, Engine Speed, Direct Injection, Power, Specific Fuel Consumption.

1. INTRODUCTION

Human needs increase along with population growth. The current problem is the decrease in the amount of fossil fuels and the increase in air pollution caused by conventional vehicle exhaust gases. Diesel and otto engines still use a lot of fossil fuels and will always increase [1]. Increasing consumption of fossil energy is causing an energy crisis both at the national and international levels. To reduce dependence on fossil energy, strategic steps can be taken by replacing fossil energy with alternative energy sources [2]. To be used as a homogeneous engine fuel mixture, ethanol fuel must have a concentration of more than 96%, known as absolute ethanol. It is used because it contains very little water, even almost pure, so that when mixed directly with fuel, the mixture will mix perfectly and can enter the combustion chamber [3]. Ethanol contains lower levels of carbon and hydrogen, so the oxygen (O_2) content will be higher, so the use of ethanol fuel makes the combustion process perfect [4]. The process of evaporation of water that occurs in the combustion chamber will form hydroxide and hydrogen at high temperatures, this aims to absorb heat during combustion [5]. Ethanol's (Higher Octane Value) increases the engine's compression ratio and also improves thermal efficiency. An electric generator, also called an alternator, is an alternating current electric machine that uses voltage and current to produce alternative current electricity, AC when there is an induced magnetic field, changes in the magnetic field in the anchor coil, or connected place, causing relative movement between the magnetic field and the generator coil. [6]. Chemical energy is converted into heat during the combustion process, which produces residual gases [7]. The combustion residue produces various dangerous substances emitted by the exhaust such as CO (carbon monoxide), O_2 (oxygen), HC (hydrocarbon), NOx (nitrous oxide), CO_2 (carbon dioxide), and H_2O. Diesel fuel is a fuel that has many carbon atoms and also long carbon chains. When compared to gasoline, diesel fuel is more stable but requires high temperatures to evaporate [8]. Research conducted by Simeon obtained results that increasing the ethanol content in the fuel mixture could cause a decrease in fuel consumption. This test was carried out on a four-

cylinder diesel engine. In addition, the smoke in the mixture of diesel fuel and ethanol decreases when the engine speed is higher [9], [10]. Jehad concluded that the addition of hydrogen and ethanol to gasoline engines can reduce fuel consumption and harmful emissions [11], [12]. Therefore, from several studies on ethanol that have been carried out by researchers who analyze that the use of fossil fuels will eventually run out with increasing population, there must be a replacement for fossil fuels as reserves and renewable sources, namely ethanol fuel. This research was carried out on a direct injection engine using a mixture of ethanol and diesel fuel, to determine the effect of ethanol on power and specific fuel consumption. Later, the combustion chamber will be modified so that the compression obtained is higher, namely by modifying the camshaft so that the injection time is more advanced which will produce a higher compression pressure than standard and changes to the cylinder head packing to obtain optimal power and more efficient fuel consumption. The use of a single cylinder diesel engine and an electric generator to act as a link between the engine and the load (lights). The engine will be processed and modified in that the injection timing is advanced so that the compression pressure is higher than standard. Thus, it is necessary to test the effect of using ethanol in direct injection engines. This research was conducted to determine the effect of ethanol content on power and specific fuel consumption in direct injection diesel engines**.** Internal combustion engine shaft power is the power used to move the load. Engine power is the amount of performance a machine performs in a certain period of time. Equation 1 shows the power formula.

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

Where, P is power, V is voltage, I is current.

Specific fuel consumption is a measure related to economic prices because it can calculate the amount of fuel used to produce a certain amount of power in a certain time [9]. To find out how much specific fuel consumption is needed, can be seen the equation 2. $BFC = \frac{Vf}{T} \times \frac{3600}{1000}$ (2)

Where, BFC is Fuel consumption (L/Hour), Vf is Amount of fuel consumed / second (ml), t is Time required for fuel consumption (s).

