The Fuel Characteristics of a Diethyl Ether–Ethanol–Gasoline Mixture as a Performance and Exhaust Improvement in Matic Spark Ignition Engine

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Abstract: Diethyl ether and ethanol are low-carbon chemical compounds as alternative energy to replace fossil fuels or commercially. Fuel has optimal calorific and octane values and a high ignition rate. What inspired us to make diethyl ether and ethanol as a fuel mixture on the 115cc matic Spark Ignition Engine. in research using experimental methods, performance test equipment using dyno test-chassis with an engine speed of 4000 rpm to 9000 rpm, the fuel used is diethyl-ether (2%, 5%, 8%, and 10%) and ethanol (5%). The test results show a significant engine performance increase in all fuel variations. Exhaust gas and engine temperatures decreased in all variations of fuel. Exhaust emissions of CO and HC decreased significantly above 5%, while CO_2 increased by 5.2% due to the characteristics of the fuel used.

1 INTRODUCTION

Recently, we have been concerned about increasing fuel emissions and efficiency in internal combustion engines such as Compression Ignition (IC) engines and Spark Ignition (SI) engines. That is why scientists and the automotive industry collaborate to find effective alternatives to overcome this. Some scientists or researchers have recently suggested that non-fossil fuels can be a good alternative to replace commercial fuels (Hasan et al., 2021). This research explores the potential of mixing diethyl ether, ethanol, and gasoline. It aims to produce a homogeneous fuel mixture to have a perfect combustion effect and reduce the level of spark ignition engine (SI) pollution without reducing engine quality characteristics. This research will quantitatively test the performance with different test fuel mixtures and compare it with commercial fuels with the anticipated increase in engine performance and reduced emissions (Okoronkwo et al., 2017; Zapata-Mina et al., 2022).

The main point of this research focuses on testing engine characteristics using diethyl ether (DEE) as an oxygenated additive in cottonseed oil fuel mixtures. The experimental results indicate that the average effective pressure decreased by 17.39%, while the specific fuel consumption increased by 29.15% at a 10% diethyl ether fuel mixture. Diethyl ether can be considered a favorable aspect as an alternative fuel. In this study, it can be underlined that the DEE blending up to 10% (by vol.) can be considered a prospective step in efficiently utilizing the fuel mixture in the engine without its modification (Yesilyurt & Aydin, 2020). The combination of slow-reacting ethanol (EtOH) and binary fast-reacting diethyl ether (DEE) is beneficial as a substitute for fossil energy for today's machines. Measurement of ignition delay in the temperature range of 550-1000 K, 0.5-1 equivalence ratio and 20-40 bar pressure. Ignition step reactions have been identified by the kinetic analysis method. The test results on the DME/EtOH and DEE/EtOH showed that the DME oxidation was influenced by formaldehyde, while the DEE mixture was influenced by acetaldehyde (Issayev et al., 2020).

The principle of two-phase heat transfer to increase the performance of machines controlled using a reactivity system. Difference in the diethyl ether-ethanol fuel mixing ratio (0%-40% diethyl ether

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and 70% mixture ratio) applied to medium capacity engines. The average effective pressure increased by 14% with the addition of 40%-diethyl ether fuel. The highly reactive effect of diethyl ether can increase the oxidation of hydrocarbons and reduce the level of hydrocarbon emissions. Increased volatility and a more effective fuel collaboration process will have an impact on improving the combustion process and reducing the level of particulate exhaust emissions (Mohebbi et al., 2018). The experimental investigation using an SI engine fueled by gasoline mixed with Acetone-Butanol-Ethanol (ABE). The study's results identified that a mixture of 5.4% ethanol with engine conditions at 1500 rpm resulted in a thermal efficiency of 28%. On the other hand, when mixing 5% ethanol with an engine speed of 2254 rpm, the resulting thermal efficiency is 30% (Zhao, Huang, et al., 2022).

