Application of Biogasoline in a Four-stroke Motorcycle Engine

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ABSTRACT The problems facing the world, in relation to the increasing consumption of petroleum and its limited sources, as well as pollution by fuel-related gases, such as CO, have sparked research on the application of biogasoline as an environmentally friendly alternative fuel. Our research aimed to determine engine performance through mixtures of biogasoline and gasoline to measure torque, power, and fuel consumption rate, and to determine the effect of the mixture on the level of air pollution. The biogasoline used was previously prepared from cooking oil through a Cr-zeolite-catalyzed process. The testing methods on the fuel mixture as a working substance included engine performance and exhaust emission tests, applied to four-stroke engines with mixtures with gasoline and biogasoline ratios of 95:5, 90:10, and 85:15. The engine performance test results showed that the highest values of torque, power, and average effective pressure were of the fuel with a composition of 85:15. CO and HC, the two emitted gases with high toxicities, based on the air quality standard, should not be more than 5.5% by volume and 2400 ppm, respectively. In this research, the findings indicated that both substances, not exceeding 3.0% by volume and not more than 200 ppm, respectively, are safe and environmentally friendly.

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1. INTRODUCTION

The demand for fossil fuels increases from time to time along with the increasing numbers of vehicles, transportation, industries, and other stationary equipment. Unfortunately, as a limited resource, fossil fuels are predicted to be exhausted within the next few decades. Moreover, as they are generated from combustion emissions, they are also considered to be environmentally unfriendly pollutants, and probably degrading human health. In this case, CO, NO_x, and UHC (unburnt hydrocarbon), as well as metallic elements such as lead (Pb) play a role as direct pollutants while the explosion in the number of CO₂ molecules, which has an impact on global warming, has played an indirect one role. These threats have prompted efforts to find substitutes for petroleum-based energy supplies, with biogasoline being found as one potential renewable energy source. Vegetable oil is currently being introduced as an alternative fuel in dealing with the reduction of fossil fuel reserves (specifically petroleum). Biogasoline should also receive greater attention as a potential contributor to improving national energy security and, in terms of national economic added value, is expected to be a business unit that creates employment (Amin et al. 2019; Hasanudin et al. 2020; Wijaya et al. 2018).

Vegetable oils that can be used as a source of alternative fuel, including palm oil, castor oil, sunflower oil, and palm oil, are common throughout the world. Where palm oil is concerned, Indonesia is its largest producer, followed by Malaysia. Palm oil-based biogasoline is preferred due

to its cheapness compared with pure palm oil. Meanwhile, palm oil residue is reported to be underutilized (Jujarama et al. 2014; Wijaya et al. 2014; Satterfield 1995).

Research on alternative fuels, such as biogasoline, are currently widespread significantly to find fuels with properties similar to those of gasoline with low exhaust emission. Some kinds of biogasoline, however, can be produced by combining or mixing gasoline and other biofuels, such as ethanol and methanol. Sandy (2007) have added ethanol into gasoline in a motorcycle engine and examined the power and exhaust gas emission, finding that the addition of ethanol decreases the exhaust gas emission for every comparative mixing composition.

To test the utilization of ethanol as an octane improver for four-stroke motorcycles with an injection system (Sulistyo et al. 2009), ethanol (with a fuel grade of 99.9%) was mixed into gasoline with a variety of levels (5%, 10%, 15%, and 20%, respectively). The aforementioned study's results showed that the power motor value, for any rpm changes, increased. Exhaust gas emissions also showed that the mixture decreased for carbon monoxide and hydrocarbon emission values.

Mixtures of gasoline and methanol have been found to affect the exhaust gas emissions of four-stroke engines (Arijanto and Haryadi 2012). Using 20%, 40%, and 60% methanol, the aforementioned study found that low exhaust emissions were obtained when using 60% methanol.

Our research aimed to determine the engine performance through mixtures of biogasoline and gasoline to

measure torque, power, and fuel consumption rate, as well as to determine the effect of the mixture on the level of air pollution.

2. MATERIALS AND METHODS

2.1 Biogasoline source

Biogasoline was obtained from an experiment previously conducted by (Jujarama et al. 2014). Biogasoline data were obtained through composition tests performed in the laboratory of the Chemical Engineering Department, Universitas Gadjah Mada, Indonesia. The results of composition test are presented in Table 1.