2. RESEARCH SIGNIFICANCE

As fuel technology develops, there are more and more types of fuel, such as alternative fuels, for example ethanol/ethyl alcohol. According to Gaol, diesel engines have a higher compression ratio than gasoline engines [13]. Therefore, this research was carried out to determine the benefits of ethanol fuel to increase fuel efficiency, improve engine performance, minimize specific fuel consumption, increase engine power, increase octane value, and provide a greater understanding of the effects of using alternative fuels. This research uses a single cylinder diesel engine with a direct injection system connected to an electric generator by adding a load in the form of a series of 3 lamps of 250 Watt each. This test is important to carry out to determine the effect of using ethanol fuel with levels of 93%, 96%, and 99% alcohol with engine speed variations of 1300, 1600 and 1900 rpm on a single cylinder diesel engine using a direct injection system.

3. RESEARCH METHODS

3.1 Experimental Setup

The experimental setup of the research shows the **Fig. 1.**

Fig 1. Experimental Setup

The method used in this research is an experimental method, namely by testing a single cylinder diesel engine with direct injection and adding an electric generator as a link between the engine and load, with variations in ethanol content (93%), (96%), (99%) and engine speed with variations (1300, 1600, 1900) rpm. This test uses an ampere clamp and a digital multimeter to determine the current and voltage produced, then to determine the engine speed, a digital taco meter is used, and in testing specific fuel consumption, a measuring cup, bured and stopwatch are used to calculate the consumption required by the engine per second. to produce power output. Renewable energy sources are ethanol [14].

Testing was carried out with a direct injection diesel engine connected to an electric generator using pulleys and fan belts and placed on an iron frame or angle bar. This test uses a load in the form of a series of three lamps, each having 250 Watts and connected in parallel.

3.1 Materials

1. This test uses alcohol/ethanol fuel, in this test the ethanol used is Smartlab ethanol (PA) type or absolute ethanol. This ethanol has a purity of up to 99%. It seen the **Fig 2.**

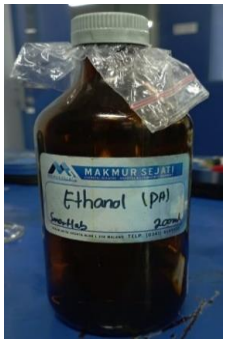


Fig 2. Etanol 99%

2. The diesel used is biodiesel, the use of diesel is used to lubricate the fuel pump so that fuel spraying can run smoothly and avoid wear and tear on the fuel pump which is caused by the water content contained in the ethanol. Diesel fuel is a type of fossil fuel that contains hydrocarbons between 9 and 27 carbon atoms [15]. can be seen below the theoretical and simple 1 chemical reaction of diesel fuel in the cylinder, It seen in equation 3 [16].

$$C_{16}H_{34} + 24.5\ \lambda\ (O_2 + 3.76\ N_2) \rightarrow 16\ CO_2 + 17\ H_2O + 24.5\ (\lambda - 1)\ O_2 + 92.12\ N_2 \quad (3)$$

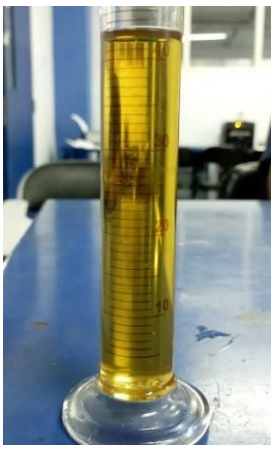
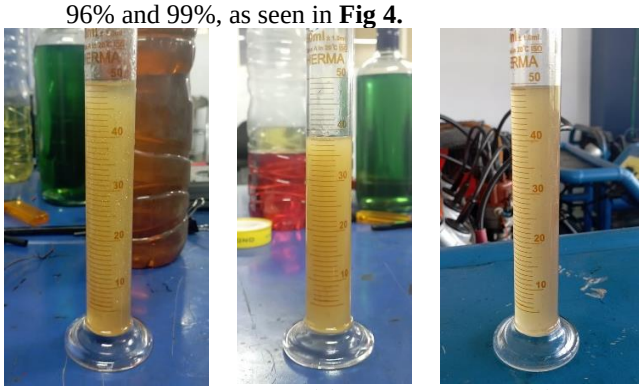


Fig 3. Solar

3. The ratio of the mixture of ethanol and diesel is 50% ethanol and 50% diesel, with levels including 93%, 96% and 99%, as seen in **Fig 4.**



(1) (2) (3)

