Study on the performance of the Otto engine by using mixtures of gasoline-bioethanol of nira

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Abstract. One of the alternative fuel that can be used for Otto engines is bioethanol. Bioethanol has a high octane number and higher oxygen content than gasoline and produced emissions are more environmentally friendly. This research to determine the Otto engine stationary four-stroke performance when using a gasoline-bioethanol mixture. The study was carried out with variations in the composition of the mix of bioethanol-gasoline, variations in engine speed and load engine. The experiment results show that the maximum thermal efficiency obtained is 29.63% when using gasoline at 1000 rpm and the load of 20 kg. The minimum SFC value is obtained 284.47 gr/kWh at 1000 rpm when using gasoline for the load of 20 kg. The SFC has increased when using a bioethanol-gasoline mixture. However, the exhaust emissions produced when the engine uses a mix of bioethanol-gasoline, it becomes more environmentally friendly.

1. Introduction

The scarcity of fuel oil that occurred in recent years has had a broad impact in various fields of life [1]. The most vulnerable area to be affected is the transportation sector. As a result of fluctuations in the supply and price of petroleum, it made people aware that the number of oil reserves on the earth was running low. Petroleum is a fuel that cannot be renewed, so the replacement material must be started. When viewed from its natural resources, in Indonesia, there are a variety of abundant renewable energy sources, such as biodiesel from Jatropha, palm oil, and soybean. Likewise with bioethanol from biomass, sugar cane, corn, and sap, which can be used as a substitute for gasoline [2, 3]. Besides, pollution from burning fossil fuels harms the environment. Decreasing air quality due to petroleum smoke is one of the effects that can be seen clearly. Then the impact of greenhouse gases caused by CO_2 gas from the combustion of petroleum. As it is known that the burning of imperfect fossil fuels will produce CO_2 gas, which over time will accumulate in the atmosphere. The intensity of solar radiation emitted to the surface of the earth should be reflected into space, but the result of this buildup of CO_2 will block the reflection. The results in radiation being re-absorbed by the earth, which ultimately increases the air temperature on the earth. Both of these effects are only part of the negative impact of fossil fuels, which are then followed by a series of other negative effects on human life. Therefore, the use of a renewable fuel that is safer for the environment is necessary. One of the alternative fuels, as mentioned above, is bioethanol. Bioethanol is one of the types of renewable fuels, which is always quite interesting to study [4]. This study has a purpose of determining the performance of a stationary otto engine by using mixtures fuel of gasoline-bioethanol from nira.

2. Literature Study

2.1. Bioethanol

Towards the 21st century, the world began to think of the alternative energy that could be used for Diesel and Otto engines [5, 6]. One of the alternative fuels developed is alcohol fuel. Alcohol is one of the types of hydrocarbons which one of the hydrogen atoms is replaced with hydroxyl radical OH. Alcohol types are methyl alcohol or methanol. Hydrocarbon fuels can be found in thousands of variations of components, not only consisting of hydrogen and carbon but also containing oxygen (ethanol), nitrogen, sulfur, and others. The chemical energy will appear to be hot when the fuel is reacted or burned with oxygen in a balanced state [7]. Oxygen converts the carbon elements in the fuel into CO_2 and hydrogen into H_2O. The most widely used hydrocarbon fuels for internal combustion engines are diesel oil and gasoline. Bioethanol is ethanol (C_2H_5OH) which produced from vegetable ingredients [8, 9]. Bioethanol is a clean liquid that is colorless if it is used, it will not cause pollution to the environment, and if burned, it produces charcoal gas (carbon dioxide or CO_2) and water. Bioethanol has a research octane number (RON) of 108.6 and an octane number of 89.7 [10, 11]. The high octane number in bioethanol that it can function as additives such as Tetra Ethyl Lead and Methyl Tertiary Butyl Ether. Bioethanol generally contains 35% oxygen to improve combustion efficiency better and reduce emissions of greenhouse gases [12]. Carbon monoxide and hydrocarbon emissions from vehicles using bioethanol are generally lower than gasoline.

