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INFLUENCE OF IODINE NUMBER OF BIODIESEL FUELS FROM WASTE COOKING OIL ON DIESEL ENGINE PERFORMANCE

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ABSTRACT

The global problem in the world today is the depletion of fossil fuel reserves and the impact on the environment. So that is needed alternative fuel which one of them is biodiesel. There are many kinds of biodiesel feed tocks one of which is waste cooking oil (WCO). Differences in the amount of iodine in WCO can occur because everyday use is not uniform. The longer used as cooking oil could increase the amount of iodine. Implementation of this research has been done by using experimental method. The iodine number of WCO is varied by adding potassium iodate. The performance of engines with biodiesel fuel from WCO with varying iodine quantities is studied using a single cylinder diesel engine. To know the quality of biodiesel from WCO conducted examine of its properties with Indonesian Biodiesel Standard (SNI). The purpose of the engine performance investigation is to determine the effect of iodine on power, torque, SFOC, BMEP, and thermal efficiency. Iodine numbers have no effect on power, torque, and thermal efficiency but have an effect on SFOC.

Keywords: Performance, Biodiesel, Waste Cooking Oil, Iodine number, Diesel Engine

1. INTRODUCTION

The fuel crisis for diesel engines from fossils is the biggest globally issue that occur with increasing fuels prices and the depletion of fossil oil reserves, for which an alternative fuel is needed which is expected to address the issue of which one is biodiesel. Biodiesel is an alternative fuel that is now growing and reducing fossil fuel use [1,2,3].

The development of biodiesel is to solve the problem of energy supply in the world, is also a hope in the future because the biodiesel is based on agriculture, that will not run out as long as there are still growing raw materials [4]. Biodiesel is also environmentally friendly and can be produced by individuals and small business units because the technology is relatively simple and does not require sophisticated technology. The feed stock for making biodiesel are quite numerous, among them are oil palm, coconut, grain, beans, jatropha, cooking oil and others [5,6,7].

Waste cooking oil is one of the potential feed stock because cooking oil is used by every level of society from low to high economic levels and from households to hotels [8,9]. The problem is the content or properties of the biodiesel. One of the content in biodiesel is the iodine number. Other than, the viscosity and flash point of the biodiesel is higher than diesel fuels thus both biodiesel properties need to be lowered to fit into fuel [10, 11]. In addition, the content of unsaturated acids in biodiesel (expressed by the amount of iodine) increases the risk of polymerization in diesel engine lubricating oil [12].

Almost all of the chemical components in biodiesel are lower than fossil fuels, the SO_2 content is relatively low and the resulting carbon monoxide (CO) emissions are quite low [13]. Exhaust gases generated by engines such as nitrogen, carbon dioxide and water vapor however contain considerable amounts of other compounds which may be harmful to health as well as to the environment such as hydrocarbon compounds, nitrogen oxide (NO_X) [14].

The compounds in the exhaust gases are formed during the energy produced for the engine operation. Some compounds that are otherwise harmful to health are various sulfur oxides, nitrogen oxides, carbon oxides, hydrocarbons, and particular ones. The formation of the exhaust gas occurs during the burning of diesel fuel in a diesel engine. Much research has been done on biodiesel in terms of sources of raw materials, production technology, machine performance, emissions and the impacts of their use on the environment. The studies that have been conducted are as follows:

Liu et al [10] state that WCOB can increase combustion efficiency and reduce PM, HC, and CO emissions. A high fraction of biodiesel blends resulted in lower PAH emissions due to no PAH in WCOB. BSFC was higher for biodiesel blends as a consequence of biodiesel having a lower heating value. Furthermore, using WCOB is an economical source and an effective strategy for reducing cost, and solves the problem of waste oil disposal.

Ali et al. [5] The experimental results that the engine fuelled by UWCO blends performed well and are comparable with the performance run by the diesel fuel, engine power output and the fuel consumption of the engine are almost the same when the engine is fuelled with UWCO blends compared with that of diesel and provides good engine performance.

Golimowski [4] state that A fuel injection system in older diesel engines powered by biofuel from cooking oil will generated less power than one using standard diesel fuel, this is due to the low calorific value of biofuels from cooking oil and the differences between fuel parameters didn’t impact on the thermal efficiency of older engines which was used to the study. Thermal efficiency of engine was the same used both fuels and amounted 30%.

