Performance Characterization of Diesel Engine Generator Set with the addition of clove oil as Bio-Additives for Diesel fuel

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Abstract. The consumption of diesel fuel in Indonesia increases every year. However, this increasing rate of fuel consumption is not followed by the increase in petroleum reserves available in Indonesia. One of the solutions to overcome the problem is by utilizing the abundantly available natural resources in Indonesia such as essential oil which potential as bio-additive for improving fuel economy. This study investigated the performance of Clove oil as additive, with the objective of reducing fuel consumption. Experiments were conducted by mixing clove oil and diesel fuel at the percentage of 1%, 0.5% and 0.1% of total volume. Generator set was operated at varied loading of 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800 and 2000 W at constant engine speed of 1500 rpm. The measured and calculated variables in this experiment were Power, Torque, BMEP, SFC, and hourly fuel consumption. Results showed that the addition of clove oil into diesel fuel at the volume percentage of 1%, 0.5% and 0.1% reduced the fuel consumption to an average of 2.94%, 6.12% and 4.74%, respectively. Maximum fuel consumption reduction of 7.7% was reached at 800 W load with 0.5% of clove oil. The next study is to perform a mixture of Clove oil and citronella oil as additives, which is expected to reduce fuel consumption while anticipating the risk of engine corrosion.

1. Introduction
The consumption of diesel fuel in Indonesia increases every year. According to the data released by BPH migas (Indonesian Regulatory Agency for oil and Gas), the general fuel consumption in 2016 was 48,655,005,967 liters, around 10 percent raise than that of the year 2015 which was 44,453,906,861 liters. Fuel consumption percentage breakdown by sector is as follows: households (35%), transportation (31%), industry (29%), commercial (4%) and others (2%) [1,2,3]. Transportation sector experienced the largest growth which reached 5.2% per year. However, the increasing rate of fuel consumption is not followed by the increase in petroleum reserves available in Indonesia. To overcome the above problems, the Indonesian government has taken various ways such as issuing the Policy of the Ministry of Energy and Mineral Resources No.12 year 2015 about the obligation to use biodiesel fuel as much as 30% by 2020. However, this policy will also be costly for the government’s side as the government is obliged to subsidize Rp. 3000 (≈$ …) up to Rp. 6000 (≈$ …) per liter.

One of the solution to overcome the problem is by utilizing the abundant natural resources in Indonesia such as essential oil. Essential oil is proven to have potential to serve as additive material or mixture of conventional fuel [4]. Aftermarket additives such as … have been widely available in market but they have a relatively expensive price so that the utilization in the community is still limited, which results in a continuously rising fuel consumption trend due to the unavailability of this fuel economy improver. Making additives out of essential oils to reduce fuel consumption can be done by selecting materials or substances that have potential for optimizing combustion process in the engine [4,5,6,7,8,9].
The potential of essential oils has been shown by many researchers working on bio-additives. M. Gürü et al, added Mn, Mg, Cu and Ca metals obtained from organic materials. The results showed that the addition of Mn metal as much as 54.2 μmo Mnl / L produces the best freezing point depression down to 12.4°C, while metal Mg, Cu and Ca are less effective than Mn [10]. A. Kadarohman et al used clove oil, eugenol and eugenol acetate mixture as a bioadditive of diesel oil [11]. A. Fayyazbakhsh et al determined the effect of adding additive to the performance and emissions of diesel engines. Additive materials used were nitroethane (NE), nitromethane (NM), 2 methoxy ethyl ether (MXEE) and addition of manganese (Mn) and Cerium (Ce) metals. Engine speeds used were 2200 rpm and 1500 rpm and load variations are 370, 275, 180 and 20 Nm. [12] M. Mbarawa used a mixture of clove branches or clove stem oil (CSO) with diesel fuel. The variations used were 25% CSO (volume) and 50% CSO (volume). It was revealed that the mixture of 50% CSO and diesel fuel provides the best result on specific energy consumption. Higher engine load also increases the effective and normal brake thermal efficiencies [13]. Accordingly, the present study investigated the performance of Clove oil as additives, with the objective of reducing fuel consumption.