Fig 4. Etanol+Solar (1) Etanol 93% (2) Etanol 96 (3) Etanol 99%

3.2 Experimental Procedure

The testing process was carried out in the ground floor engine room. The tests used a series of diesel engines and electric generators connected to parallel light circuits with varying mixtures of ethanol and water fuel with alcohol levels (93%, 96%, 99%). A mixture of diesel fuel and ethanol is more difficult to mix due to the higher solubility and stability of alcohol [17]. The addition of additives functions to increase the solubility between ethanol and diesel fuel [18]. The effect of the diesel-diesel mixture can increase the BSFC [19]. The heat of combustion of alcohol is lower than the heat of diesel fuel [20]. Setting engine rpm using the Digital Taco Meter for engine rpm between 1300, 1600 and 1900. According to Peniel, engine performance with fuels with different heat values and densities can be compared with brake specific fuel consumption (BSFC). Diesel engines are called compression ignition and (high pressure engines) [21].

The process of collecting power test data is as follows:

1. Prepare a single cylinder diesel engine, electric generator, and a load in the form of 3 is 250 Watt lamps.
2. Prepare the fuel to be used, namely a mixture of ethanol and water.
3. Prepare a taco meter to determine the engine speed.
4. Installing a series of general diesel engines and electric generators
5. Install a multimeter probe into the generator socket to determine the electrical voltage produced.
6. Install an amperage clamp on the light circuit cable to determine the current emitted.
7. Record power test results data.

The higher the octane of the fuel, the more power the vehicle will produce [22]. Butanol is an alcohol that has a high concentration, this can be used to prevent phase separation in diesel-ethanol mixtures [23]. One of the most commonly used measuring instruments to measure electric circuit current is an ammeter or amperage clamp [24]. Indirect pure ethanol fuel can be used as a substitute for gasoline engines [25]. Biodiesel or diesel oil functions as a vegetable lubricant in diesel internal combustion engines [26].

The process of collecting consumption test data is as follows:

1. Prepare a measuring cup (100 ml size)
2. Prepare a mixture of ethanol + water fuel
3. Enter a variety of fuel mixtures, namely 50 ml, into the engine
4. The timer for each test is recorded for every 2 minutes of fuel consumed from variations in fuel mixture and engine speed
5. Calculate the difference between incoming and fuel consumption

4. RESULT AND DISCUSSION

According to Putra, the higher the compression ratio, the power increases, will increase and tend to decrease further. Tests were carried out on direct injection diesel engines using a mixture of ethanol and diesel fuel, so that a graph is obtained regarding the power released by the engine and the specific fuel consumption. So that a graph is obtained regarding the power released by the engine.

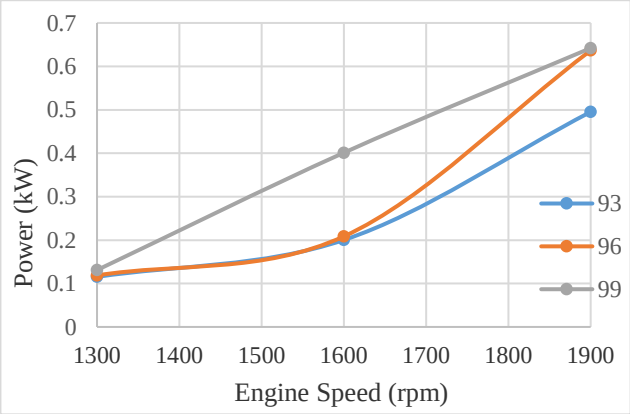


Fig 5. Corelation of Engine Speed and Power

From the results of research carried out on direct injection diesel engines using a mixture of ethanol and diesel fuel, test results were obtained as shown in Fig 5. when using 93% ethanol fuel, an average result of 0.115 kW is obtained, meanwhile using 96% ethanol content produces a power of 0.118 kW, then at 99% the power yield continues to increase drastically, until the power is obtained. The highest is reaching 0.642 kW at 1900 engine speed, so it can be stated that the higher the alcohol content, the higher the power, this is because the water content in the fuel mixture is less and makes combustion in the combustion chamber more complete. In the graph it can be seen that the levels of 93% and 96% at engine speeds of 1300 to 1600 rpm have not increased significantly compared to 1900 rpm, because the higher the engine speed, the more easily the fuel will burn and the ethanol content of 99% is more responsive during the combustion process.

