Performance and emission study of exhaust gas single cylinder diesel engine based on fuel bioethanol – high speed diesel (HSD) using fumigation and blending methods

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Abstract. Diesel engine exhaust gas contains a lot of particulates because it is influenced by factors from fuel which is not clean. The addition of ethanol to diesel fuel is expected to provide a solution to reduce exhaust emissions from diesel engines. The first step is fumigation method, process of mixing High Speed Diesel (HSD) and bioethanol directly in the combustion chamber of a diesel engine. The second method is compared with Blending method. HSD is mixed with bioethanol, there are 5 variation mixing. Variation 1 blending method diesel fuel (diesel), variation 2 (93% diesel, 2% surfactant and 5% ethanol), variation 3 (HSD 88%, 2% surfactant and ethanol 10 %), variation 4 (83% diesel fuel, 2% surfactant and 15% ethanol) and variation 5 Fumigation method (ethanol and diesel). This work were carried out at the Performance Engine Laboratory and Mechanical Engineering Manufacturing Laboratory in Engineering Faculty of Universitas Sultan Ageng Tirtayasa. The hypothesis of this research is that the mixture of ethanol and diesel fuel produces greater power and consumption compared to diesel fuel. Ethanol and diesel fuel mixtures can also reduce air pollution compared to diesel. Judging from the smoke density of each fuel.

1. Introduction
The number of road transportation in Indonesia increases every year and in the last 5 years there has been an increase of up to 33.1 percent [1]. The increase in the number of vehicles is certainly followed by an increase in exhaust emissions produced. According to the Committee on the Elimination of Leaded Gasoline, motorized vehicles accounted for 47 to 70 percent of emissions in Jakarta, while industry only 22%. Jakarta had become the city with the highest air pollution compared to major cities in the world ahead of the 2018 Asian Games. Greenhouse gas (GHG) emissions come from transportation in 2017 reaching 28.9 percent. This is the highest percent above the industrial (22%) or electricity (28%). GHG emissions from this transportation come from cars, buses, trucks, trains, ships and planes. More than 90 percent of the fuel is used for petroleum-based transportation, which includes gasoline and diesel. Another factor that is very dominant in contributing pollutants to the air is the factor of compressed air mixture with fuel being sprayed. Mixing is not comparable (too much fuel) will produce exhaust gas containing excessive particulate matter. Emission of diesel vehicles was recognized as a gas that contributes to air pollution and increases Ozone Depletion Potential (ODP) [2].

Diesel engine exhaust gas contains a lot of particulates because many are influenced by factors that are not clean fuel. Particulate in diesel engine exhaust gas comes from particles of fuel arrangement which still contains coarse dirt (ash) due to unfavorable fuel processing [3]. Indonesia government target...
to use biofuel to be 30% biodiesel and 20% bioethanol from the total demand for diesel oil and gasoline by 2025 [4].

The objective study is to determine the effect of adding bioethanol to diesel fuel on performance and decreasing exhaust emissions caused. The target to be achieved from this study is an increase in engine performance and a decrease in exhaust emissions. Novelty from this research is to innovate on "Non-ECU Injection Diesel Engine" for fumigation systems. Some of the research that has been done for the fumigation method is the diesel engine with injection system demanding high technology, namely the existence of a special injection pump that is connected to the ECU system to drain ethanol into the combustion chamber.

2. Methodology

2.1 Fuel preparation and properties

Methanol has a lower viscosity compared to diesel oil so that it is more easily injected, atomized and mixed with air. The fuel can be used purely or mixed with other fuels. The main characteristic of methanol which is an obstacle as diesel engine fuel is the low cetane number, high latent heat and the length of ignition time caused by these two factors [5].

| Table 1. Properties of High Speed Diesel (HSD) and Ethanol [6]. |
|---------------------------------------------------------------|
|                  | HSD         | Ethanol     |
| Specific gravity  | 0.84        | 0.785       |
| [kg/m3] at 15.5 oC|             |             |
| Viscosity [cP] at 20oC and 1 Atm | 3.35  | 1.2       |
| Molecular Weight | 170         | 46.07       |
| Higher heating value [kj/kg] | 46,100   | 29,700      |
| Lower heating value [kj/kg] | 43,200   | 26,900      |
| Heat of vaporization [kj/kg] | 270     | 840        |
| Cetane number    | 50          | 8           |

This study uses a 132 cc diesel engine to be tested using bioethanol-diesel fuel with fumigation and blending methods. For testing carried out at the Machine Achievement Laboratory and Manufacturing Engineering Laboratory, Department of Mechanical Engineering, University of Sultan Ageng Tirtayasa.

