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Study the Performance and Emissions of Biodiesel Hydrofuel in Diesel Engine

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Abstract. The current situation of high prices of petroleum oil needs to be studied to find alternative fuels that can reduce some emissions. The use of biodiesel in a mixture of diesel fuel is an alternative to address the global crisis related to the depletion of petroleum reserves. Moreover, mixing biodiesel into diesel fuel can reduce some emissions such as CO, HC, and particulate matter. However, the NOx emissions are still high. The purpose of this study is to analyze the performance and emissions using diesel fuel with a mixture of deionized water (ratio 60:40) in comparison with Indonesian diesel fuel (B30). Test fuels are conducted in a diesel engine with different loads of idle, 36% and 68% with the engine rotation of 1500 rpm. The results show that mixing 40% deionized water with diesel fuel can reduce emissions of HC up to 0,29%, and NOx by 21,56% than diesel fuel at 68% load. Moreover, the specific fuel consumption can be down up to 3% more than diesel fuel. Therefore, deionized water fuel can be the solution to make better fuel properties, can reduce emissions, and be friendly to the environment.

INTRODUCTION

Diesel engines are still the prime mover with the highest thermal efficiency. Generating considerable power and torque, diesel engines are also used for diesel power plants (PLTD), driving heavy equipment in mining and agriculture, driving fleet ships as well as motorized vehicles such as trucks, passenger cars, and so on. Its use is practical, it can be used as a generator drive. Compared to the PLTU steam turbine, which has to heat the steam boiler for 6 to 7 hours before it can be used. PLTD systems that are compact and practical, can be turned on and off instantly as needed. For areas that have electricity needs that do not reach 24 hours, the PLTD system is very suitable for island areas such as Indonesia (note that PLTU is not economical and impractical to use in areas where electricity usage is less than 24 hours). Until now there has been no substitute for diesel engines to drive heavy equipment such as mining machines, tractor machines, and agricultural equipment [1].

One of the disadvantages of diesel engines is the use of diesel fuel which is quite expensive and not environmentally friendly and the continuity of its supply is not guaranteed [2-3]. Moreover, diesel fuel can make some pollution and some study explained by blending it to another fuel can solve some problems [4-6]. Therefore, the solution to this problem is to make diesel fuel with economic value, environmentally friendly, and sufficient continuity of supply by mixing biodiesel with the standard applied by the government (B30). Blending with deionized water through a distillation process [7], then giving surfactants and conditioned by this sonification method into Biodiesel Hydrofuel products with a ratio of 60:40. In this case, the process that is carried out makes the surfactant level in this product a level of 0.1% of the total. In this study what will be investigated is performance (SFC, torque, and power) and concentration levels of exhaust emissions (CO, HC, and NOx) at each consumption of 50 ml of fuel that will be used as diesel engine fuel compared to the results of the study using biodiesel B30 products which are now used as national standards in the industry and the wider community.

This research is aimed at the industrial sector which is very dependent on the use of diesel engines and the costs spent on fuel. Based on this, this research was made as additional knowledge for the development of engine combustion science and research on fuel with good performance results.

METHOD

The methods of this study are experiment and collection of data in a diesel engine. The process is carried out using a burette to measure fuel consumption, a stopwatch, and then the use of an exhaust gas analyzer, namely IMR 2800, to measure concentrations in the emissions released by a running diesel engine. Data collection was recorded for every consumption of 50 ml of diesel engine fuel in which the diesel engine used ran at a constant engine speed parameter of 1500-1600 rpm with a load variation of 0%, 36%, and 68%.

The first step is to start the diesel engine for (approximately) 20 minutes with the engine speed at 1500-1600rpm. Furthermore, a periodic load (0%, 36%, and 68%) will be given along with a calculation of fuel consumption compared to the time of use for every 50 ml of fuel and the taking of exhaust emission test values for every 100 ml of fuel consumption.

Engine Specification

YANMAR 4TNV84T specifications used in this study are presented in Table 1. Furthermore, the main features of the engine can be seen in the manual book provided by the manufacturing company.

TABLE 1. Specification of YANMAR 4TNV84T

Item		**Specification**
Engine	:	4TNV84T
Type	:	Vertical in-line diesel engine
No. of cylinders	:	4
Bore x stroke	:	Ø84 x 90mm
Displacement	:	1.995 L
Length	:	683 mm
Width	:	498,5 mm
Height	:	713 mm
Maximum Output Rate	:	21,3 kW/1500 rpm, 26,9 kW/1800

Fuel consumption testing

Calculations are made by turning on the diesel engine at constant rotation with a certain time calculation without a specified load to see the volume of fuel used. The tool used is a burette with an assessment of the use time of 50 ml of B30 fuel or Biodiesel Hydrofuel in a diesel engine.