Ethanol fuel has a higher oxygen quantity and a faster laminar ignition. The use of the EGR system cannot reduce the level of losses to the pump, but it can significantly improve pump power performance, reduce fuel consumption and reduce exhaust emissions in the engine (Zhao, Yu, et al., 2022). The main focus of this research is the use of alternative fuels that have the characteristics of density, pour point, cloud point, and kinematic viscosity (Venu & Madhavan, 2017). This study uses a fuel variation of 2% diethyl ether and 10% ethanol. The pilot injection angle implemented is 8° to 18° BTDC. The results of this investigation indicate that increasing the injection angle on the fuel pilot has an impact on increasing engine performance. Thermal efficiency increased by 13.36% at an injection angle of 16° BTDC (Bhowmik et al., 2022). A mixture of ethanol and diethyl ether has a very significant impact on the increase in volumetric efficiency, thermal efficiency, and output power, while the increase in these values is 7%, 9%, and 8.2%, the same thing happened to the specific fuel consumption which decreased by 2.4 % of commercial fuel consumption. Adding diethyl ether-ethanol to commercial fuels can shorten the ignition and spark time of the spark plugs (Dhanapal et al., 2016).

Fuel mixtures of diethyl ether and alcohol with 4 different combinations, including combination 1 (5% DEE-10%E-85%P), combination 2 (5% DEE-15%E-80%P), combination 3 (10% DEE-15%E-75%P) and combination 4 (15% DEE-25%E-60%P). gasoline is used as a reference fuel for comparison during experiments. The experimental results identify that the power that occurs in the combination of the two does not experience a significant increase. The output power increases when the engine speed is low by 22.4% (Maciej Serda et al., 2016). Diethyl ether and ethanol are unleaded fuels that can be used to improve SI engine performance. The effect of mixing ethanol-diethyl ether is an increase in engine performance. The high octane number of diethyl ether and ethanol impacts the faster combustion process, so the complete combustion process in the combustion chamber will be realized (Awad et al., 2018; Balaji et al., 2016; Efemwenkiekie et al., 2019; Srinivas Rao et al., 2019). Diethyl ether has good characteristics as an alternative fuel. It is shown that the addition of 3%, 6% and 9% diethyl ether in commercial fuels, with the effect of these additions producing a significant increase in performance, shows the maximum increase in the 6% mixture variation (Srihari et al., 2018).

Research on ethanol-diethyl ether-gasoline fuel is still being developed by varying the factors that can affect the performance of the SI engine, including volatility at average temperatures, low specific gravity, low flash point, and low price. However, the results obtained are not as expected. Variations in the amount of fuel volume will affect the characteristics of the combustion process. Adding ethanol-diethyl ether to gasoline is expected to make the combustion process in the combustion chamber cleaner because ethanol comes from biomass. With a clean combustion reaction, combustion can run perfectly and reduce exhaust emissions. It maximizes the performance of a single-cylinder injection automatic engine, and it is necessary to add the appropriate ethanol-diethyl ether. The correct mixture ratio can produce better combustion. This study will be analyzed the effect of variations in the addition of ethanol (2%, 5%, 8% dan 10% v/v)-diethyl ether (5% v/v) on performance and exhaust emissions of single cylinder injection automatic gasoline engines.

2 EXPERIMENTAL METHODS AND MATIC ENGINE-SI ATTEST

2.1 Fuel Properties

In testing the performance of the SI automatic engine, 3 variations of fuel have been used, namely gasoline, ethanol and diethyl ether. Table 1 (Maciej Serda et al., 2016; Okoronkwo et al., 2017; Setyono, 2020; Setyono & Arifin, 2020; Setyono & Kholili, 2021; Srihari et al., 2018) shows that the octane value of gasoline is lower than ethanol and diethyl ether. However, for the cetane number of diethyl ether, which is higher than for gasoline and ethanol, the cetane number is a measure of the delay in burning the fuel. The calorific value of the fuel affects the flame character of the fuel. The higher the value, the smaller the ignition energy and vice versa. The stoichiometric condition of A/F of ethanol is lower than diethyl ether and gasoline. The self-ignition temperature of ethanol is higher than gasoline and diethyl ether, and it is directly proportional to the low heating value of the fuel. The flash point value of ethanol is higher than gasoline and diethyl ether because the fuel fraction will evaporate and cause fire when exposed to sparks and then turn off by itself within a short time. In these conditions, it has been unable to make the fuel react and produce a continuous fire. The boiling point of diethyl ether is lower than that of ethanol and gasoline, and this occurs when the temperature at the vapour pressure of a liquid is the same as the external pressure experienced by the fuel.

