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Experimental study of the effect of adding bioethanol to RON 90 gasoline on exhaust gas emissions of a four-stroke motor vehicle

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ABSTRACT

The use of biofuels in the world is increasing due to their economic prices and an energy crisis. Bioethanol is an alternative renewable fuel suitable for use in internal combustion engines. When compared to the octane number of gasoline, this fuel has a relatively high octane number. Another major property is that bioethanol can reduce motor vehicle emissions when compared to fossil fuels. This study aimed to determine the number of exhaust emissions with fuel that uses a mixture of pertalite RON 90 gasoline and bioethanol. The test method uses a loaded engine with three rpm variations, namely 1200, 6000, and 9000 rpm, with exhaust emission measurement parameters consisting of CO_2, CO, HC, and NO_x. The test used four kinds of bioethanol mixtures, namely bioethanol 5% (E5), bioethanol 10% (E10), bioethanol 15% (E15), and bioethanol 20% (E20), in addition to pure gasoline RON 90 (pertalite). Measurement of exhaust emissions is carried out using an exhaust gas analyzer. The test results show that using a mixture of bioethanol as fuel does not reduce the total amount of exhaust emissions. The proportion of CO_2 tends to grow as the bioethanol mixture increases, and vice versa for the percentage of CO. Meanwhile, the proportion of HC reduced as the bioethanol mixture rose, whereas the percentage of NO_x increased.

ABSTRAK

Penggunaan bahan bakar nabati di dunia semakin bertambah disebabkan oleh harga ekonomisnya dan adanya krisis energi. Bioetanol sebagai bahan bakar alternatif yang bersifat terbarukan sesuai untuk digunakan pada mesin pembakaran dalam. Bahan bakar ini memiliki angka oktan yang cukup tinggi jika dibandingkan dengan angka oktan bensin. Sifat utama yang lain yaitu bioetanol dapat mengurangi emisi kendaraan bermotor jika dibandingkan dengan bahan bakar fosil. Tujuan dari penelitian ini untuk mengetahui besar emisi gas buang dengan bahan bakar yang menggunakan campuran bensin jenis pertalite RON 90 dan bioetanol. Metode pengujian menggunakan mesin terbebani dengan tiga macam variasi *rpm* yaitu 1200, 6000 dan 9000 *rpm* dengan parameter pengukuran emisi gas buang terdiri dari CO_2, CO, HC dan NO_x. Pengujian menggunakan empat macam campuran bioetanol, yaitu bioetanol 5% (E5), bioetanol 10% (E10), bioetanol 15% (E15) dan bioetanol 20% (E20), selain bensin murni RON 90 (pertalite). Pengukuran emisi gas buang dilakukan dengan menggunakan *exhaust gas analyzer*. Hasil pengujian menunjukkan bahwa penggunaan campuran bioetanol sebagai bahan bakar tidak mengurangi seluruh jumlah emisi gas buang. Persentase CO_2 cenderung naik terhadap kenaikan campuran bioetanol dan sebaliknya pada persentase CO. Sedangkan persentase HC menurun dengan naiknya campuran bioetanol dan sebaliknya persentase NO_x meningkat dengan campuran bioetanol pada bensin.

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1. Introduction

Motor vehicles are one of the most significant sources of air pollution in metropolitan areas since they are the primary mode of transportation. The amount of emissions produced by motorized vehicles is strongly influenced by the quality of the fuel and the combustion process in the vehicle's engine. Several pollutants are produced by motorized vehicles that use fossil fuels, namely CO_2, CO, HC, NO_x, and particulates that endanger human health. The

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increasing use of fossil fuels every year causes an increase in pollution and a decrease in the content of petroleum, encouraging people to look for other alternative energy sources as a substitute for petroleum. As a source of renewable energy, bioethanol can be used as fuel for motor vehicle.

Bioethanol (C_2H_5OH) is an alternative fuel obtained and processed from plants with high carbohydrate content such as sugarcane or bagasse, corn or corn cobs, sap, sugar palm, sorghum, cassava, and straw [1-4]. Using bioethanol as a biofuel for motor vehicle fuel mixtures is expected to reduce the number of exhaust emissions that degrade environmental quality [5, 6]. Changes in the composition of fuel using a mixture of bioethanol will affect the concentration of exhaust emissions, so research on the performance of motorized vehicle engines is still being carried out today, both in Indonesia and abroad.