Feasibility Analysis

After fuel consumption could be estimated, Specific Fuel Consumption (SFC) analysis was conducted to determine the amount of fuel consumed by a vehicle for each unit of power output [8-10]. *SFC* was calculated using Equation (1) followed by torque calculations (2). Furthermore, it can also be examined regarding the performance of the relationship between the load given and the engine speed by retrieving data from the information display screen on a diesel engine to see the engine speed at a certain load.

$$SFC = \frac{Fuel\ Consumption\ (\frac{Liter}{hours})}{Load\,(kW)} \qquad (1)$$

$$Torque = \frac{Load\ or\ power\ (kW) \times 60 \times 1000}{2 \times \eta \times RPM} \quad (2)$$

Exhaust Gas Emission Test

Measurements were made using an exhaust gas analyzer type IMR 2800 to measure the values of the various concentrations contained in the diesel engine exhaust gas tested for each change in the variation in the levels of Biodiesel Hydrofuel.

RESULT AND DISCUSSION

Operation data

The relationship between fuel consumption and engine speed can be seen in Figures 1 (a) and (b). The minimum FC (Fuel Consumption) value for the two types of fuel is achieved at 1576 rpm when the shaft is not loaded, the minimum FC value for each fuel includes Biodiesel Hydrofuel (1,214 Liters/kW) and B30 (1,247 Liters/kW), while when the load increases by 36%, namely 6 kW, it shows Biodiesel Hydrofuel (2,442 Liters/kW) and B30 (2,583 Liters/kW). Furthermore, the last experiment with a load of 68%, which is 11 kW of the maximum power of the diesel engine, showed FC with the value of Biodiesel Hydrofuel (3,769 Liters/kW) and B30 (3,877 Liters/kW). The average SFC value of the two fuels at the same load respectively as follows 0.407 Liters/kWh (6 kW), 0.343 Liters/kWh (11 kW) for Biodiesel Hydrofuel and 0.43 Liters/kWh (6 kW), 0.352 Liters/kWh (11 kW) for the B30. The average FC comparison for Biodiesel Hydrofuel to B30 is 3-4% smaller than the FC B30, while the average SFC comparison also shows Biodiesel Hydrofuel 3% smaller than the average SFC for B30. This is due to the calorific value of B30 which is not much different compared to Biodiesel Hydrofuel due to the condition of the presence of oxygen in the biodiesel which results in a leaner air-fuel mixture so to obtain the desired performance the air-fuel mixture must be richer (rich mixture). This condition makes the required fuel a little more than when using Biodiesel Hydrofuel fuel.

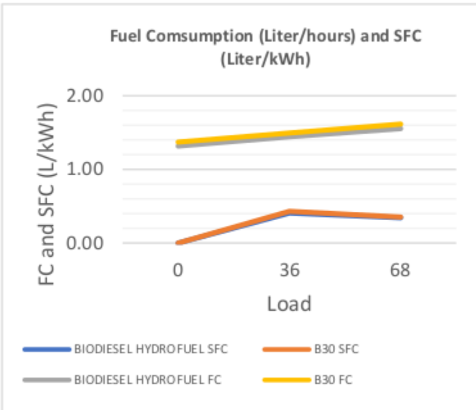
The increase in the highest value of SFC occurred in the speed range of 1544-1550 rpm at 36% loading but the SFC number from the next loading was not much different even though the engine rotation speed showed a considerable difference where Biodiesel Hydrofuel at 68% loading was 1579 rpm while using B30 at figure 1526 rpm. This is because 40% of the volume of deionized water which is part of the Biodiesel Hydrofuel product does not change the shape and content of B3O which is used as 60% of the basic ingredients. Therefore, the result shows that Biodiesel Hydrofuel is more efficient with the same conditions and levels.

Table 1 shows the parameters of fuel from B30 and biodiesel hydrofuel. Density B30 is higher 2,6 points than biodiesel hydrofuel. Biodiesel hydrofuel has less sulfur content than B30 and this can affect the emissions value in a combustion engine, especially in the reduction of sulfur dioxide in the emissions. The flash point for biodiesel hydrofuel is higher 2 points than B30. Moreover, the water content in biodiesel hydrofuel is reduced to 53,1% more than B30.