2.2 Matic Engine-SI Utilized

This study uses a one-cylinder automatic engine with a capacity of 115cc single-OHC. The maximum power of the engine increases when the speed is 8000 rpm. Table 2 shows that the fuel supply system uses a conventional carburetor with air mixing through the manifold. The ignition system in the combustion chamber uses iridium spark plugs. The engine transmission system uses an automatic timing belt with an ACC-dry clutch type.

2.3 Performance Testing Engine

There are several stages of performing a performance test on the chassis dyno test shown in figure 1. First, the fuel variations have been determined, namely ethanol (2%, 5%, 8% and 10% v/v) and diethyl ether (5% v/v). In the second step, a variety of fuel is supplied to the 115cc automatic engine, and make sure all hardware (CPU, screen, keyboard) is functioning on the Dyno test system. The third step, raise the vehicle to be tested on Dynotest, setup the fasteners on the front tires, as well as the sides of the vehicle frame so that when testing the vehicle, it is safe and stable, Then adjust the position of the rear wheels on the roller, turn on the vehicle, and apply the test torque and power by dragging the vehicle's throttle lever from low to high speed (4000-9000 rpm) on the vehicle. In the fourth step, observe the results of the test graph reading on the monitor screen. It will get the results of the vehicle's torque, power and exhaust emissions.

Table 1: Characteristics of the variety of fuels used

Properties	Index	Ethanol	Gasoline	Diethyl Ether
Chemical term	-	C_2H_5OH	C_nH_{2n+2}	C_2H_5-O-C_2H_5
Octane number (RON)	Rs	107-111	90	105-123
Vapor pressure at 58°C	^{0}C	0.21	0.8	-
Boiling point	^{0}C	78	43-170	34.6
Lower calorific value	kJ/kg	26880	44100	33900
Stoichiometric	A/F	9	14.7	11.1
Cetane number	Rs	8	8.14	>125
Self-ignition temperature	^{0}C	423	300-450	160
Flash point	^{0}C	13	-43	-45
Molecular weight	kg/mol	46	114.2	74.12

Table 2: Details of the rigs matic engine-SI.

Description Details	Specifications value
Maximum power (kW)	8 kW / 8.000 rpm
CR	8.8 : 1
Weight (kg)	164 kg
Volume of Step (cm^3)	4-stroke, 113.7 (SOHC)
Fuel system	Carburettor
Cooling system	Air cooling
Transmission	Otomatic, V-Matic
Ignition System	Iridium
Coopling	ACC Dry Type

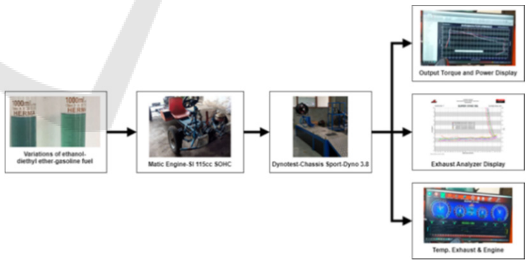

Figure 1: Performance testing matic engine-SI flow.

3 RESULT AND DISCUSSION

The highest maximum power generated on the E10D5 fuel is 8.36 kW at an engine speed of 8000 rpm. The most undersized maximum power is produced by E2D5 fuel, with a power of 7.76 kW at 8000 rpm engine speed. On average, adding 10% ethanol and 5% diethyl ether to RON 90 fuel will increase engine power by 8.6% compared to RON 90. On the other hand, adding ethanol with levels of 2%, 5%, 8 %, and 10% can reduce engine power. Figure 2 shows the lowest power generated by the E2D5 engine, with a power of 7.76 kW at an engine speed of 8000 rpm. The addition of Ethanol-diethyl ether can reduce power compared to using pure premium. It happens because adding Ethanol-diethyl ether will reduce the calorific value to too low. With this decrease in calorific value, the energy that can be released from the fuel also decreases, so the power produced is also lower. Another thing happened with the addition of 10% ethanol and 5% diethyl ether (E10D5) which could increase engine power. The increase is due to the addition of suitable ethanol-diethyl ether to produce the right chemical mixture to complete combustion. It will provide greater power so that the power generated is more excellent than standard fuel. In addition, it can also be caused by better fuel fogging, so fuel atomization becomes better and produces better combustion.