2.2. The Parameter of The Internal Combustion Engine

2.2.1. Power

The main power in the combustion engine is generally namely the shaft power or effective power and the actual power or indicator power. This power is affected by the engine speed and torque produced by the engine. But in the field is used the shaft power. The power of the shaft is the power generated by an engine on the output shaft or commonly known as the brake horsepower calculated by the formula [13]:

$$\dot{W}_b = \frac{2\pi \, . \, N \, . \, \tau}{60000} \tag{1}$$

Where $\dot{W}_b$ is engine power (kW), N is engine speed (rpm), and τ is torque (Nm).

2.2.2. Specific fuel consumption

The fuel consumption is the fuel consumed by the unit of power produced per hour of operation. Indirectly specific fuel consumption (SFC) is an indication of engine efficiency in generating power from fuel combustion. The specific fuel consumption can be defined as follows:

$$sfc = \frac{\dot{m}_f}{\dot{W}_b} \, . \, 3600000 \tag{2}$$

Where SFC is specific fuel consumption (gr/kWh), and $\dot{m}_f$ is mass flow fuel to the combustion chamber (kg/s).

2.2.3. Thermal Efficiency

The thermal efficiency of an internal combustion engine is defined as the ratio between the output energy and the chemical energy contained in the fuel in the form of fuel sucked into the combustion chamber. Thermal efficiency can be defined as:

$$\eta_t = \frac{\dot{W}_b}{\dot{m}_f \cdot Q_{HV} \cdot \eta_c} \tag{3}$$

Q_{HV} is calorific value (kJ/kg) and η_c is combustion efficiency (0,97).

2.2.4. Volumetric Efficiency

One of the most important to regulate the power and performance that can be obtained from a combustion engine is to get the maximum air into the cylinder during each cycle. The more air means more fuel can be burned so that more energy can be converted into output power. Volumetric efficiency is defined as:

$$\eta_v = \frac{m_a}{\rho_a \cdot V_d} \tag{4}$$

Where m_a is air mass (kg), ρ_a is specific mass (kg/m^3), and V_d is volume displacement (cc).

3. Methodology

The fuels used are premium or gasoline (P), a mixture of 95% gasoline and 5% bioethanol (P95 + E5), 90% gasoline mixture and 10% bioethanol (P90 + E10), 85% gasoline mixture and 15% bioethanol (P85 + E15), a mixture of 80% gasoline and 20% bioethanol (P80 + E20). The equipment used in consisted of a stationary four-stroke Otto engine with four cylinders, a calorimeter bomb to calculate the calorific fuel value and a gas analyzer to determine the composition of exhaust emissions. A stopwatch is used to determine the time needed of the engine to consume fuel with a volume of 50 ml. This experiment is performed on variations in engine speed, namely 1000, 1500, 2000, 2500, 3000, 3500 rpm and variations in the load of 10 kg and 20 kg. The experiments are carried out without modifying the Otto engine.Table1 shows the specification of TD4A 024 4-stroke gasoline engine.

Figure 1. Otto engine used

Table1.Specification of TD4A 024 4-stroke gasoline engine

TD4A 024 - 4 Stroke Otto Engine	
Type	TecQuipment TD4A 024
Bore/stroke	73 mm/80.5 mm
Compression ratio	10
Displacement volume	1347.7 cc
Firing order	1-3-4-2
Fuel tank capacity	10 liters

4. Results and Discussions

4.1. Calorific value

The experimental results show that was the lowest heating value was found in the fuel of P80 + E20 about 28671.85 kJ/kg. The fuel heating value indicates the energy produced during the fuel combustion process per unit of mass where the heating value is affected by the composition of the fuel. Table 2 shows that the higher the concentration of bioethanol in the mixtures, the lower the fuel heating value. This is due to the presence of oxygen in the structure of bioethanol. So to get the same energy, the amount of bioethanol needed is higher.