2.2 Exhaust gas emission

The materials used for examining exhaust gas emissions were gasoline and biogasoline, while the tools used were a tachometer, exhaust gas analyzer, measuring cups, and other essential equipment in the form of warehouse tools.

The exhaust gas emissions test steps were as follows. The engine was warmed up for 5 minutes while the fuel tank was drained and refueled with the fuel that would be tested. The tachometer was installed on the spark plug wires and the wind was set to achieve the desired speed of 2000 rpm. The exhaust gas analyzer was turned on and set into the auto-zero position to eliminate any influence of previous emission analysis. When CO reached its highest level and went back down, the data were recorded. The results of the test data for each fuel and rpm were recorded. For different rpm values with similar fuel, the gas analyzer was set into the auto-zero position to read rpm data. The tank was then drained in order to test other fuel mixture variations through the same steps.

2.3 Engine performance test

The materials used for the engine performance test were the gasoline and biogasoline. The instruments used were a dyno test, a stopwatch, measuring cups, and other essential equipment in the form of warehouse tools.

The engine performance test steps were as follows. The engine was warmed up for 5 minutes while draining the tank, which was then refueled with the fuel that would be tested. The engine was turned on for measuring rpm,

fuel consumption, and torque. The data obtained were then transferred to the computer to achieve the engine operating condition. The gears were fed into transmission 3 to let the rotation and torque generated become the same as the crankshaft rotation (dyno procedure).

The engine rotation was set to reach 2000 rpm. The computer operator was then ready to retrieve data for 60 seconds using a stopwatch. The data obtained were stored in a computer. At 2000 rpm, data collection was performed once. The computer was normalized when the engine rotation was increased up to 3000 rpm. The computer was reset for data retrieval by adjusting the time on the stopwatch to be 60 seconds. The same procedure was used at 4000 rpm. The fuel tank was drained again thoroughly for each fuel variation.

3. RESULTS AND DISCUSSION

3.1 Engine performance data

3.1.1 Torque

The results of the engine test carried out with fuel variations and different engine speed torques are presented in Figure 1.

The torques measured for this test were those after passing the centrifugal automatic clutch, transmission gears, and the connection between shaft, clutch, and transmission gears. Figure 1 shows that the torque on each variable would rise at an engine speed of 3000 rpm. On the other hand, it went down at an engine speed of 4000 rpm. The highest torque value of all the variables, namely of 8.82 Nm, was obtained at 3000 rpm using 85% gasoline-15% biogasoline, while the lowest one, namely 7.32 Nm, was at 2000 rpm using gasoline.

FIGURE 1. Torque vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

FIGURE 2. Shaft power vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

TABLE 1. Results of composition test of biogasoline ASTM (Jujarama et al. 2014).

No.	Test properties	Unit	Biogasoline result	Test method
1.	Specific gravity at 60/60°F	kg/m ³	736	ASTM D 1298
2.	Copper strip corrosion	-	1B	ASTM D 130
3.	Gross heating value	Btu/Lb	20.255	Calculation
4.	Reid vapour pressure	Kpa	61.9	Astm D 323
5.	Distillation	-		IKU/5-4/TK4
	10% rec.	°C	52	
	50% rec.	°C	93	
	90% rec.	°C	170	
	FBP	°C	230	

Source: results of test conducted in Coal, Gas, and Oil Laboratory, Chemical Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Indonesia.

3.2 Shaft power

A similar equation was applied on different rotations and mixing fuel variations, with the data obtained as follows.

Figure 2 shows that the shaft power generated increased along with the increase in engine rotation. Shaft power is the product of the torque and the angular velocity. Therefore, it is highly dependent on the value of the torque generated by the motor fuel. The greater the torque and angular velocity, the greater the power generated. The differences of each variable or rpm on each fuel variable were not too significant, as shown by the graph of power vs. engine rotation.

3.3 Average effective pressure

At 2000, 3000, and 4000 rpm, the average effective pressure values resulting from the 95%-5% gasoline-biogasoline mixture were 72.2 kPa, 69.1 kPa, and 24.6 kPa, respectively, while that of the 90%-10% gasoline-biogasoline mixture were 109.4 kPa, 92.9 kPa, and -16.4 kPa, respectively (Figure 3). Of the 85%-15% gasoline-biogasoline mixture, the average effective pressure values were 115 kPa, 94.2 kPa, and -13.6 kPa, respectively. It can be concluded that the average effective pressures of all mixture types had smaller values compared with that of pure gasoline when applied at 4000 rpm.