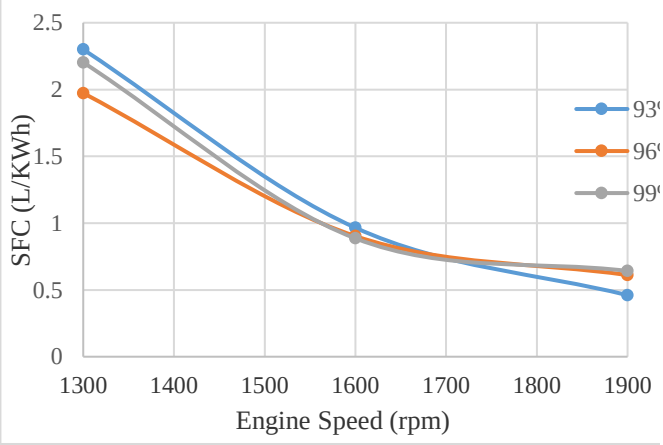


Fig 6. Corelation of Engine Speed and SFC

from the results of research carried out on direct injection diesel engines using a mixture of ethanol and diesel fuel, test results were obtained as shown in Fig 6. Specific fuel consumption when using 93% ethanol at rpm 1300 requires more fuel consumption and the value SFC is 2.2997 L/kWh. Then at 1600 rpm there is a decrease in terms of the specific fuel consumption graph, because when the engine speed is higher, the fuel pump will supply more fuel to the combustion chamber. At 1300 SFC the resulting engine speed is unstable because at the start the engine requires a large amount of fuel. In fuel mixtures with higher ethanol content, specific fuel consumption decreases, this occurs because the higher the ethanol content and engine speed, the more efficient the combustion that occurs in the combustion chamber and burns completely.

The problem formulation in this research includes:

1. How does ethanol content affect power and specific fuel consumption in direct injection engines?
2. How does engine speed affect specific power and fuel consumption in direct injection engines?
3. What is the interaction between ethanol content and engine speed on specific power and fuel consumption in direct injection engines?

Furthermore, the calculation of power and specific fuel consumption (SFC) can use two-way ANOVA calculations. By looking at the comparison between ethanol content and direct injection diesel engine speed. The following are the results of the two-way ANOVA calculation with the results, how does ethanol content and engine speed affect power and specific fuel consumption (SFC):

- Two-way anova calculation with 93% ethanol content
  In the above test using an ethanol-diesel fuel mixture, the heat of combustion of alcohol was lower than that of diesel fuel, which means less thermal effect on cylinder and piston components [27]. by adding 93% ethanol content and varying engine speed between 1300, 1600 and 1900 rpm. One of the engine characteristics is the amount of fuel consumed which is usually called the Specific Fuel Consumption (SFC) [28]. The following are the results of the analysis in Table 1. Two-way ANOVA:

Table 1. Anova Using 93% Content Etanol

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
rpm	0.528819	2	26.44097	2.639056	0.0011223	3.885294
levels	4.823831	1	4.823831	48.14635	0.00001	4.747225
Interaction	2.791204	2	1.395602	13.92941	0.0007446	3.885294
Within	1.202292	12	0.100191			
Total	9.346146	17				

1. The results of testing the ethanol content on the P-value obtained an rpm value of 0.00089. This value is less than 0.05, so the ethanol content of 93% affects the power and specific fuel consumption.
2. The results of the engine speed test are the same as the P-value results for engine speed, namely <0.05 and a value of 0.04072. indicates that there is an influence of engine speed on power and specific fuel consumption.
3. The interaction between 93% ethanol content and engine speed in this test obtained a result of 0.00485, so this value is less than 0.05, which means there is an influence between the two in tests using a mixture of ethanol and diesel fuel in a direct injection diesel engine.

so the use of 93% ethanol content produces constant power and high SFC values due to the large amount of water content present in the fuel, so that the fuel mixture is not homogeneous.