Table 2. The calorific value of fuels tested

Fuel	Calorific value (kJ/kg)
Gasoline	44260.12
P95 + E5	40013.05
P90 + E10	33818.92
P85 + E15	30730.68
P80 + E20	28671.85

4.2. Otto Engine Performance

4.2.1. Torque

The maximum torque value obtained is 86 Nm when using gasoline fuel at 1000 rpm and the load of 20 kg. The minimum torque obtained is 55 Nm when using P80 + E20 and a load of 10 kg at 3500 rpm. The average torque obtained during testing is 71.1 Nm. The torque generated when the engine uses a mixtures fuel decreases with the increasing composition of bioethanol in the mixture. The energy of the fuel combustion strongly influences the torque. The energy produced by combustion is affected by the heating value of the fuel. As a note that the heating value of gasoline is higher than the heating value of the mixtures fuel.

4.2.2. Power

The maximum power obtained is 25.47 kW when the engine uses gasoline at 3500 rpm and the load of 20 kg. The minimum power obtained is 7.59 kW at 1000 rpm and the load of 10 kg when using P80 + E20. The average power generated from the test is 16.25 kW. The most influences on the energy produced by the engine are torque. This is because changes in power are directly proportional to engine torque.

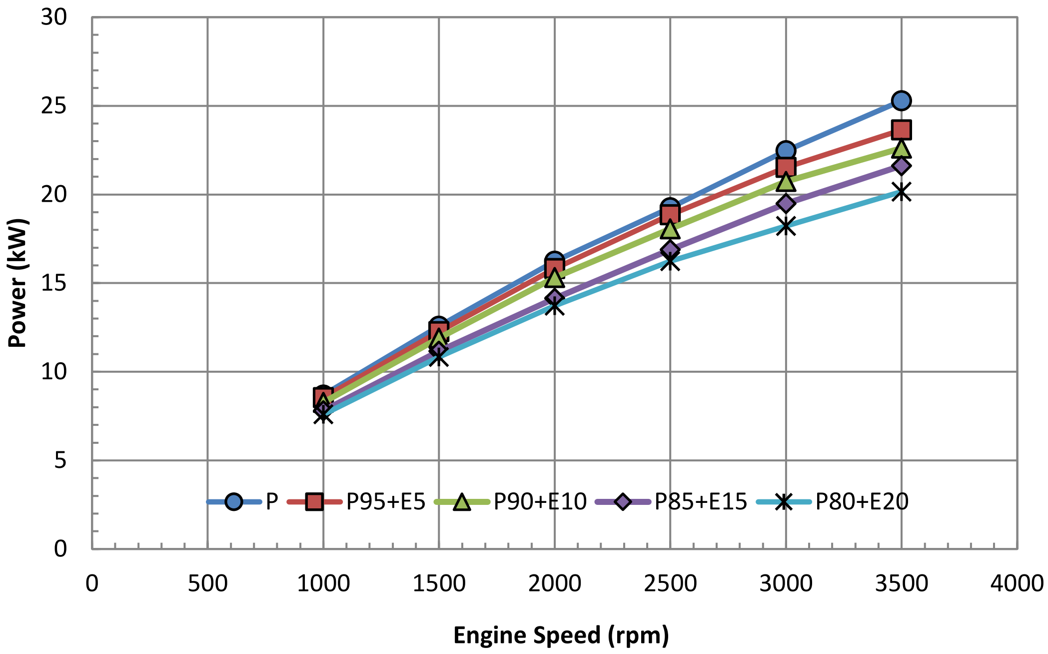

Figure 2. Power versus engine speed for the load of 10 kg

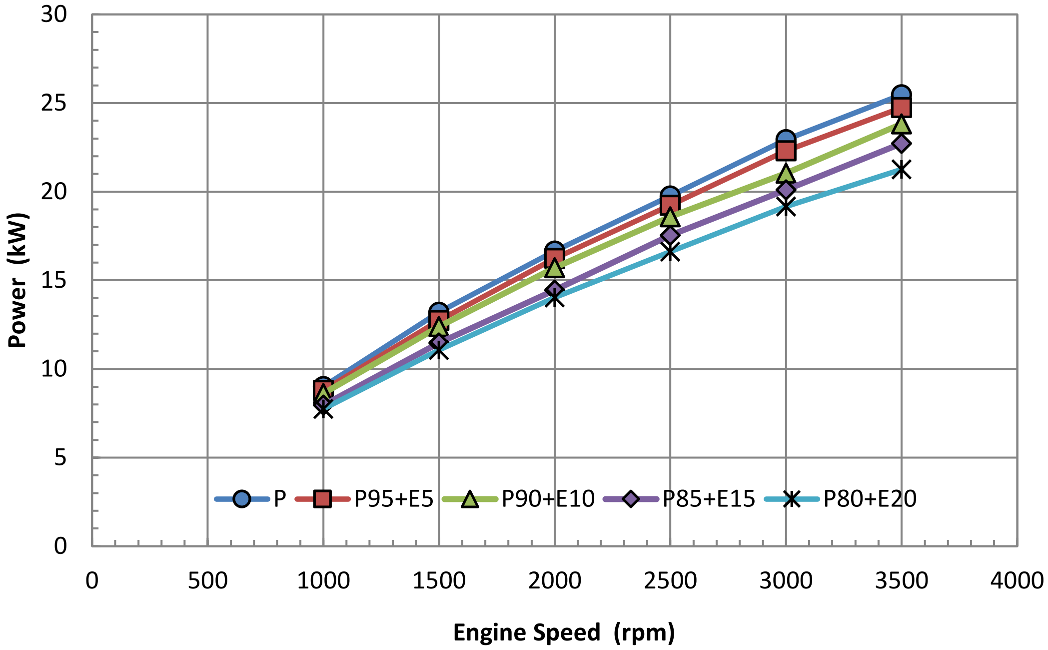

Figure 3. Power versus engine speed for the load of 20 kg

4.2.3. Specific fuel consumption (Sfc)

The test results show that the maximum SFC of 536.56 gr/kWh when using mixed fuel of P80 + E20 at 3500 rpm and the load of 20 kg. The minimum SFC value is obtained 284.47 gr/kWh at 1000 rpm and the fuel used is gasoline at the load of 20 kg. The average specific fuel consumption achieved is 380.24 gr/kWh. In general, the specific fuel consumption for the Otto engine when using mixedgasoline- bioethanol has increased. This is because the presence of oxygen in bioethanol causes the mixture of air-fuel to be poorer so that to get the desired performance, the air-fuel mixture must be the rich mixture. This condition makes the fuel needed to be higher than when using gasoline.