The research results on the use of bioethanol mixtures in motorized vehicles show a decrease in the amount of HC, CO, and NO_x content caused by excess oxygen, thus helping the combustion process more completely [7, 8]. Compared to the octane number of gasoline, this fuel has a relatively high octane number [9]. Observations on exhaust gas pollution conclude that there is a decrease in CO_2, CO, and an increase in HC, especially in a 10% bioethanol mixture for cars with gasoline engines [10]. Research on exhaust gas emissions showed that HC emissions in the bioethanol mixture were higher, and CO was more or less the same in the low bioethanol mixture [11]. Furthermore, in the reduced bioethanol mixture, there can be a decrease in exhaust temperature caused by a lower engine temperature and an air-fuel mixture with excess air [12]. The addition of bioethanol to 2-stroke motor vehicle fuel increased HC emissions at a low percentage of the bioethanol mixture, while CO was the opposite [13]. Another study stated that from experiments conducted on four-wheeled vehicles, it was found that there was a decrease in CO, CO_2, HC, and NO_x due to the addition of a mixture of bioethanol to the vehicle fuel used [14]. The research results in the form of experiments concluded that mixing gasoline with ethanol in the form of a 10% mixture of ethanol with gasoline gave the most effective results compared to the percentage of other mixtures [15]. Some disadvantages of bioethanol mixtures that need to be considered include lower energy, the presence of several aldehydes, difficulty starting the engine in cold conditions due to lower vapor pressure, and increased corrosion, especially on ferrous metal materials [16-18].

From various studies that have been carried out, it can be concluded that bioethanol fuel is a substitute for fuel for motor vehicle. This article results from research in the form of experiments using a mixture of bioethanol 5%, 10%, 15%, and 20% on non-subsidized gasoline fuel type pertalite with RON 90 (research octane number 90) for a four-stroke motorcycle engine. The purpose of the study was to determine exhaust gas emissions consisting of CO_2, CO, HC, and NO_x gases at various engine speeds.

2. Research Methodology

A gasoline motor is a prime mover that utilizes the fuel combustion process in the combustion chamber to convert heat energy into mechanical energy in the form of shaft power with crankshaft rotation [19, 20]. The heat energy resulting from the combustion process in the combustion chamber is obtained from the spark that comes from the ignition of the spark plug. Gasoline motors have a work cycle divided into two types, namely four-stroke gasoline engines and two-stroke gasoline engines. A 4 stroke gasoline motor is a gasoline motor that works in four strokes of the piston and two revolutions of the crankshaft to produce motor power. While the two-stroke gasoline motor only requires two strokes of the piston and one rotation of the crankshaft to produce motor power [21]. This study uses a four-stroke gasoline motor in one work cycle, namely the intake stroke, press stroke, work stroke, and exhaust stroke, with specifications as shown in Table 1.

Table 1. Specifications of 150 cc gasoline motor.

Type	Description
Engine type	Four-stroke, DOHC
Cooler	*Liquid Cooled*
Cylinder diameter	57.3 mm
Piston stroke	57.8 mm
Cylinder capacity	149.16 cc
Maximum power	16.6 HP / 9000 rpm
Maximum torque	13.8 Nm / 7000 rpm
Compression ratio	11,3:1
Clutch system	Wet, *coil spring*

2.1. Bioethanol

Ethanol or bioethanol with the molecular formula C_2H_5OH is a carbon chain compound obtained from the extraction process of plants containing sugar, starch, and cellulose components. The common name also knows ethanol in the market as alcohol. Bioethanol as a chemical is a clear, colorless, volatile liquid and has a sharp aroma. Another important property of bioethanol is that it can be mixed with water, while gasoline is not, so the use of bioethanol as a fuel can cause water content to enter the combustion chamber [22]. The presence of water entering the combustion chamber can cause long-term damage to several engine components, especially components made of copper, brass, aluminum, or steel alloy materials. Damage that may arise in long-term use in the form of corrosion of metal components of the machine. However, when viewed from the auto-ignition temperature and the burning point of bioethanol, which is higher than that of gasoline, bioethanol is safer in storage [23]. Several comparisons of physical properties between fuels derived from bioethanol and gasoline are shown in Table 2 [24].

