Study Of Diesel Engine Performance On The Electromagnetic Effect Of Biodiesel (Waste Cooking Oil)

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Abstract. Research has been conducted that the use of electromagnetic fields as a medium to conserve fuel, especially diesel fuel, has proven to be around 7-17%. Given that diesel is one of the conventional fuels whose supply is running low, so that alternative fuels are sought and to slow down the shortage of diesel fuel biodiesel is used from waste cooking oil. The purpose of this study is to analyze the use of electromagnets for biodiesel fuels derived from waste cooking oil. The engine used in this study is a 13 HP diesel engine, the fuel used is a mixture of diesel and biodiesel derived from waste cooking oil with a ratio of B0 (Diesel), B10 (10% Diesel and 90% Biodiesel), B20 (20% Diesel and 80% Biodiesel), B50 (50% Diesel and 50% Biodiesel), B100 (100% Biodiesel). Diesel engines are given a load of 4.45-10.39 KW. The data obtained in the form of the amount of fuel consumption per unit of time and exhaust emissions. The data is used to calculate specific fuel consumption (SFC). The result was a fuel saving of 7-11% this value is still below diesel, this happens considering the mixture uses biodiesel fuel (waste cooking oil) whose viscosity is greater than solar so that a magnetic field that is large enough to break down the molecule is not clumped so that combustion can be more perfect. Reduction of exhaust emissions of CO and NOx by 13-53% and 7-21%

1. Introduction

The use of magnetic fields as a medium to improve the quality of combustion has been carried out by researchers. Most researchers use permanent magnets or razor iron as a magnetic field source, the weakness of the strength of the magnetic field will decrease as time goes by, otherwise the magnetic field generated from the winding of the wire at the core of the coil is electrically flowed, or commonly called an electromagnet, its magnetic strength is not reduced as long as there is an electric current. Okoronkwo reported the results of a study of electromagnet fields mounted on a 4-cylinder 1-cylinder gasoline engine against exhaust emissions [1]. Magnetic effects cause changes in fuel molecules from clusters to de-clusters, this effect is claimed to cause HC exhaust emissions to decrease by 40% and particulate material to decrease by 35%. The information given in this study is less complete due to the amount of coil in the coil, the magnitude of the magnetic field, the magnitude of the reduction in fuel consumption was not discussed in this study.

The study of other electromagnetic fields was carried out by Habbow which used a magnetic field intensity of 3000 Gauss on a 4-cylinder 1-cylinder gasoline engine [2]. The result is that using magnets of 1000 Gauss can increase thermal efficiency by 7% and power increase by 16.4%. HC
exhaust emissions decreased by 90% and COC decreased 58%. Faris reported the results of his research on the effect of magnetic fields on fuel consumption and exhaust emissions on a 4-cylinder 1-cylinder engine [3]. That with the addition of magnetic field intensity to the fuel effect, the fuel consumption decreased by 9-14% and HC and CO exhaust emissions decreased by 30% and 40% respectively after the fuel was magnetized with a magnetic field intensity of 2000-9000 Gauss. In this study not discussed about the use of electromagnetic fields.

Jain and Deshmukh conducted a study of MFC (Magnetic Fuel Conditioner) with a strength of 1000-1800 Gauss on a 5 HP diesel engine with varying loads, this magnetic effect causes changes in fuel molecules from clusters to de-cluster, this claimed to consume fuel consumption decreased by 10-30% and exhaust emissions of HC, CO and NOx decreased by 40% [4]. The advantage of this research is that the magnetic field used is relatively small but the results obtained such as fuel consumption and exhaust emissions are relatively large compared to previous researchers.

Based on the results of the study above most researchers used a magnetic field above 1000 Gauss, in its application this will have an effect on other machine devices, besides that the fuel used in the previous researchers was fossil fuels, therefore in the research made quality enhancing devices. The fuel uses an electromagnet field with a magnetic field strong intensity of less than 1000 Gauss and observes how it affects the performance of the engine and exhaust emissions for diesel fuel and biodiesel engines. The biodiesel used in this research uses used cooking oil.