The composition of HSD-bioethanol, which is pure diesel (E0), Bioethanol 5% - HSD + surfactant 95% (E5), Bioethanol 10% - HSD + surfactant 90% (E10) and Bioethanol 15% - HSD + surfactant 85% (E15). Stable emulsions refer to a separation process that runs slowly in such a way that the process is not observed at the desired time interval. The higher the viscosity of an emulsion system, the lower the rate of precipitation that occurs, resulting in higher stability [7].

2.2 Blending process

Figure 1 A. Mixing results carried out at a temperature of 60 degrees with stirring 2200 rpm for 10 minutes obtained the saturated or turbid mixture results. Figure 1B. The results of mixing are carried out at a temperature of 70 degrees with a stirring rotation of 720 rpm for 10 minutes resulting from a saturated or turbid mixture.
Figure 1. Blending resulted of ethanol and HSD A, B and C.

The choice of mixing ethanol with diesel was carried out at a temperature of 70 degrees with 2200 rpm for 10 minutes to obtain a homogeneous result and fused was showed on figure 1C. Then the test results are used to blend HSD-ethanol fuel with different presentations of 5%, 10% and 15% ethanol.

Figure 2. Blending resulted of ethanol and HSD A= ethanol 5% HSD 95%, B= A= ethanol 10% HSD 90% and C= ethanol 15% HSD 85%.

2.3 Engine test setup
The test equipment used is a one-cylinder diesel engine that is modified using a converter for the fumigation process so that this engine can convert bioethanol fuel into gas entering the combustion chamber with air, which previously was only pure air.

Engine performance is measured by the modification of the equipment so as to get Break Horse Power (BHP) and Torque. Fuel consumption is measured by seeing a decrease in fuel during testing in a measuring cup. While exhaust emissions are connected to the Opacity smoke meter to see the amount of exhaust gas opacity.
In the fumigation method, HSD goes into the combustion chamber by injection. Ethanol is injected into the intake manifold to mix with fresh air by being atomized. The fumigation method has several additional instruments which are then controlled to cloud ethanol fuel and mixed with air flowing into the intake manifold towards the combustion chamber. When testing in diesel engines, the diesel engine's rotational speed is set at 1200 rpm, 1400 rpm, 1600 rpm, 1800 rpm, and 2000 rpm.

3. Results and discussion

The following are the results of the data obtained from the experiment, both in power testing, motor torque using load cell, testing of 5 minutes consumption time of fuel on engine speed without loading, and testing of smoke density (opacity). Fuel variations use E0, E5, E10, E15 and ethanol fumigation.

Table 2. Experimental data for maximum loading on variation engine speed.

| No | Rotation (rpm) | E0 Force (kg) | E5 Force (kg) | E10 Force (kg) | E15 Force (kg) | ECS Force (kg) |
|----|----------------|---------------|---------------|---------------|---------------|---------------|
| 1  | 1200           | 1.44          | 1.9           | 2.11          | 2.2           | 2.5           |
| 2  | 1400           | 3.4           | 3.4           | 3.7           | 3.75          | 3.77          |
| 3  | 1600           | 3.83          | 4.3           | 4.4           | 4.53          | 4.6           |
| 4  | 1800           | 4.1           | 4.56          | 4.55          | 4.7           | 4.75          |
| 5  | 2000           | 4.8           | 5.1           | 5.2           | 5.4           | 5.41          |

Table 3. Data fuel consumption (5 minutes fuel) of diesel engine without loading.