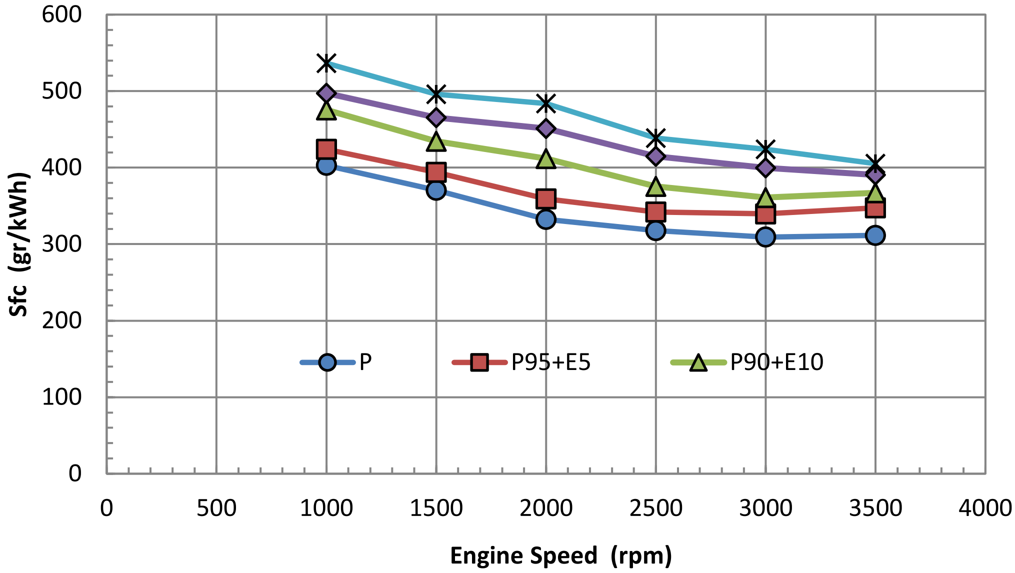

Figure 4. SFC versus engine speed for a load of 10 kg

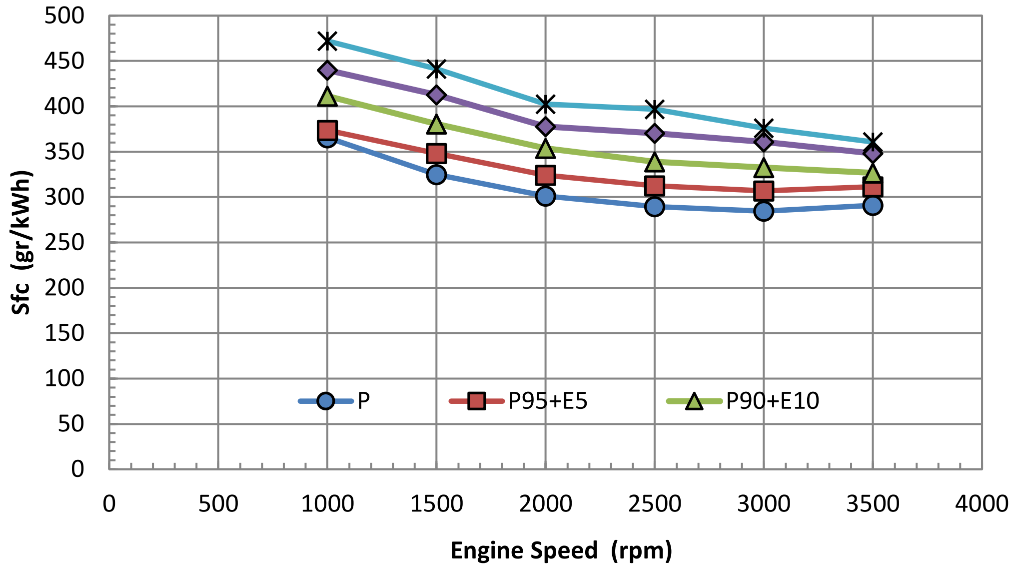

Figure 5. SFC versus engine speed for a load of 20 kg

4.2.4. Thermal and Volumetric Efficiency

The experimental results show that the maximum thermal efficiency was 29.63% using gasoline at 1000 rpm and the load of 20 kg. The minimum thermal efficiency value was obtained 15.71% when using P80 + E20 at 3500 rpm for the load of 20 kg. The average thermal efficiency resulting from the experiments was 22.67%. As it is known that the thermal efficiency of the internal combustion engine is influenced by engine power, the fuel flow rate to the combustion chamber and the heating value of the fuel used. All three simultaneously affect the achievement of thermal efficiency of a combustion engine. The average volumetric efficiency of 83.68%. The volumetric efficiency is affected by the mass of water entering the combustion chamber, environmental air density, and volume displacement. Water density is affected by air pressure and ambient temperature during testing. In these experiments, the air pressure is 1 atm, and the ambient temperature is around 28^{o}C.