2. Methodology

This study uses experimental methods combined with theoretical analysis in answering the research objectives. Data obtained by direct observation and measurement in the field with available measuring instruments. The study was conducted in the Energy and Heavy Equipment Conversion Laboratory, Jakarta State Polytechnic, during the period June 2018 - September 2018.

Tools and materials

In this study used diesel generator (Perkin 403D-150) with 13 HP power which is connected to the bank load which ranges from 3-11KW. The fuel needed in the research is solar (B0), B10, B20, B50 and B100. Combustion quality enhancement devices (specifications are seen in table 1) and battery voltage sources are 12 volts. Emission testing uses the Gas Analyzer MRU NOVA 2000 tool. The research begins by calibrating the equipment needed, inspecting diesel engine components such as lubricating oil, lubricating oil filters, fuel filters, engine cooling water tanks and water tanks. Furthermore, all instruments are assembled as shown in Figure 1. The magnitude of the observed fuel consumption and exhaust emissions. The test was started by turning on the Perkin P135-4 diesel engine at 1550 rpm and then holding it for ± 10 minutes to get the engine's normal working temperature. After the machine is operating normally, data retrieval begins. Data retrieval is done by looking at the measuring instrument and recording on the recording sheet.

| Parameter                           | Value   | unit     |
|-------------------------------------|---------|----------|
| Galvanum pipe length                | 1.206   | meter    |
| Galvanum pipe diameter              | 35      | mm       |
| Number of copper wire coils         | 1000    | coil     |
| Copper wire diameter                | 0.15    | mm       |
| Electric current                    | 0.039   | Amper    |
| Voltage source                      | 12      | Volt     |
| Copper wire type barriers           | $1.72 \times 10^{-8}$ | Ohm meter |
| Magnetic field strength             | 713.57  | Gauss    |
| The core permeability of the coil   | 0.57    | Gauss m/Amp |
The independent variables in this test are the composition of the fuel (B0, B10, B20, B50, & B100) and variations in load (4.5 and 10.37 kW). The dependent variable for this performance test is fuel consumption and exhaust emissions. Fuel consumption is calculated based on the difference in the reading of the fuel level in the measuring cup, which is attached to the fuel tank, per unit time. Measurement and recording of fuel consumption is carried out every time the fuel and load changes. This activity was carried out five times. Exhaust gas emissions of CO, NO and NOx are measured using the NOVA 2000 Gas analyzer.

Data processing
The results of the research data were compared between the fuel before and after magnetization and then processed quantitatively in the form of several graphs that graph the fuel consumption of the composition of the fuel, and CO and NOx gas emissions to the fuel composition, then analyzed again by referring to several reference journals that listed in the bibliography. Diesel engine performance is shown through the success rate in converting the chemical energy contained in the fuel into mechanical energy.

Use of fuel (fuel consumption)Fuel consumption (fuel consumption) is the amount of fuel used by the engine for a certain time unit. Meanwhile, sfc (specific fuel consumption) is the amount of fuel consumption of the engine for a certain unit of time to produce an effective power. If in the test data is obtained regarding the use of fuel m (kg) in time s (seconds) and the power produced is bhp (hp), then the fuel consumption per hour (m_{bb}) : [5]

\[ m_{bb} = \frac{m_{bb}}{s} \text{ (kg/sec)} \]
\[ \dot{m}_{bb} = \frac{3600 \cdot m_{bb}}{s} \text{ (kg/hour)} \]

While the amount of specific fuel usage is
\[ Sfc = \frac{3600 \cdot \dot{m}_{bb}}{bhp} \text{ (kg/kW.hour)} \]

dengan:
\[ \dot{m}_{bb} = \text{fuel consumption per unit of time (kg/sec or kg/hour)} \]
s = fuel consumption time (sec)
sfc = specific fuel consumption (kg/hp.hour)