2. Research Methods

The experiment was conducted by mixing clove oil into the diesel fuel at the percentage of 0.1% , 0.5% and 1% of total volume. Diesel fuel that had been mixed with the additives was fed into the engines fuel line. Generator set was operated at varied loading of 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800 and 2000 watt. Engine speed was maintained at 1500 rpm. Output variables that were measured and/or calculated in this experiment are Power, Torque, BMEP, SFC, hourly fuel consumption.

![Figure 1. Experimental process](image)

The experiment was conducted at constant engine rotation (stationary speed) with variation of electrical load. The steps were as follows:

1. Turn on the diesel engine,
2. Warm up the engine for about 15 minutes until it reached the temperature of normal operating condition.
3. Set the electrical load from 200 Watt to 2000 Watt with 200 Watt increment, while maintaining the engine speed of 1500 rpm
4. Record the data of each engine loading, i.e.:
   • The time required to consume 5 ml of fuel,
   • Temperatures of inlet air, lubricating oil, coolant, exhaust gas
   • Voltage (V) and electric current (I),
5. After the data recording is done, the load was gradually lowered to zero,
6. Leave the engine in a no-load condition for approximately 5 minutes,
7. Turn off the engine

3. Results and Discussion
Based on the experimental study, the following results were obtained and depicted in the following figures. As shown in figure 2, power increases following the increase in the electrical load as the consequences of the increase in fuel entering the combustion chamber. Increasing fuel intake causes more energy to be converted into heat and mechanical energy with sufficient air. Energy makes the engine power higher according to the load given to the engine.

As can be seen in figure 3 the engine torque graph of the electric load function has the similar characteristics as the power of engine graph. Torque is a measure of the ability of a machine to produce work, in which the torque value then depends on the power (Ne) and engine rotation (n), as seen in Eq. 1.

\[
Ne = \frac{V \times I}{746 \times \eta_{\text{generator}}}
\]

(1)

Where
- \(Ne\): Engine Power (Hp)
- \(V\): voltages
- \(I\): Ampere
- \(\eta_{\text{generator}}\): Generator Efficiency

Because in this research the engine rotation is constant, thus the torque depends on the variation of engine power. Consequently, the trend of the graph is the same as that of the power load function graph. Ideally, engine torque is linear with respect to load increment.

As shown in figure 4 the combustion process of the air-fuel mixture produces pressure that works on the piston to do the work step. The graphic have a tendency to increase along with the increase in load.

It can be seen that the variable that influences changes in the value of the engine in the test is engine power (Ne), while the other variables are constant, including engine speed (n).

![Figure 2. Engine Power: pure and mixture fuel](image-url)
As shows in Figure 5, Specific Fuel Consumption (SFC) reached the highest value at the lowest load and then continued to decline with increasing load. Based on the analysis using Eq. 1, the SFC is only affected by the engine power (Ne) and fuel consumption (s), while the fuel mass of diesel oil is constant. As shown in Figure 6, lower fuel consumption was obtained at 0.5% of bio-additives. This figure shows that the addition of bio additive can reduce the fuel consumption. With the volume percentage of 1%, 0.5% and 0.1%, bioadditive reduces fuel consumption to the average of 2.94%, 6.12% and 4.74% respectively. Maximum fuel consumption reduction reached 7.7% at 800 W load with 0.5% of clove oil.
4. Conclusions
The current study revealed that the addition of clove oil into diesel fuel at the volume percentage of 1%, 0.5% and 0.1% significantly reduced fuel consumption down to 2.94%, 6.12% and 4.74% respectively. Maximum fuel consumption reduction reached 7.7% at 800 W load with 0.5% of clove oil. A planned future research is to perform a mixture of Clove oil and citronella oil as additives, which is expected to reduce fuel consumption while anticipating the risk of engine corrosion.

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