- Two-way ANOVA calculation with 96% ethanol content

The following are the results of two-way ANOVA calculations with statistical tests, what is the effect of using a mixture of ethanol and diesel fuel, with the addition of ethanol content of 96% and engine speed on power and specific fuel consumption (SFC). So that the anova results are obtained as follows:

Table 2. Anova Using 96% Content Etanol

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
rpm	1.86786424	2	9.33932	4.22941488	0.00407195	3.8852938
levels	4.24753203	1	4.24753203	19.2354185	0.00088719	4.7472253
Interaction	3.79009723	2	1.89504862	8.5819372	0.00485307	3.8852938
Within	2.64981936	12	0.22081828			
Total	12.5553129	17				

The results in the ANOVA table above are using an ethanol-diesel fuel blend, adding 96% ethanol content and varying the engine speed between 1300, 1600 and 1900 rpm. The following are the results of the analysis in Table 2. Two-way ANOVA:

1. The results of testing the ethanol content on the P-value obtained an rpm value of 0.000056. This value is less than 0.05, so the ethanol content affects the power and specific fuel consumption.
2. The engine speed test results are the same as the P-value results for engine speed, namely <0.05 and get a value of 0.00112. indicates that there is an influence of engine speed on power and specific fuel consumption.
3. The interaction between 96% ethanol content and engine speed in this test obtained a result of 0.00074463, so this value is less than 0.05, which means there is an influence between the two in tests using a mixture of ethanol and diesel fuel in a direct injection diesel engine.

So that the use of 96% ethanol content results in an increase in power and lower SFC values due to the less water content contained in the fuel, so that combustion in the combustion chamber can be homogeneous.

- Two-way ANOVA calculation with 99% ethanol content

The following are the results of two-way ANOVA calculations with statistical tests, what is the effect of using a mixture of ethanol and diesel fuel, with the addition of 99% ethanol content and engine speed on power and specific fuel consumption (SFC), so the following calculation results are obtained:

Table 3. Anova Using 99% Content Etanol

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
rpm	1.91936116	2	0.95968058	118.629789	0.0000124	3.8852938
levels	2.06605185	1	2.06605185	255.392576	0.0000187	4.7472253
Interaction	4.374769	2	2.1873845	270.39097	0.0000104	3.8852938
Within	0.09707652	12	0.00808971			
Total	8.45725853	17				

a mixture of ethanol-diesel fuel was used, adding 99% ethanol content and varying engine speed between 1300, 1600 and 1900 rpm. The following are the results of the two-way static ANOVA analysis: The results of testing the

ethanol content on the P-value obtained an rpm value of 0.00000. This value is less than 0.05, so Ethanol content affects power and specific fuel consumption. The following are the results of the analysis in Table 3. Two-way ANOVA:

1. The test results of ethanol content at P-value obtained rpm value of 0.00000. The value is less than 0.05, so ethanol levels affect power and specific fuel consumption.
2. The results of testing engine speed are the same as the results of the P-value at engine speed, which is <0.05 and gets a value of 0.00000 indicating that there is an effect of engine speed on power and specific fuel consumption.
3. The interaction between 99% ethanol content and engine speed in this test was found to be 0.00000. So that the value is less than 0.05, which means that there is an influence between the two in the test using a mixture of ethanol and diesel fuel in a direct injection diesel engine.

Because the higher the ethanol content and engine speed, the power increases and the consumption required will be less, this indicates that the engine combustion is perfect and produces a minimum SFC.

This study uses a single-cylinder general diesel engine with homogeneous ethanol + water and diesel fuel blends, with variations of 93%, 96%, and 99% ethanol blends and 50% diesel fuel, at 1300, 1600, and 1900 rpm engine speeds, which only focuses on analyzing the use of ethanol in direct injection engines under standard air conditions.

5. CONCLUSION

Based on tests on power and specific fuel consumption using a mixture of ethanol and diesel fuel in direct injection diesel engines, the following conclusions were obtained:

- Adding ethanol content can increase engine power from 0.0976 kW at 1300 rpm to 0.726 kW at 1900 rpm.
- Meanwhile, specific fuel consumption (SFC) when using a mixture of ethanol and diesel fuel decreases with each variation in engine speed. When varying the ethanol content of 96%, the SFC results show a stable decrease, this indicates that at the 96% level, a good SFC value is obtained. At 1300 rounds with an ethanol content of 93%, the highest average SFC value was obtained at 2.2997 L/kWh. Then at the highest ethanol content variation, namely 99%, the SFC value decreases to 0.641838 L/kWh.