| No | Rotation (rpm) | E0 Fuel Const (ml) | E5 Fuel Const (ml) | E10 Fuel Const (ml) | E15 Fuel Const (ml) | ECS Fuel Const (ml) |
|----|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| 1  | 1200           | 8.3               | 8                 | 7.6               | 8.6               | 13.6              |
| 2  | 1400           | 9                 | 8.6               | 8.3               | 8.6               | 17.6              |
| 3  | 1600           | 10                | 9                 | 9                 | 9.6               | 19.6              |
| 4  | 1800           | 10.6              | 9.3               | 9.3               | 10                | 21.5              |
| 5  | 2000           | 11.6              | 10.3              | 11                | 11.3              | 32.6              |

Table 4. Data exhaust gas emissions are measured by opacity.

| No | Rotation (rpm) | E0 Opacity | E5 Opacity | E10 Opacity | E15 Opacity | ECS Opacity |
|----|----------------|------------|------------|------------|------------|-------------|
| 1  | 1200           | 22.26      | 11.76      | 22.36      | 15.56      | 15.9        |
| 2  | 1400           | 19.43      | 14.76      | 11.93      | 12.3       | 10.56       |
| 3  | 1600           | 16.43      | 11.73      | 5.1        | 11.06      | 8.7         |
| 4  | 1800           | 14.6       | 12.03      | 7.43       | 9.13       | 10.03       |
| 5  | 2000           | 22.1       | 18.46      | 11.53      | 11.56      | 10.9        |

In figure 4 A shows a graph of the rotation ratio with torque. Every change in torque on the rotation has the engine rotating power to do work. Ethanol mixed fuel can increase torque due to the dissolved oxygen element or inherently helping the combustion improvement process. Each fuel has the same tendency at 1200 rpm to 2000 rpm torque goes up along with engine speed, maximum torque at
2000 rpm is 13.30 Nm for E15. E10 is 12.78 Nm, E5 is 12.52 Nm and pure HSD is 11.79. For fuel ethanol Fumigation is 13.33 Nm. Fuel Ethanol Fumigation has a higher torque compared to other fuels.

**Figure 4.** A. Comparison of rotation with torque, B. Comparison of rotation with power

In figure 4B show a graph of the rotation with power. Every change in power in the rotation has the energy to do work. From the graph above shows the greater the rotation of the engine, the energy generated will be even greater. Ethanol mixed fuel can increase power due to the dissolved oxygen element or inherently helps the combustion improvement process.

**Figure 5.** Relation between rotation to (a) specific fuel consumption (b) gas emission (opacity)

In figure 5, Specific fuel consumption (SFC) shows the influence of rotation on fuel consumption, the greater the rotation value, the SFC tends to decrease. The mixture of HSD with ethanol blend method has a low fuel consumption so it can be said that the mixture of diesel fuel and ethanol is more efficient. Whereas for the fumigation method it has high consumption so it is said to be wasteful of fuel and less efficient.

In figure 5 B shows a graph of the rotation relationship with opacity. Where every fuel that has ethanol content is relatively decreased when compared to diesel fuel. At low speeds of 1200 rpm carbon combustion does not have enough time to react with oxygen as a result there is excess carbon from non-combustible fuel, judging from the results of high gas opacity. At intermediate speed 1600 has decreased opacity compared to low engine rotation times. Decreasing opacity levels reached 5.1% for E10 fuel due to a decrease in concentrations because the air needed in the combustion process is fulfilled to burn all the fuel so that near-perfect combustion occurs. Dissolved or inherent oxygen elements in ethanol help improve combustion while at high rpm 2000 rpm the result of increased opacity of smoke is due to optimal combustion work not in high rotation.
4. Conclusion

From a series of studies, calculations and analysis of data that have been carried out it can be concluded that the power is produced by ethanol and HSD greater than pure HSD fuel. The greatest power is at 2000 rpm with 3.74 HP for fumigation ethanol fuel. A mixture of ethanol and HSD produces greater torque compared to pure HSD. Both the blend method and the fumigation method. The largest torque is at 2000 rpm with 13.33 Nm for fumigation ethanol HSD. Blending of HSD and ethanol has an efficient specific fuel consumption. The lowest SFC obtained at 2000 rpm is 40.099 g/kWh for E5 fuel. Overall, the mixture of ethanol and diesel fuel can reduce air pollution compared to diesel fuel. Judging from the smoke density of each fuel.

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