The highest maximum adequate pressure is produced on the engine using E10D5 fuel with a maximum average adequate pressure of 925.54 KPa at an engine speed of 5000 rpm. The most negligible maximum adequate pressure produced on E2D5 fuel is 872.41 kPa. In Figure 3, it can be seen that RON 90 fuel, with the addition of 2%, 5%, 8% and 10% ethanol and 5% diethyl ether concentrations, has a decreasing average adequate pressure. It can be seen that the lowest average adequate engine pressure on E2D5 fuel is 872.41 kPa at 5000 rpm. The decrease in the average adequate pressure is caused by adding 2%, 5%, 8% and 10% ethanol, reducing the calorific value to too low. With this decrease in calorific value, the energy that can be released from the fuel also decreases, so the resulting pressure is also lower. Different things happen in mixing Premium fuel with 10% ethanol. With this addition, the average adequate pressure of the engine tends to increase. Figure 3 shows the maximum adequate pressure generated by the engine when using a fuel mixture of 90 RON, 10% ethanol and 5% diethyl ether, with an average adequate pressure of 925.54 KPa at an engine speed of 5000 rpm.

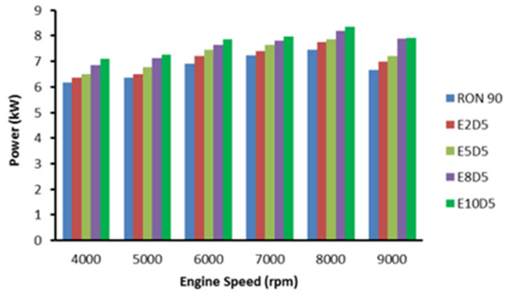

Figure 2: Function of comparison of output power to engine speed.

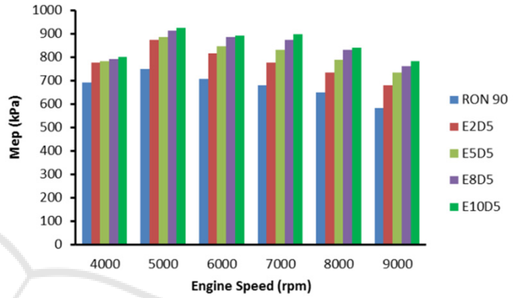

Figure 3: Effective pressure comparison function to engine speed.

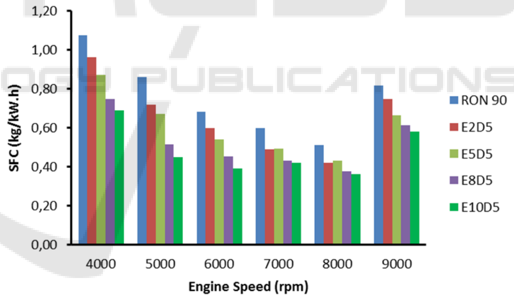

Figure 4: Specific fuel comparison function to engine speed.

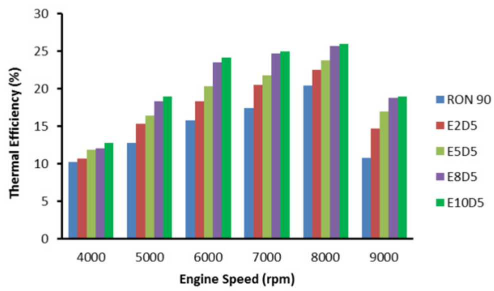

Figure 5: Thermal efficiency comparison function against engine speed.