Table 2. Comparison of physical properties between bioethanol and gasoline.

Physical property	Bioethanol	Gasoline
Chemical formula	C_2H_5OH	C_8H_{18}
Composition by weight (%)		
- Carbon	52.2	85-88
- Hydrogen	13.1	12-15
- Oxygen	34.7	0
Octane Number		
- Research Octane Number (RON)	108	90-100
- Motor Octane Number (MON)	92	81-90
- Density (kg/L)	0.792	0.703
- Boiling temperature (^oC)	77	26-225
- Flash temperature. (^oC)	13	-43
- Auto-ignition temperature (^oC)	423	257
- Specific heat (J/kg. ^oC)	2,386.47	2,009.66

2.2. Methodology

The research method used in the form of experimental observations of motorized vehicles in a horizontal position so that the distribution of fuel flow is normal, as shown in Figures 1 and 2. The motor engine is heated for 40 seconds with an engine temperature of between 600^0 C to 700^0C and observations are made to prevent this from happening leak in the exhaust pipe or muffler. The test was carried out three times with three kinds of RPM, namely 1200, 6000 and 9000 RPM. The test used the loaded method with a dynamometer mounted on the rear wheel of a motorcycle (as shown in Figure 1) on five kinds of fuel mixtures, namely pertalite, pertalite with a mixture of 5% bioethanol (E5), pertalite with a mixture of 10% bioethanol (E10), pertalite with a mixture of 15% bioethanol (E15), and pertalite with a mixture of 20% bioethanol (E20). Mixing gasoline and bioethanol is carried out with a measuring cup with a total volume of 1 liter. The volume composition of gasoline and bioethanol is adjusted to the type of fuel to be tested. For E5 fuel, it is made with a composition of 950 ml of gasoline and 50 ml ml of bioethanol. E10 fuel, has a composition of 900 ml of gasoline and 100 ml of bioethanol. E15 fuel is made with a composition of 850 ml of gasoline and 150 ml of bioethanol and for E20 fuel is made with a composition of 800 ml of gasoline and 200 ml of bioethanol.

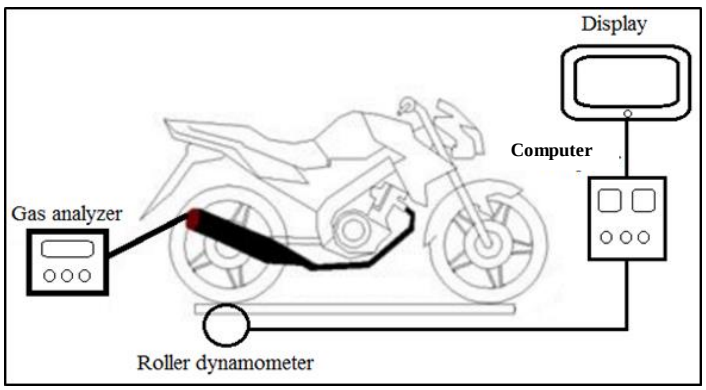


Figure 1. Test scheme using dynamometer and gas analyzer.

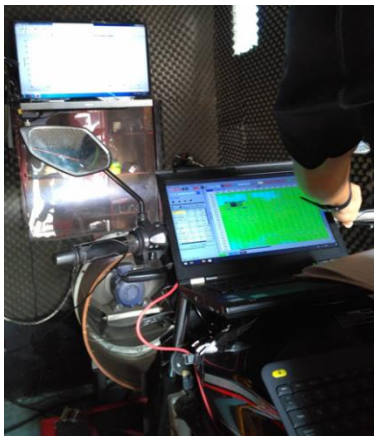


Figure 2. Motor testing using a dynamometer and gas analyzer.

Exhaust emission testing using a gas analyzer as shown in Figure 3 with specifications such as the test equipment as shown in Table 3. The tests were carried out at three different engine speeds, namely 1200 rpm, 6000 rpm, and 9000 rpm. Exhaust emission measurements are carried out for 30 seconds for each type of fuel tested.

Table 3. Specifications of gas analyzer.