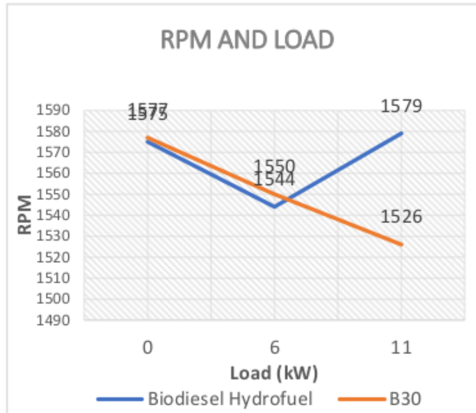
TABLE 1. Lab analysis report B30 dan Biodiesel Hydrofuel

No	Parameter	Unit	B30	Biodiesel Hydrofuel
1	Density @15°C	Kg/m^3	848	845,4
2	Sulfur Content	%m/m	0,06	0,02
3	Flash Point	°C	59	61
4	Water Content	Mg/kg	229,1	176

5	FAME Content	%v/v	30,12	12,28
6	Appearance		Clear	Clear
7	ASTM Color		1,0	1,0



(a)



(b)

FIGURE 1. (a) Graph of SFC; (b) Engine RPM compared to power

Furthermore, Figure 2 shows engine torque in the load. The test results obtained a maximum torque of 68.96 Nm which occurs when the engine operates at an engine speed of 1526 rpm and a load of 11 kW using B30 fuel while for Biodiesel Hydrofuel at 1579 rotation the torque produced is 66.55 Nm which the results are not much different as shown in Figure 3. The minimum torque obtained was 36.96 Nm with B30 fuel and a load of 6 kW with an engine speed of 1551 rpm. The torque generated when the engine uses B30 fuel shows a lower number because the amount of torque is strongly influenced by the energy produced by burning the fuel. The amount of energy produced from burning fuel is influenced by the calorific value of the fuel, which can be judged that the calorific value of B30 fuel is lower when compared to the heating value of Biodiesel Hydrofuel.

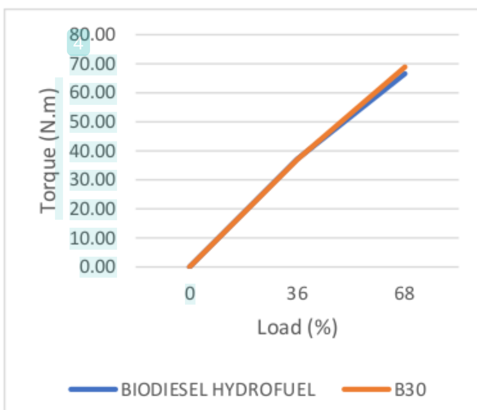
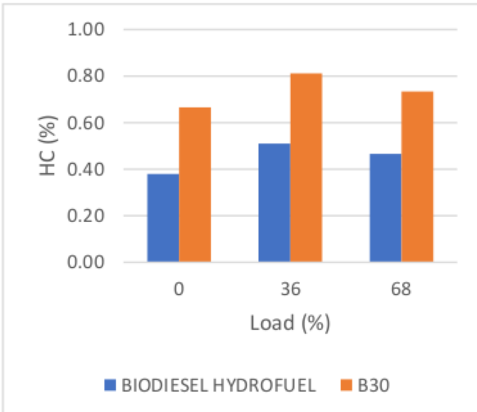
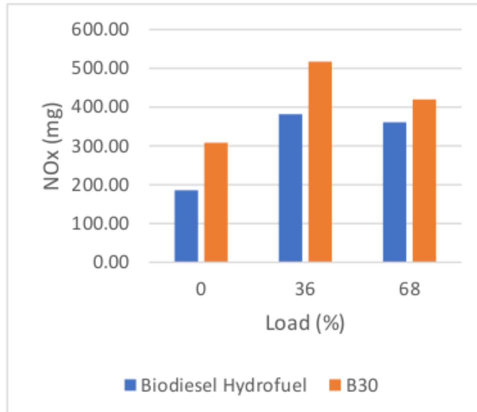


FIGURE 2. Engine torque for the load

In this study, the exhaust emissions studied were Carbon Dioxide (CO_2), hydrocarbons (HC), Nitrogen Oxide (NOx), Sulfur Dioxide (SO_2), and carbon monoxide (CO) where the measuring instruments used were a smoke meter and a gas analyzer. Data on the results of measuring exhaust emissions can be seen in Figure 3 (a-e).



