Analysis of fuel pressure on the performance of motorcycle engine with ethanol fuel

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Abstract. Gasoline engines fuel cannot be directly replaced with pure ethanol, moreover ethanol contains a lot of water. The purpose of the study was to analyze the effect of fuel pump pressure on performance of 4-stroke engine motor cycle by ethanol fuel. The independent variable is pressure of the fuel and the engine speed. The dependent variable is the engine power, torque, and specific fuel consumption. The power and torque test use inertia dynamometer. The results showed the addition of fuel pump pressure, at 3.5 bar pressure can produce higher power at each engine speed with a maximum power of 6 HP at 8000 rpm. As for the best results torque obtained at a pressure of 3.5 bar which is 5.5 Nm at 7500 rpm, besides that the lowest specific fuel consumption SFC at a pressure of 3.5 bar is 0.409 kg/HPh. The results of this study can be concluded that gasoline vehicles can use ethanol fuel by increasing the fuel pressure up to 3.5 bar.

1. Introduction
The fossil fuel is dwindling rapidly due to increasing application of fossil fuel for the generation of energy and gasoline engine use. Therefore, it is necessary to increase the use of renewable energy and alternative fuels. One of options is the alternative energy and renewable energy is ethanol. Ethanol presently are being used for fuel blending with gasoline or can use alone. Ethanol is a fairly extensive alternative energy to replace petroleum. In Indonesia, the sugar mill produces white sugar, bagasse and molasses. the ethanol is produced from molasses fermentation.

There have been many studies on ethanol being used as fuel for motor vehicles, but the research is that alcohol is mixed with gasoline. There is very little research on the use of pure ethanol for fuel. It clearly confirmed that E100, 95.5 vol % ethanol, can be effectively used as an alternative fuel in used 4-stroke motorcycles whose carburetor were purposely designed for the use of gasoline91 [1].

This research is about ethanol used for motorcycle fuel, pure ethanol (E100) without being mixed with gasoline. Pure 100% ethanol without water is expensive and difficult to find. This study used ethanol with a content of 95% and 5% water.

Vehicle engines without direct modification use pure ethanol (E100) fuel is difficult to live. Can live but cannot be normal, if the engine speed is accelerated it be halting. Analysis of using gasoline-corncob waste bioethanol blends in motorcycle engine onto compression ratio [2,3]. Optimization of the octane response of gasoline and ethanol mixtures [4].

The problem is how to make a vehicle engine using E100 fuel, the engine can start normally. One of them is by increasing the amount of ethanol fuel into the engine. To increase the amount of fuel, one way is to increase the fuel pressure.
There have been many studies conducted by several researchers such as research. Ethanol–gasoline and methanol–gasoline fuel for spark-ignition engines [5]. Fuel effect of 5% ethanol in 88, 92, and 98 RON gasoline on motorcycle engine performance [6]. Make use of the benefits of ethanol in advanced engine-fuel system [7]. The benefits of high octane fuels in spark-ignition engines [8]. Optimal use of ethanol in dual fuel application [9]. Effect of the compression ratio and duration injection on performance of engine [10]. Estimate the octane ratings of ethanol-gasoline mixtures using base fuel properties [11]. Performance enhancement of used carburetor motorcycles fueled by flex-fuel gasoline-ethanol blends [12]. Performance of bioethanol petrol blends in a spark ignition engine [13,14]. Experimental on twin spark ignition gasoline engine at different gasoline-methanol blends [15]. Bioethanol and gasoline mixture to power on motor vehicle [16]. Performance of a spark-ignition automobile engine while using ethanol blends as fuel [17]. Review on bioethanol as alternative fuel for gasoline engines [18]. Summary of ethanol-fuel engine [19].