3.4 Specific fuel consumption

A similar equation was applied on different rotation variations and different mixing fuel variations. The data obtained were as follows.

Figure 4 shows that the fuel consumption rate increased along with the increase of engine rotation and decreased along with the addition of biogasoline, at similar a

FIGURE 3. Average effective pressure vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

FIGURE 4. Fuel consumption vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

TABLE 2. Motorized vehicle exhaust emissions pick-test results.

Category	Year	Limit value	
		CO (%)	HC (ppm)
2-stroke engine	< 2010	4.5	12000
4-stroke engine	< 2010	5.5	2400
2- and 4-stroke engine	≥ 2010	4.5	2000

Source: Yogyakarta Environmental Agency.

rpm. The fuel consumption is the mass of the fuel required per time unit. It depends on the engine rotation: the higher the engine speed, the more the fuel required for the combustion process. The specific fuel consumption is the fuel consumption rate divided by the shaft power. The higher the power generated with the same fuel value, the lower the specific fuel consumption. The faster the engine rotation, the smaller the specific fuel consumption value and the greater the fuel's mass flow rate per unit time (g/s), or MF value, since the specific fuel consumption value, which is strongly influenced by the power generated by the combustion, is obtained from the MF value divided by the power.

3.5 Exhaust gas emission data

Each motorized vehicle produces exhaust gases that are very dangerous for the environment, including human health. For this reason, there must be regulations to restrict the maximum levels of toxic gases such as CO and HC generated by engines, as those shown in Table 2

An efficiency value indicates the air composition in the combustion process. The efficiency value for each variable had no significance, as can be seen in Figure 5.

FIGURE 5. Efficiency vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

FIGURE 6. CO vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

FIGURE 7. CO₂ vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

FIGURE 8. HC vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

Figures 5 and 6 show that at each rpm, there was not much difference in the levels of carbon monoxide generated using pure gasoline and the 95% gasoline-5% biogasoline and 90% gasoline-10% biogasoline mixtures. However, the 85% gasoline-15% biogasoline mixture (coded 4) had a low level of CO, which was the best compared with the values of the other variables. The highest level of CO was found when using pure gasoline at 4000 rpm, namely 3.38% (v/v). However, all fuel variations generated CO below 5.5% (v/v), and were thus categorized as safe for the environment.

Figure 7 shows that the CO₂ resulting from this research ranged from 2.0% to 3.0% (v/v). In the comparison of all the variables and mixtures, the highest level of CO₂ was obtained when using pure gasoline, but there was no significant effect.

Figure 8 shows that the use of the 85% gasoline-15% biogasoline mixture could produce a better HC level below 100 ppm, compared with gasoline and other fuel mixtures with HC levels ranging from 100 to 216 ppm. However, all of the variables had HC levels not exceeding the air quality standards, where air quality limits for HC are not more than 2400 ppm.

Figure 9 shows that the lowest O₂ level of exhaust gas emission came from using gasoline, and the highest level was the result of using the 85% gasoline-15% biogasoline mixture. There was no significant difference between all of the variables.

4. CONCLUSIONS

The engine performance test results showed that the highest values of torque, power, and BMEP were obtained when using the 85% gasoline-15% biogasoline mixture. Through the comparison of rpm, the peak torque was found at 3000

FIGURE 9. O₂ vs. engine rotation. 1 = pure gasoline fuel; 2 = 95% gasoline-5% biogasoline mixture; 3 = 90% gasoline-10% biogasoline mixture; 4 = 85% gasoline-15% biogasoline mixture.

rpm. The highly toxic gases that were generated by motorcycle engine were CO and HC. The CO level, based on the test, was not more than 3.0% (v/v). This suggests that it was not exceeding the air quality limit of 5.5% (v/v). The HC level was not more than 200 ppm, meaning that it also did not exceed the air quality limit of 2400 ppm. It could be concluded that all the values of the variables and variations of rpm were safe and environmentally friendly, below the air quality standard limits.

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AUTHORS' CONTRIBUTIONS

KW and M designed the study. SS performed laboratory work and collected the research data. M analyzed the data. All of the authors conducted manuscript proofreading and approved the final version of the manuscript.

COMPETING INTERESTS

The authors have no competing interests to declare.

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