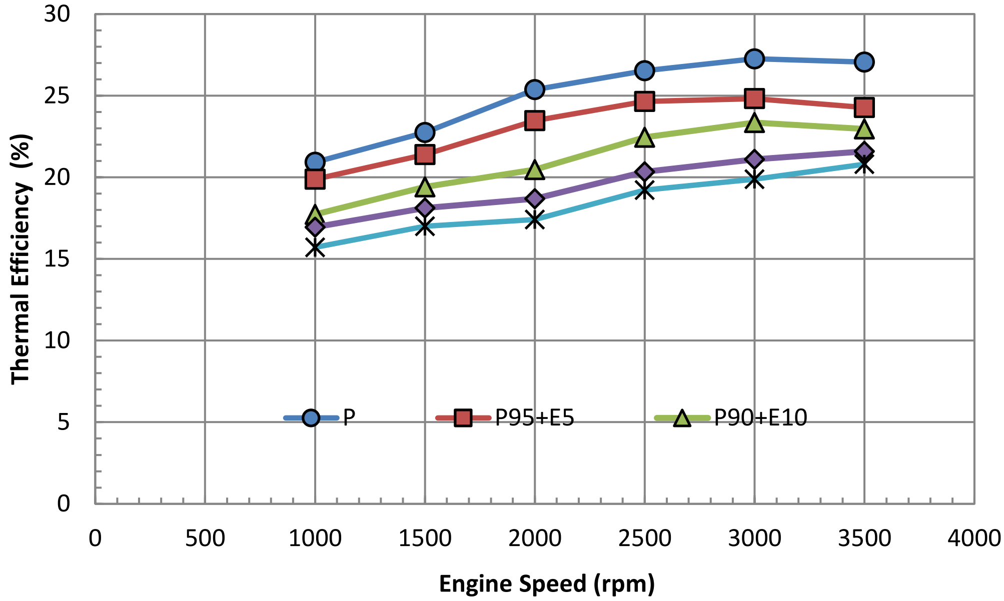

Figure 6. Thermal efficiency versus engine speed for a load of 10 kg

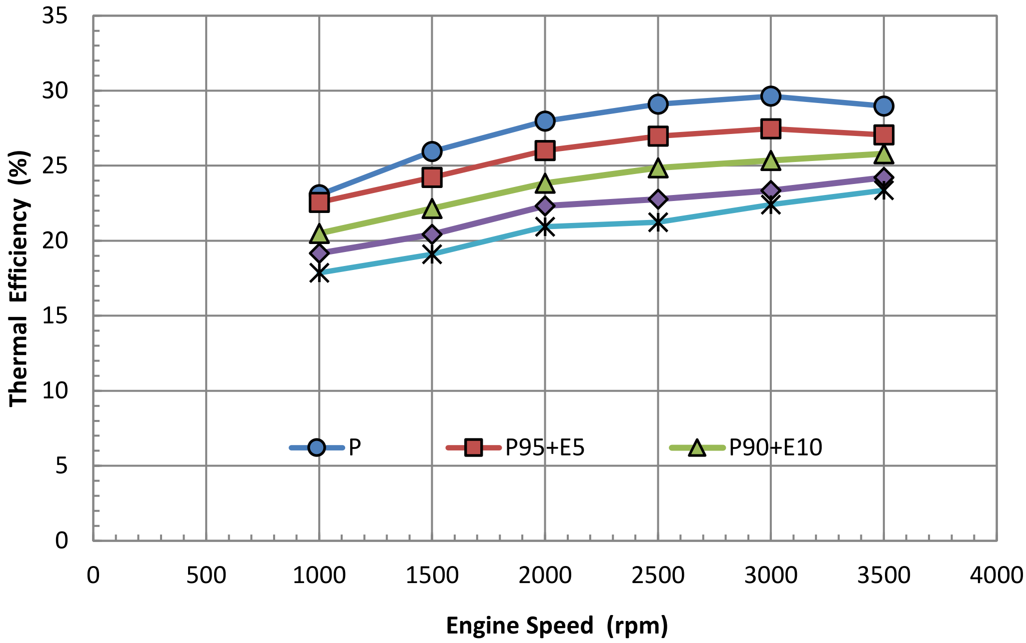

Figure 7. Thermal efficiency versus engine speed for a load of 20 kg

4.3. Exhaust Gas

4.3.1. Carbon monoxide (CO)

Based on the test results that the use of gasoline-bioethanol mixture for various compositions was obtained by reducing carbon monoxide (CO) exhaust emissions by 17.69%. Exhaust emissions of CO occur due to lack of oxygen so that the combustion process takes place imperfectly because many carbon atoms do not get enough oxygen to form CO gas. CO gas emissions increase with increasing engine speed. Bioethanol has one OH molecule in its molecular composition. The oxygen contained in the bioethanol molecule helps improve combustion between the air-fuel mixture in the cylinder, and bioethanol has a long range of flammability when compared to gasoline so that combustion takes place correctly.

4.3.2. Carbon dioxide (CO_2)

The measurement data of the gas analyzer show that by using gasoline-bioethanol mixtures, fuel makes carbon monoxide (CO) emissions decrease thereabouts 23.11%. Carbon and oxygen produce CO as a result of incomplete combustion and carbon dioxide (CO_2) as a result of complete combustion. If the air-fuel mixture is stoichiometric, CO_2 compounds will be produced. Fuel volatility indicates the ability of a fuel to evaporate. Bioethanol has less volatility than gasoline, wax formation, and more natural evaporation of fuel and air-fuel mixing goes well.

4.3.3. Unburned Hydro Carbon (HC)

Based on the measurement data was obtained 34.27% reduction in exhaust emissions of unburned hydrocarbons (UHC) when Otto engines used mixtures fuel for various compositions. The emission levels of UHC is higher in the use of gasoline when compared to mixtures fuel because the gasoline has a heavy compound that has a more extended number of carbon chain bonds compared to bioethanol. This is also due to incomplete combustion in the cylinder. Bioethanol, which has an OH bond in its molecular structure makes fuel combustion better.

4.3.4. Oxygen (O_2)