2. Basic theory
Properties of gasoline and ethanol [20].

|                      | Gasoline | Ethanol |
|----------------------|----------|---------|
| Air fuel ratio       | 14.6     | 9       |
| Density (kg/l)       | 0.74     | 0.785   |
| $O_2$ (%)            | 34.73    |         |
| RVP (kPa)            |          | 250     |
| RON                  | 91-99    | 111     |
| MON                  | 81-89    | 104     |
| Molecular weight     | 111.21   | 46.07   |
| Carbon (%)           | 86.3     | 52.2    |
| Hydrogen (%)         | 14.8     | 13.1    |
| Lower Heating (MJ/kg)| 44.3     | 27      |
| Heat of Evaporation (MJ/kg) | 305 | 840 |
| Normal boiling ($^\circ$C) | 38 | 78 |
| Autoignition Temp. ($^\circ$C) | 246-280 | 365 |

Reaction of ethanol fuel [21].
Perfect reaction:
\[
\text{a C}_2\text{H}_5\text{OH} + \text{b H}_2\text{O} + \text{c O}_2 \rightarrow \text{d CO}_2 + \text{e H}_2\text{O} + \text{Energy}
\]

Not perfect reaction:
\[
\text{a C}_2\text{H}_5\text{OH} + \text{b H}_2\text{O} + \text{c O}_2 \rightarrow \text{d CO}_2 + \text{e H}_2\text{O} + \text{f CH} + \text{g CO} + \text{h O}_2 + \text{Energy}
\]

Mass flow rate of fuel:
\[
m = A.(2.\rho.dp)^{0.5}.c_f
\]

Where:
- $m$ = mass flow rate (kg/s)
- $A$ = area of injector hole (m$^2$)
- $dp$ = difference of fuel pressure (Pa)
- $\rho$ = density (kg/m$^3$)
- $c_f$ = correction factor (viscosity, shape, etc)

The fuel pressure changes so that the mass flow rate of fuel will change.
3. Materials and methods

3.1. Materials

3.1.1. The engine. The engine used for this investigation is an motor cycle spark ignition engine whose main characteristics are:

- **Type**:  
- **No of cylinder**: 1  
- **power**: max. 7.5 HP  
- **Bore and Stroke**: 50 mm and 58 mm  
- **Compression ratio**: 9.1:1  
- **Type of cooling**: air cooling  
- **Type of transmission**: automatic  
- **Normal fuel pressure**: 2.6 bar  
- **Duration of injection**: plus 30% from normal

3.1.2. Apparatus test

- Dynamometer, inertia type  
- Flowmeter  
- Manometer  
- Thermometer  
- Tachometer

3.1.3. Raw materials

- Ethanol (ethanol 95% + water 5%)  
- Gasoline RON 92

3.2. Methods

Gasoline fuel is not used to mix with ethanol but is used only to compare the test results with ethanol. The first test uses pure gasoline with the engine condition as it is without changing specifications. Furthermore, using pure ethanol fuel without mixture with gasoline. Testing with ethanol fuel injector opening duration is increased by 30%, without additional injection time, the engine cannot start normally. Testing with ethanol fuel in addition to the opening time of the injectors plus the pressure is increased. The fuel pressure for ethanol is made at 3.5 bar, 4 bar and 4.5 bar.

![Figure 1. Implementation of data collection.](image-url)
4. Results and discussion

Ethanol fuel with normal original standard pressure can cause the engine to not start normally. When the engine accelerates, there will be a abnormal and even when the engine is running, the engine may die. This can happen because the amount of ethanol fuel that enters the cylinder is not fulfilled.

![Figure 2. Engine speed vs fuel consumption.](image)

Figure 2 shows a graph of the measurement results of the fuel consumption of gasoline and ethanol. It can be seen that gasoline fuel is much less than ethanol, this happens because gasoline does not change the engine while ethanol has increased fuel pressure and increased injection time.

As the fuel pressure entering the injector increases, the amount of fuel entering the intake manifold will increase according to the equation. From Figure 2 the total fuel consumption rates increases as the engine speed. These fuel consumption rates show how it may be much more economical to power the engine with gasoline than with the investigated of ethanol. This behavior is attributed to the low energy value of the ethanol fuel, which is distinctly lower than that of the gasoline fuel. The maximum fuel consumption value is ethanol with a pressure 4.5 bar, 4 bar, 3.5 bar and the minimum is gasoline.