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7. AUTHOR CONTRIBUTIONS

Concept and Design: Bambang Irawan
MT & Akhmad Nafii
Methodology: Akhmad Nafii
Data acquisition: Akhmad Nafii
Data Analysis and Interpretation: Akhmad Nafii
Publication Author: Akhmad Nafii
Final Publication Approval: Bambang Irawan
Resources, Technical support and Materials: Akhmad Nafii, Bambang Irawan
Supervisor: Bambang Irawan

8. REFERENCE

[1] Gumte, K., Pantula, D. V., Miriyala, S., Mitra, K., (2020). “Achieving wealth from bio-waste in a nationwide supply chain setup under uncertain environment through data driven robust optimization approach" Department of Chemical Engineering, Indian Institute of Technology Hyderabad, Kandi, Sangareddy, Medak, 502285, Telangana,India. https://doi.org/10.1016/j.jclepro.2020.125702

[2] Bietresato, M., Caligiuri, C., Renzi, M., Mazzeto, F., (2019). "Use of diesel-biodiesel-bioethanol blends in farm tractors: first results obtained with a mixed experimental-numerical approach". University of Bozen/Bolzano, Faculty of Science and Technology, Piazza Università 5, Bolzano 39100,Italy. https://doi.org/10.1016/j.egypro.2019.01.237

[3] Gürbüz1, H., Sandalci, T,. (2019). "Modeling Of Post-Injection Strategies Of Ethanol And Experimental Analysis Of The Use Of Ethanol In The Form Of Dual Fuel And Emulsion In Diesel Engine". Department of Mechanical Engineering, Şırnak University, Şırnak 73000, Turkey. https://doi.org/10.2298/TSCI191223073G

[4] Thakur, A. S. (2018). ""Study of Ethanol-Camphor Mixture as an Alternative of Conventional Liquid Engine Fuel"." Progress in Petrochemical Science 3(1).

[5] Redel-Macías, M. D., D. E. Leiva-Candia, J. A. Soriano, J. M. Herreros, A. J. Cubero-Atienza and S. Pinzi (2021). "Influence of Short Carbon-Chain Alcohol (Ethanol and 1-Propanol)/Diesel Fuel Blends over Diesel Engine Emissions." Energies 14(5): 1309. https://doi.org/10.3390/en14051309

[6] Thakur, A. S. (2018). ""Study of Ethanol-Camphor Mixture as an Alternative of Conventional Liquid Engine Fuel"." Progress in Petrochemical Science 3(1). https://doi.org/10.31031/pps.2018.03.000553

[7] Sudarma, A. F., H. Pranoto, M. A. Sera and A. Aziz (2020). "Analysis of Fuel Injection Pressure Effect on Diesel Engine Combustion Opacity Value." International Journal of Advanced Technology in Mechanical, Mechatronics and Materials 1(1): 1-5.

[8] Can, Ö., E. ÖZtÜRk and E. ArcaklioĞLu (2021). "Artificial neural network based determination of the performance and emissions of a Diesel engine using ethanol-diesel fuel blends." International Journal of Automotive Science and Technology 5(1): 43-51.https://doi.org/10.30939/ijastech..805531

[9] Wang, Z. and L. Li (2022). "Effects of Different Ethanol/Diesel Blending Ratios on Combustion and Emission Characteristics of a Medium-Speed Diesel Engine." Processes 10(1): 173.

[10] Paniel. P, Sundar R.C., Michael K,. Effective application of ethanol in diesel engines. International Journal of Green Energy (2017). DOI:10.1080/15435075.2017.1354300 http://dx.doi.org/10.1080/15435075.2017.135430 0

[11] Simeon, L,. “An experimental investigation of performance and emissions of a common-rail diesel engine fueled with ethanol additives”. (2021). AIP Conference Proceedings 2439, 020001. https://doi.org/10.1063/5.0068527

[12] Jehad, A. Y., Eiman Ali., Khalid S.R., (2021). “Relative Change in SI Engine Performance Using Hydrogen and Alcohol as Fuel Supplements to Gasoline” Advances in Sciences and Technology. DOAJ. https://doaj.org/article/04f4e88c2e4b4094b27ec878cc6abb2f

[13] Gaol, R. P. L. (2020). Performance Test of One Slinder Otto Engine with Pertalite and Pertamax Fuel. (Jurnal Ilmiah Teknik Mesin Fakultas Teknik UISU) 4(2): 64-70