Measurement	**CO, HC, CO2, O2, λ, AFR, NOx**			
Measuring range	CO	0.00-9.99%	HC	0-9999 ppm
	O_2	0.0-20.0%	CO_2	0.00-25.00%
	λ	0-2000	NOx	0-5000 ppm
Heating time	2 - 8 minute			
Sample collection speed	4 - 6 L/ minute			
Power	AC 110V, 50/60Hz			
Working temperature	0℃ - 40^{0}C			

Figure 3. Gas analyzer, a tool to measure exhaust emissions.

3. Results and Analysis

Exhaust gas emission is a pollutant that comes from combustion gases resulting from incomplete combustion, and the rest of this combustion is channeled into the free air through the exhaust gas channel in motorized vehicles. The equation for the complete combustion reaction or stoichiometry in the combustion chamber of gasoline (C8H18) is as follows [25]:

$$C_8H_{18} + 12{,}5\ (O_2 + 3{,}76N_2) \rightarrow 8CO_2 + 9H_2O + 47N \quad (1)$$

Carbon dioxide CO_2 and elemental water H_2O are created after full combustion.. However, complete combustion is extremely difficult to achieve in the combustion chamber, resulting in several pollutant compounds. Hydrocarbons (HC) arise due to unburned carbon compounds, causing them to transform into other forms of carbon compounds. Carbon monoxide (CO) arises from gasoline which does not burn completely due to a lack of air in the combustion chamber, and nitrogen oxides (NO_x) which arise due to high temperatures.

The results of testing and measuring exhaust emissions on a four-stroke motorcycle can be concluded that using a mixture of bioethanol in gasoline can reduce CO and HC gases, and vice versa increases CO_2 gas. The bioethanol mixture has a larger oxygen element to increase the amount of air in the combustion chamber.

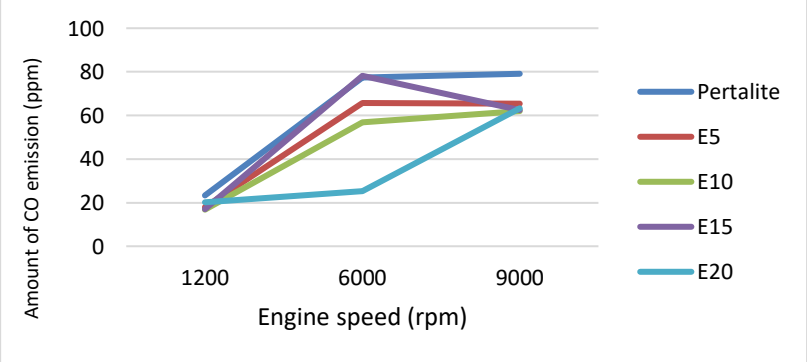
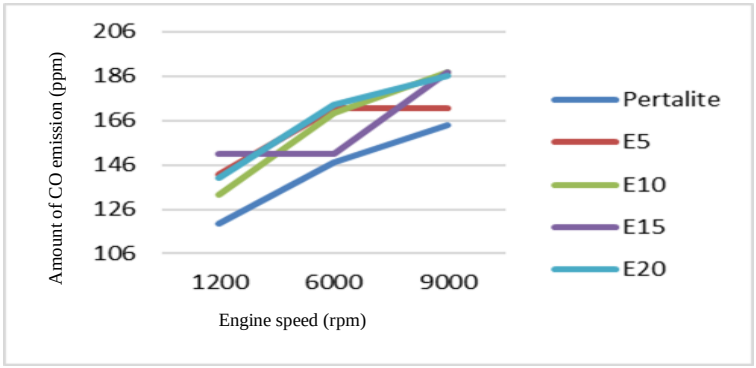


Figure 4. CO2 emissions to engine speed (rpm) for bioethanol fuel mixture.

Measurements using a gas analyzer showed that the amount of CO2 gas increased with fuel use with a mixture of bioethanol (as shown in Figure 4). These results indicate that the fuel mixture of bioethanol experienced a complete combustion reaction. The higher percentage of bioethanol in gasoline fuels causes higher CO2 emissions than using only gasoline [26].