![Figure 3. Engine speed vs power.](image)

The effect of ethanol and gasoline on engine power can be observed in Figure 3. Maximum power obtained with gasoline is 5.13 HP at 8500 rpm. The maximum power obtained for ethanol with pressure of 3.5 bar is 6.0 HP at 8000 rpm, pressure of 4 bar is 5.6 HP at 7500 rpm, and pressure 4.5 bar is 5.3 HP at 7500 rpm. The power produced by ethanol fuel is always higher than that of gasoline, whereas based
on theory shows that the calorific energy value of gasoline is 1.7 times the calorific of ethanol. This is because the amount of ethanol that enters the cylinder is far more than gasoline, so the power is large.

The picture shows that the power produced is different. Based on the theory that the more fuel that is put into the cylinder, the greater the power produced. The graph shows that for pressures ranging from 3.5 bar until 4.5 bar the power generated does not coincide. At first it shows that the high power pressure is high but at higher revolutions the power can be different. At a pressure of 3.5 bar, the power is actually higher than at a higher pressure. This can happen because the engine speed, the higher the air entering the cylinder, the less so that the fuel cannot burn properly due to excess fuel.

The effect of ethanol and gasoline on engine torque can be observed in Figure 4. Maximum torque obtained with gasoline is 4.3 Nm at 6000 rpm. The maximum torque obtained for ethanol with pressure of 3.5 bar is 5.5 Nm at 7500 rpm, pressure of 4 bar is 5.3 Nm at 7000 rpm and pressure 4.5 bar is 5.1 Nm at 7000 rpm. The torque produced by ethanol fuel is always above the torque of gasoline. This is because the amount of ethanol that enters the cylinder is far more than gasoline so that the torque is greater.

Based on the theory that the more fuel that is put into the cylinder, the greater the torque produced. The graph shows that for pressures ranging from 3.5 bar to 4.5 bar the resulting torque is not the same. At first it shows that the high torsion pressure is high but at higher revolutions the torque can be different. At a pressure of 3.5 bar, the torque is actually higher than at a higher pressure of ethanol. This can happen because the engine speed, the higher the air entering the cylinder, the less so that the fuel cannot burn properly due to excess fuel. It can also be caused by greater engine friction so that the torque decreases.
Figure 5 shows a graph of the measurement results and calculations of the specific fuel consumption of gasoline and ethanol. It can be seen that the SFC for gasoline is much less than that of ethanol, this happens because there is no change in the engine for gasoline, while the ethanol fuel pressure is increased and the injection time is increased. As the engine speed increases, the injector will be opened for longer as a result, the fuel increases. With the increase in fuel, SFC does not necessarily increase because there is a power factor generated by the engine. Figure 5 shows that the initial SFC is high and with increasing rotation it will decrease but until a certain engine speed the SFC will increase again. This incident is due to the fact that the power produced does not increase significantly with the fuel being entered, due to incomplete combustion. The minimum SFC value of ethanol for 3.5 bar is 0.409 (kg/HPh) at 6000 rpm, 4 bar is 0.48 (kg/HPh) at 5000 rpm and 4.5 bar is 0.577 (kg/HPh) at 5000 rpm. The gasoline SFC smaller then ethanol, for the normal pressure of fuel is 0.148 (kg/HPh) at 5000 rpm.

5. Conclusion
By increasing the ethanol fuel pressure and increasing the injector opening time, the engine can run normally. However, ethanol fuel consumption is more wasteful than gasoline. The maximum power obtained for ethanol with a pressure of 3.5 bar is 6.0 HP at 8000 rpm. The maximum torque obtained for ethanol with a pressure of 3.5 bar is 5.5 Nm at 7500 rpm. The fuel pressure for ethanol is made at 3.5 bar, it can make the vehicle's engine run normally up to 9,000 rpm.

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