(a)



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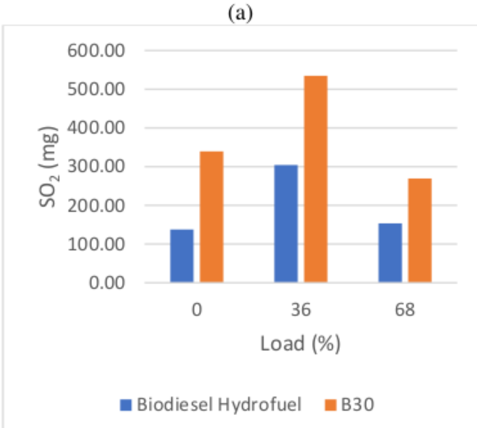

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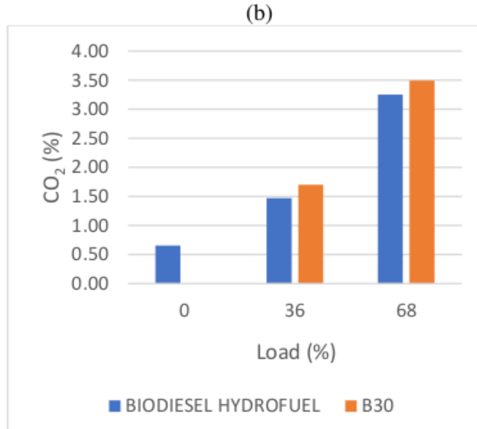
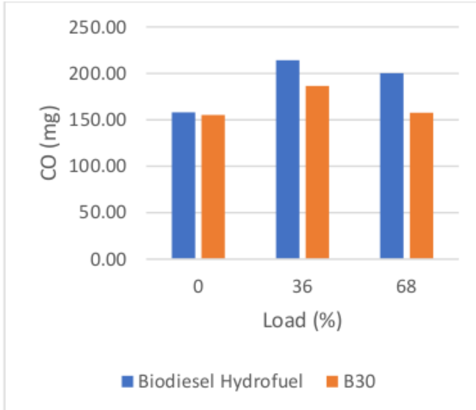


(d)



(e)

Figure 3. All data from exhaust emission measurement results.

Based on the test results, it was found that diesel engine uses Biodiesel Hydrofuel can decrease exhaust emissions with an average number of Nitrogen Oxide (NOx) 105.05 mg, Sulfur Dioxide (SO_2) 182.8 mg, and a slight increase for Carbon Monoxide (CO) is around 24.4 mg for all types of variations in load and engine speed compared to the use of B30 fuel. CO exhaust emissions occur due to a lack of oxygen so the combustion process takes place imperfectly because many C atoms (carbon) do not get enough oxygen to form CO gas. This condition, on the other hand, will increase CO_2 emissions. The experiment showed that the value of the average percentage of Biodiesel Hydrofuel was 0.06% higher for CO_2, which means that even though the CO_2 figure was lower on average, for the overall assessment at each loading the percentage value was still higher than B30. This argues that B30 has an excess of oxygen atoms in which biodiesel is an oxygenated fuel that can bind CO molecules to CO_2. Meanwhile, the reduction in exhaust emissions of Biodiesel Hydrofuel to an average HC value is around 0.29%, better than B30 for all types of variations in load and engine speed. The presence of HC emissions is caused by an incomplete combustion process. Biodiesel Hydrofuel which has the same OH bonds as B30 in its molecular structure makes the process of burning fuel in the combustion chamber better but the resulting exhaust emissions are more environmentally friendly. Furthermore, in theory, the use of biodiesel as fuel will not reduce NOx emissions in engine exhaust gases but instead increase its concentration [11,12]. This happens because biodiesel is made from plant oils that contain lots of nitrates. The more biodiesel added to the engine fuel mixture, the higher the nitrate content in the fuel mixture, as shown in the test results using B30. Based on this, we can conclude that the results of mixing B30 with deionized water in a ratio of 60:40 to produce Biodiesel Hydrofuel can reduce NOx levels up to 21,56% at 68% load which are harmful to society according to the observations.

CONCLUSION

The results showed that biodiesel hydrofuel has the same combustion characteristics as B30 in the small to medium load range showing torque values that are not much different. However, the SFC of Biodiesel Hydrofuel is lower than that of B30. Biodiesel Hydrofuel can reduce HC and NOx emissions up to 0,29% and 21,56% more than B30. Therefore, Biodiesel Hydrofuel is the best solution for increasing production volume and the economic value of industrial fuel products that are more economical and good performance as the objective of this research. This refers to the current high price of diesel raw materials which is expensive and also as a solution for the industrial sector as large-scale consumers who must follow national regulations that require the use of standard B30 from the Indonesian oil and gas ministry.

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