Figure 4 shows that with the addition of 2%, 5%, 8% and 10% ethanol and diethyl ether 5%, the specific fuel variation of ethanol-diethyl ether produced by the engine is higher than using RON 90 fuel. RON 90 fuel, with an optimum value of 0.36 kg/KW.hour at an engine speed of 8000 rpm. Fuel with the addition of 2%, 5%, 8% and 10% ethanol and 5% diethyl ether will increase the engine's specific fuel consumption. The increase was caused by adding ethanol-diethyl ether in RON 90, which would reduce the calorific value of the fuel so that in order for combustion to take place more completely, the fuel supply had to be increased. Figure 5 shows that the highest optimum efficiency is obtained when the engine uses RON 90 fuel with the addition of E10D5 of 25.89% at an engine speed of 8000 rpm, while the lowest optimum efficiency is obtained when the engine uses RON 90 fuel with the addition of E2D5 of 22.47% at rpm. 8000 rpm engine. On average, compared to engines using RON 90 fuel, the increase in thermal efficiency when E10D5 is added is 5.3%, while the decrease in efficiency due to the addition of E2D5 is 7.8%. In general, the thermal efficiency tends to decrease with the addition of ethanol-diethyl ether. This is because adding ethanol-diethyl ether with this concentration can reduce the calorific value of the fuel so that the fuel used for complete combustion is more than pure Premium. With a low calorific value, the energy released from fuel tends to decrease, so the resulting performance also tends to decrease. Therefore, with a decrease in performance, efficiency will also decrease.

Figure 6 shows that the highest CO emissions occur when the engine uses RON 90 fuel. In comparison, the lowest emissions are produced by engines using an E10D5 fuel mixture. In general, the decrease when using the addition of E10D5 is 32% compared to RON 90. In general, with the addition of ethanol-diethyl ether, CO exhaust emissions tend to decrease. This decrease is caused by adding ethanol-diethyl ether, resulting in better combustion in the combustion chamber. With this addition, CO emissions which tend to be high when using pure Premium, will decrease. In addition, it can also be caused by adding ethanol, resulting in better fuel misting, so that fuel atomization becomes better and produces better combustion. Figure 7 shows that with a mixture of ethanol-diethyl ether, the HC emissions produced by exhaust gases tend to decrease. This decrease is caused by adding ethanol-diethyl ether, resulting in better combustion in the combustion chamber so that the exhaust's unburned hydrocarbon wasted exhaust is reduced by it. With this addition, the HC emission at high speed, which tends to be high when using pure Premium, will decrease. In addition, it can also be caused by adding ethanol, resulting in better fuel misting, so that fuel atomization becomes better and produces better combustion. Figure 8 Generally, with the addition of ethanol-diethyl ether, CO exhaust emissions tend to decrease. This decrease is caused by adding ethanol-diethyl ether, resulting in better combustion in the combustion chamber. With this addition, CO emissions which tend to be high when using pure Premium, will decrease. In addition, it can also be caused by adding ethanol, resulting in better fuel misting so that fuel atomization becomes better and produces better combustion.

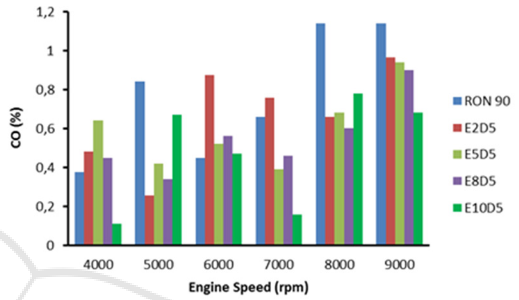

Figure 6: Comparison function of carbon monoxide to engine speed.

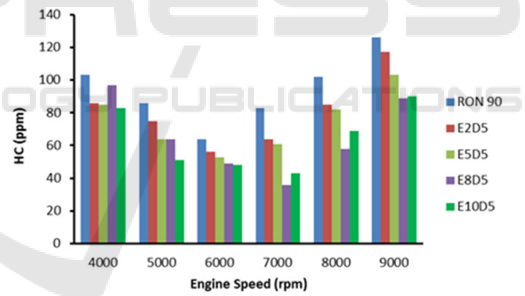

Figure 7: Comparison function of hydrocarbons to engine speed.