[14] Subrahmanyam, D. V. S. R. B. M. and M. Manikandan (2023). "Effects of diesel-ethanol-waste oil cooking and plastics blends

reused in common rail direct injection diesel engine." Indonesian Journal of Electrical Engineering and Computer Science 32(2): 643. https://doi.org/10.11591/ijeecs.v32.i2.pp643-653

[15] Özgür, T., E. Tosun, C. Özgür, G. Tüccar and K. Aydın (2017). "Performance, Emission and Efficiency Analysis of a Diesel Engine Operated with Diesel and Diesel-Ethanol (E20) Blend." MATTER: International Journal of Science and Technology 3(3): 51-61.

[16] Jagtap, S. P., A. N. Pawar and S. Lahane (2021). "Effect of Ethanol-Biodiesel-Diesel Blend on Performance and Emission Characteristics of a DI Diesel Engine." International Journal of Heat and Technology 39(1): 179-184.

[17] Florian A.Y., (2017). Use of Biofuels In Compression Ignition Engines. Pontifícia Universidade Católica Do Rio De Janeiro. https://doi.org/10.17771/pucrio.acad.29914

[18] Artur, K., Hubert, K., Kazimier L., Adam, U., (2017). Effect of Dodecanol Additive On Auto-Ignition Properties Of Diesel Oil And Ethanol Blends. https://doi.org/10.19206/CE-2017-317

[19] Olanrewaju. F.O., H. Li., Andrews. G.E., H.N. Phylaktou. (2021). Effect of Diesel-Ethanol Fuel Blends On Engine Performance And Combustion Behaviour of Compression Ignition (CI) engines. Powertrain Systems for Net-Zero Transport. BookChapter. https://doi.org/10.1201/9781003219217-7

[20] Roslyakov. A., Andrey. B., Valiullina. O., Evgeny. C. (2022). The Use of Ethanol in Diesel. International Scientific Conference On Aeronautics, Automotive And Railway Engineering And Technologies. https://doi.org/10.1063/5.0100697

[21] Firdiansyah, A., N. Ilminnafik, A. Triono and M. N. Kustanto (2021). "Effect of Biodiesel B100 and Ethanol Blends on the Performance of Small Diesel Engine." International Journal of Mechanical Engineering Technologies and Applications 2(2): 101.

[22] Rodríguez-Fernández, J., Ramos, Á., Barba, J., Cárdenas, D., & Delgado, J. (2020). Improving fuel economy and engine performance through gasoline fuel octane rating. Energies, 13(13), 3499.

[23] Prabakaran, B., (2021). An Attempt in Blending Higher Volume of Ethanol with Diesel for Replacing the Neat Diesel to Fuel Compression Ignition Engines. Bioetanol Technologies. https://doi.org/10.5772/intechopen.95263

[24] Faradiba, F. (2022. Length, Mass and Current Measurement Practicum Module. Universitas Kristen Indonesia. http://repository.uki.ac.id/id/eprint/13991

[25] Irawan, B., Winoko, Y., Puspitasari, E., & Dwiyono, T. (2021). Analysis Of Fuel Pressure On The Performance Of Motorcycle Engine With Ethanol Fuel. Paper presented at the IOP Conference Series: Materials Science and Engineering

[26] Baustista, C.S., (2022). Performance and Emissions of Ethanol and Ethanol-Diesel Blends in Direct-Injected and Pre-Chamber Diesel Engines. Diesel Engines and Biodiesel Engines Technologie. https://doi.org/10.5772/intechopen.103663

[27] Osmano, V., (2019). "An assessment of fuel consumption and emissions from a diesel power generator converted to operate with ethanol". Sustainable Energy Technologies and Assessments 35 (2019) 291–297. Environmental Science. https://www.academia.edu/83374229/An_assessment_of_fuel_consumption_and_emissions_from_a_diesel_power_generator_converted_to_operate_with_ethanol?sm=b&b=vector&rhid=28724660629

[28] Tutak, W., A. Jamrozik, M. Pyrc and M. Sobiepański (2017). "A comparative study of co-combustion process of diesel-ethanol and biodiesel-ethanol blends in the direct injection diesel engine." Applied Thermal Engineering 117: 155-163. http://dx.doi.org/10.1016/j.applthermaleng.2017.02.029