The measurement data shows that there is an increase in oxygen levels in the exhaust gas emissions of 16.82% when the engine uses mixtures fuel for various compositions. The combustion process on the Otto engine takes place on a rich air-fuel mixture to ensure the continuity of the combustion process so that in the exhaust gas the combustion results still contain O_2. The remaining O_2 exhaust gas from burning the mixtures fuel is higher than gasoline. This is because the oxygen content is directly bound to the bioethanol fuel compound.

Based on data from the test results conducted so that an analysis of Otto engine performance and exhaust emissions has been analyzed using mixtures of bioethanol from nira-gasoline oil. The study shows that the bioethanol from nira can be considered as an alternative fuel. Due to the depletion of fossil fuel supply conditions, it is expected that the development of alternative fuels such as bioethanol oil needs to be increased. Besides that, this fuel is immensely contributing to supporting environmental sustainability globally and has the potential availability of raw materials to be developed.

5. Conclusions

The heating value of fuel greatly influences the energy produced by the combustion of fuel. The higher the heating value of the fuel, the higher the combustion result and vice versa, and the heating value of the gasoline-bioethanol mixture was lower than gasoline. The experimental data show that the performance of the four-stroke stationary Otto engine with four cylinders, when using gasoline produces higher torque, power, and thermal efficiency and lower specific fuel consumption when compared to mixtures fuel. The maximum thermal efficiency obtained is 29.63% when using gasoline at 1000 rpm, and the load of 20 kg and the minimum SFC value is obtained 284.47 gr/kWh at 1000 rpm when using gasoline for the load of 20 kg. The advantage of using bioethanol is that the exhaust emissions produced are more environmentally friendly and reduce emissions for CO, CO_2, UHC, and O_2 thereabouts 10-35%. The most important thing is bioethanol of nira is a renewable fuel that will never run out. As a note that bioethanol from nira is immensely contributing to supporting environmental sustainability globally and has the potential availability of raw materials to be developed.

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