Gad et al. [12] Diesel- biodiesel blends showed increase in fuel consumption due to the lower heating value of the biodiesel. B20 and B10 showed an increase of 2.6 and 1.4 %, respectively in fuel consumption compared to diesel fuel. Biodiesel blends B20 and B10 showed increase in specific fuel consumption about 2.2 and 1.3%, respectively in comparison with diesel fuel and the decrease in engine thermal efficiency about 3.5 and 2.5%, respectively in comparison with diesel fuel.

Biodiesel is one of the alternative fuels that have different characteristics from other fuels, therefore there needs to be experiments on engine performance emissions and feasibility studies related to greenhouse effect when used as alternative fuel to replace fossil fuels on diesel engines. This research use biodiesel from waste cooking oil each with 0% (B0), 20% (B20), and 30% (B30). In addition to these compositions is also vary the iodine number such as 60.76, 61.93, 66.09 which is shown in table 2.

1.1 Biodiesel

Biodiesel is a fuel consisting of a mixture of mono-alkyl esters of a long chain of fatty acids, used as an alternative to diesel fuel and made from renewable sources such as vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required [15]. Biodiesel is the best candidate to replace fossil fuels as the world's primary source of energy, because biodiesel is a renewable fuel that can replace petrol diesel in today's engines and can be transported and sold using today's infrastructure [3,16]. All vegetable oils and animal fats consist primarily of triglyceride molecules such as that shown Fig. 1 [15].

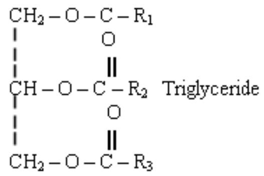


Fig.1. Triglyceride molecules of Vegetable oils and animal fats [15]

R 1, R 2 and R 3 represent the hydrocarbon chain of the triglyceride fatty acyl group. In their free form, the fatty acid has a hydrocarbon chain configuration of ≥ 10 carbon atoms [15].

Prior to use as biodiesel, biodiesel feed tocks need to be estrified to reduce viscosity and flash point. Transesterification is the process of reaction a triglyceride molecule with an excess of alcohol in the presence of a catalyst (KOH, NaOH, NaOCH3, etc.) to produce glycerol and fatty esters. The chemical reaction with methanol is shown schematically in Fig. 2 [15].

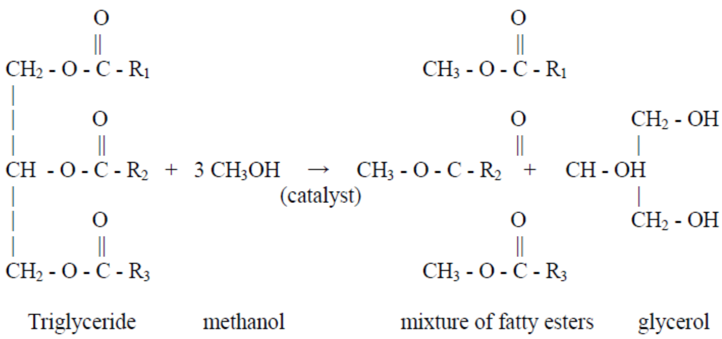


Fig.2. Process of reaction a triglyceride molecule [15]

The application and production of biodiesel is increasing rapidly, especially in Europe, the United States and Asia, although in the market it is still a fraction of the fuel sales. The growth of fuels stations makes more biodiesel supply to consumers and also the growth of transportation using biodiesel as fuel [4].

1.2 Waste Cooking Oil

Waste cooking oil (WCO) a household waste, mainly from restaurants and food industries, it is well known fact that, when oils such as these are heated for an extended time, they undergo oxidation and give rise to oxides [11]. WCO contains some compounds that are harmful to human health produced during the heating process (frying) within a certain time, among others: polymers, aldehydes, free fatty acids, and aromatic compounds. During the frying process there is degradation of the oil caused by heat, water, and air resulting in oxidation of hydrolysis and polymerization [17,18].

1.3 Diesel Engine Performance

Performance on diesel engine such as power and torque is influenced by the large amount of heat combustion, which is the calorific value of combustion of fuel and compressed air [19]. Fuel that has a low calorific value requires a higher amount of fuel to generate power by one horsepower than a fuel that has a high calorific value, that is, the lower the heating value of the fuel the higher the level of fuel consumption compared to fuel which is higher calorific value [21]. For long-term operation of diesel engines which use alternative fuels could cause performance degradation. The formation of carbon deposits and damage can also be seen visually against diesel motor components. Possible causes of the problem occur are changes in load and rotation when the engine is tested [5,21].