The measurement results on CO gas show that all bioethanol gasoline mixtures produce CO gas, which decreases compared to the use of pertalite gasoline, especially at higher engine speeds, namely 6000 and 9000 rpm (as shown in Figure 5). The bioethanol fuel mixture has oxygen which can increase the percentage of air in the combustion chamber so that the fuel can burn more completely, and there is a decrease in the amount of CO gas [8].



|Figure 5. CO emissions to engine speed (rpm) for bioethanol fuel mixture.

The results of the measurement of HC hydrocarbon gas for gasoline with a mixture of bioethanol tend to decrease the amount of HC gas, as shown in Figure 6. The decrease in the amount of HC gas in fuel with a mixture of bioethanol occurs because the fuel undergoes complete combustion so that the hydrocarbon groups formed by the fuel unburned fuel get smaller [27].

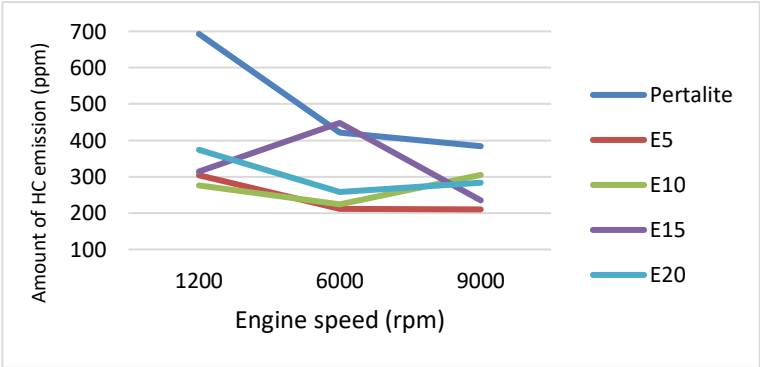


Figure 6. HC emission to engine speed (rpm) for bioethanol fuel mixture.

The high combustion chamber temperature can cause the amount of NO_x gas produced. The amount of NO_x gas in fuel with a mixture of bioethanol increases, especially at low engine speed (1500 rpm), indicating that the combustion chamber temperature is higher than the combustion chamber temperature when using fuel without a mixture of bioethanol (as shown in Figure 7). The temperature in the combustion chamber is higher because bioethanol has an element of O so that it increases the amount of air in the combustion chamber and makes the AFR (air-fuel ratio) value higher. The high AFR value causes less fuel in the combustion chamber, which can help cool the engine, causing the temperature in the combustion chamber to be higher [28].

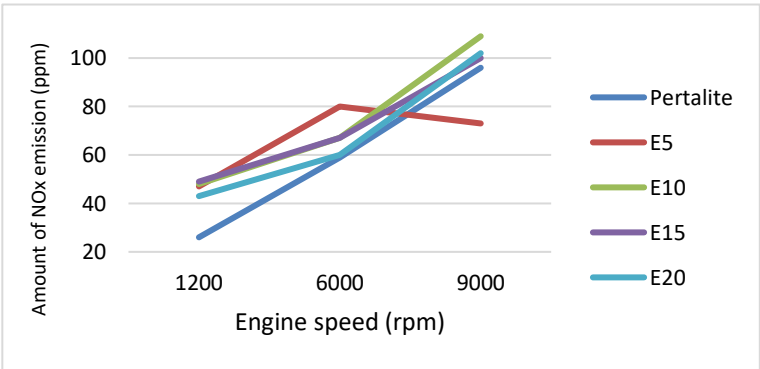


Figure 7. NO_x emission to engine speed (rpm) for bioethanol fuel mixture.

4. Conclusion

Alternative fuels for motor vehicles are increasingly important due to limited fossil fuel reserves and environmental issues. As an alternative fuel that can be used, bioethanol can be produced from renewable energy sources and also produces cleaner exhaust emissions. The results of testing and measuring exhaust emissions on a four-stroke motorcycle with a cylinder capacity of 149.16 ccs show that adding bioethanol to pertalite gasoline can reduce the amount of CO and HC gas emissions. On the contrary, there is an increase in the amount of NO_x gas. Based on the test results data, the E20 bioethanol mixture fuel at 6000 rpm engine speed is better than other bioethanol blended fuels because it produces lower CO and HC gas emissions than other fuel mixtures.

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