Combustion process with Stoichiometric calculation

Hydrocarbon fuels will be oxidized thoroughly to carbon dioxide (CO$_2$) and water vapor (H$_2$O) if there is sufficient oxygen supply. Such combustion conditions are called stoichiometric combustion and the chemical reaction equation for stoichiometric combustion of a Biodiesel fuel (esters from palmitate) (C$_{x}$H$_{y}$O$_{γ}$) with air written as follows [6].

\[ C_{α}H_{β}O_{γ} + a(O_2 + 3.76N_2) \rightarrow bCO_2 + cH_2O + dN_2 \]

equilibrium C : $α = b$
equilibrium H : $β = 2c - c = β / 2$
equilibrium O : $γ + 2a = 2b + c \rightarrow 2a = 2α + β / 2 - γ \rightarrow a = α + β / 4 - γ / 2$
equilibrium N : $2(3.76)a = 2d \rightarrow d = 3.76a \rightarrow d = 3.76(α + β / 4 - γ / 2)$

Substitution of the equilibrium equations above into the combustion reaction equation C$_x$H$_y$O$_γ$ produces the following equation:

\[ C_{α}H_{β}O_{γ} + a(O_2 + 3.76N_2) \rightarrow bCO_2 + cH_2O + dN_2 + \text{energy} \]

Incomplete combustion

The combustion mechanism is demanded to take place quickly so that the combustion systems are designed with excess air conditions. This is intended to anticipate air shortages due to imperfect mixing between air and fuel. Such combustion is called non-stoichiometric combustion. The equation of the chemical reaction for non-stoichiometric combustion of a biodiesel fuel (ester of palmitate) (C$_{α}$H$_{β}$O$_{γ}$) with air is written as follows

\[ C_{α}H_{β}O_{γ} + a(O_2 + 3.76N_2) \rightarrow b\text{CO} + cH_2O + d\text{NOx} + eN_2 + \text{energy} \]

3. Results and Discussion

The results of the research data were compared between the fuel before and after magnetization and then processed quantitatively in the form of several graphs that graph the fuel consumption of the composition of the fuel, and CO and NOx gas emissions to the fuel composition, then analyzed again by referring to several reference journals that listed in the bibliography. Diesel engine performance is shown through the success rate in converting the chemical energy contained in the fuel into mechanical energy.

Fuel Magnetization on Fuel Consumption.

Fuel consumption as a function of the composition of biodiesel at a load of 4.45 KW, is presented in Figure 2a, it appears that the magnetized fuel causes the SFC to be reduced by 4-8% but in the composition of biodiesel above 70%, the SFC has increased 1.8% compared to the fuel not magnetized. This happens because the fuel composition is 0-70%, the magnetic field is 713.57 Gauss is able to break down the fuel molecules which initially become de cluster clusters which makes the reaction between fuel and air easier, and combustion becomes more perfect so the engine becomes more efficient. Fuel with a low biodiesel composition results in low viscosity and fuel molecules will be atomized better resulting in smaller fuel grains. With these conditions, the process of mixing fuel with air will be more homogeneous so that the fuel that burns more and the energy released increases. In other words, for the same load the amount of magnetized fuel is injected into the engine less or decreased.
Conversely, if the composition of biodiesel is above 70% the magnetic field is 713.57 Gauss is unable to decompose the fuel into a de-cluster so that the fuel molecules are difficult to react with air as a result the combustion is not perfect and the engine becomes wasteful. Fuel with a large biodiesel composition results in high viscosity and fuel molecules will be difficult to atomize to produce larger fuel grains. With these conditions, the process of mixing fuel with air becomes homogeneous so that less fuel is burned or the use of fuel becomes more and the energy released decreases.