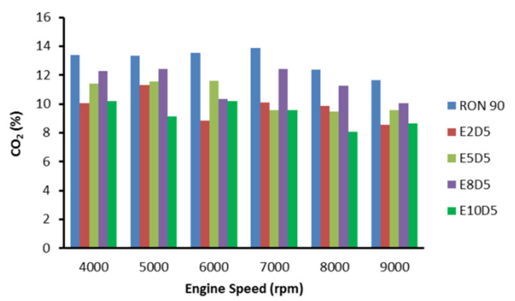

Figure 8: Comparison function of carbon dioxide to engine speed.

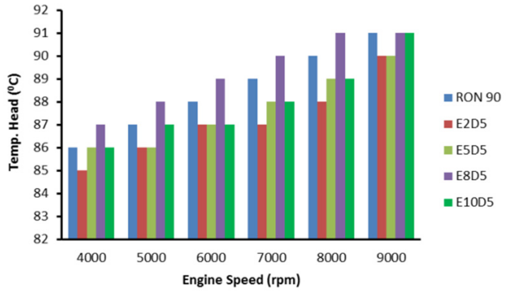

Figure 9: Temperature head comparison function to engine speed.

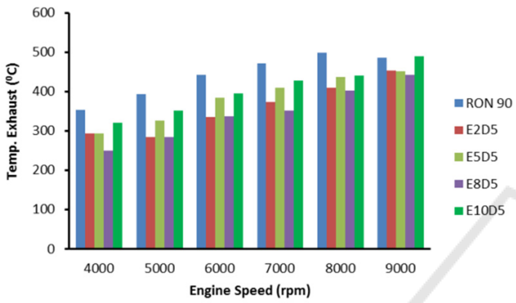

Figure 10: Temperature exhaust comparison function against engine speed.

In Figure 9, the engine temperature with various compositions of the addition of ethanol-diethyl ether shows that the highest engine temperature occurs in the E10D5 fuel mixture. In contrast, the lowest temperature is produced by it when the engine uses the E5d5. On average, the temperature increase when the engine uses the E10D5 fuel mixture is 7% compared to RON 90. In general, with the addition of ethanol-diethyl ether to RON 90, the engine temperature tends to decrease due to the low heating value of the fuel. Another thing is different in the composition of E8D5. First, the correct chemical mixture causes combustion to be complete. With this composition, the combustion process in the combustion chamber occurs so that the energy contained in the fuel can be released more wholly compared to when using RON 90. In addition, it can also be caused by adding ethanol-diethyl ether, resulting in better fuel misting, so that fuel atomization is better and results in better combustion. With good combustion, the resulting temperature in the combustion chamber becomes higher. It can be proven by the low emission of E8D5 followed by E10D5. While for E10D5 fuel, although there is better fogging, the calorific value is much smaller than E8D5, so the temperature graph drops again. Figure 10 shows the highest exhaust temperature when the engine uses a RON 90 fuel mixture. Meanwhile, the lowest exhaust temperature is produced by it when the engine uses E8D5 fuel. On average, there is a decrease of 15% compared to RON 90. In addition, it can be caused by better fuel misting, so that fuel atomization becomes better and produces better combustion.

4 CONCLUSIONS

The maximum power increase in the E10D5 fuel variation is 7.76 kW at 8000 rpm engine speed, so the percentage increase is 8.6%. Mep experienced a maximum increase of 925.54 kPa at an engine speed of 5000 rpm with a percentage increase of 8.7%, Sfc has an optimum increase of 0.36 kg/kW.hour at an engine speed of 8000 rpm, and Thermic efficiency has a maximum increase of 25.89% at an engine speed of 8000 rpm with a percentage increase of 5.3%. The highest increase in exhaust temperature occurred in the engine fueled by RON 90. The highest increase in engine temperature occurred in the E10D5 mixed fuel engine. CO exhaust emissions decreased by an average of 7.2% for all variations of the fuel mixture. HC exhaust emissions decreased by an average of 6.8%. In comparison, CO_2 exhaust emissions increased by 5.2% for all variations of the fuel mixture.We hope you find the information in this template useful in the preparation of your submission.

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