The same thing happened to the engine that was given a load of 10.37 KW as shown in Figure 2b, the difference is for a large load, the specific fuel consumption is greater than the engine which is given a small load. SFC experienced a decrease of 2-9% in the composition of biodiesel 0-70% and increased 1.8% in the composition of bidiesel above 70%.

Figure 3a shows a graph of the relationship between CO exhaust emissions and the composition of biodiesel for a 4.45 KW load. It appears that the magnetized fuel causes CO (carbon monoxide) exhaust gas emissions to decrease by 45-67%, while for engines that are given a 10.37 KW load of CO 2 exhaust gas decreases 13-53%. The formation of CO gas due to lack of oxygen in the reaction with fuel during the combustion process. At a constant rotation of the diesel motor to overcome the increasing load, the more injected fuel. With the amount of fuel entering the combustion chamber, there will be greater combustion and higher temperatures. At high temperatures there is a reaction between carbon dioxide (CO2) and carbon (C) which produces CO gas. The higher the temperature of combustion results, the greater the amount of CO2 gas that dissociates into CO and O [7].
The addition of the percentage of biodiesel mixture in diesel fuel causes a decrease in CO2 emissions. This is due to the influence of oxygen which is bound to the methyl ester, this oxygen molecule causes no CO molecule formation but CO2 molecules are formed, causing a more perfect combustion. The greater the addition of biodiesel, the greater the oxygen in the mixture and the more complete combustion, resulting in low carbon monoxide [8]. This is evident from the data obtained from the results of the study that in B100 there was an average CO decrease of 56%. Fuel magnetization causes fuel viscosity to decrease so that when injected into the combustion chamber it will form finer granules so that the mixture of air and fuel becomes more homogeneous which results in a more perfect combustion. This perfect combustion causes CO emissions to decrease.

Figure 4 NOx exhaust gases before and after magnetized engine load (a) 4.45 KW (b) 10.37 KW

Figure 4 shows a graph of the relationship between NOx exhaust emissions and the composition of biodiesel. The vertical axis states the NOx (ppm) and horizontal axis states the composition of biodiesel. It appears that the magnetized fuel causes NOx exhaust emissions to decrease by 5-33% for engines that are given a load of 4.45 KW, while for engines that are given a 10.37 KW load of CO2 exhaust decreases 7-21%. There are several causes of NOx emissions including high oxygen concentrations coupled with high temperature of the combustion chamber. In addition, the carbon crust in the combustion chamber will also increase engine compression and can cause hot spots that can increase NOx levels. Machines that often detonate will also cause high NOx concentrations [9].

The addition of the percentage of biodiesel mixture in diesel fuel causes a decrease in NOx exhaust emissions. This is due to the influence of oxygen bound to the methyl ester so that for less combustion of the required air, this causes the combustion temperature to decrease, and NOx concentration also decreases [10]. Fuel magnetization causes fuel viscosity to decrease so that when injected into the combustion chamber it will form finer granules so that the mixture of air and fuel becomes more homogeneous which results in a more perfect combustion. This perfect combustion causes NOx exhaust emissions to decrease. NOx gas emissions decreased the most occurred in B100 fuel which was an average of 26.5%. All emission test results state that fuel magnetization causes decreased levels of exhaust emissions.

4. Conclusion
In this research, a device has been successfully made to improve the quality of combustion in diesel engines made of electromagnet fields with a magnetic field strength of 713.57 Gauss, the specifications of the device:
   a. Email wire diameter = 0.15 mm
   b. Tube length = 1200 mm
   c. Tube diameter = 35 mm
   d. Number of turns = 1000
e. Electric current = 0.03 amperes  
f. Voltage = 12 volts  
By using this tool, the performance of a diesel biodiesel-fueled diesel engine obtained from the results of this study:  
   a. Fuel consumption decreases by 7-11%  
   b. CO and NOx exhaust emissions decreased by 53%  

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