2. EXPERIMENTAL SET UP

2.1 Engine Set Up

Planning and preparation of equipment can be seen in Figure 3. In the implementation of this experiment engine is operated with variable speed and load. The speed performed are 1800 rpm, 1900 rpm, 2000 rpm, 2100 rpm, and 2200 rpm. For loading is starting from 1000 watt, 2000 watts, 3000 watts, 4000 watts, and 5000 watts respectively.

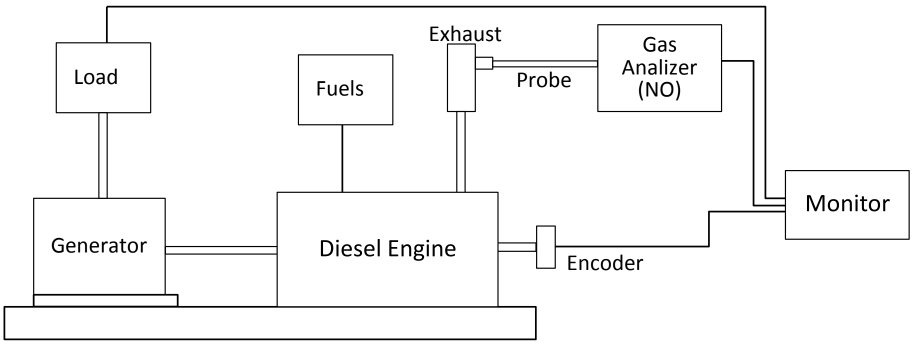


Fig.3. Engine set up

2.2 Iodin Number Variable

Potassium iodate (KIO3) is used for variations in iodine numbers in this experiment. Potassium iodate is granular iodine that is widely used in the salt industry as a chemical that is mixed in salts that can be consumed by humans. The addition of iodine to WCO aims to obtain different iodine numbers and is performed before WCO is heated. In this research there are 3 variations of iodine addition that is 0 gr/liter, 10 gr/liter and 20 gr/liter. Figure 4 is a type of iodine to be added to biodiesel in this experiment.

Fig.4. Potassium iodate

2.3 Fuels

The fuel to be used in this experiment consists of 2 types of fuel, diesel fuels and biodiesel from WCO with 3 variations of iodine addition. Diesel fuels and biodiesel will be mixed with the percentage of 20%: 80% (B20), and 30%: 70% (B30) to form 6 types of fuel:

- Variation 1 with the composition of 20% biodiesel and 80% diesel fuel (BA1)
- Variation 2 with the composition of 30% biodiesel and 70% diesel fuel (BA2)
- Variation 3 with the composition of 20% biodiesel and 80% diesel fuel (BB1)
- Variation 4 with the composition of 30% biodiesel and 70% diesel fuel (BB2)
- Variation 5 with the composition of 20% biodiesel and 80% diesel fuel (BC1)
- Variation 6 with the composition of 30% biodiesel and 70% diesel fuel (BC2)

2.4 Biodiesel Properties and Engine Performance Testing

2.4.1 Biodiesel Properties Testing

A Biodiesel property testing is intended to determine the physical and chemical properties of biodiesel that have been processed through the transesterification process. Parameters to be tested in this test are viscosity, density, flash point, Cetane number, iodine number, cloud point, sulfur content, sediment content, pour point, ash content, lower heating value (LHV) and distillation and acid number. The results of this test will be compared with the Indonesian National Standard (SNI) established by the National Standards Agency (BSN) of Indonesia in 2015.

2.4.2 Engine Performance Testing

Performance testing is done after biodiesel is tested its properties on each type of variant that has been produced. The purpose of performance test is to know the effect of iodine number on biodiesel made from WCO to diesel engine performance. In this test, data will be obtained and will be analyzed to determine the amount of power, torque, specific fuel oil consumption, BMEP and thermal efficiency in each revolution. The rotations used in this test are 1800 rpm, 1900 rpm, 2000 rpm 2100 rpm and 2200 rpm. While the load used is 1000 watts, 2000 watts, 3000 watts, 4000 watts and 5000 watts.

3. RESULTS AND DISCUSSION

3.1 Properties of Biodiesel

The results of testing the properties of biodiesel are as shown in table 1. The results of this test are adjusted to Indonesian biodiesel standards.

Tabel 1. Result of biodiesel properties testing

Parameters	Units	Results	Test Method
Kinematik Viscosity at 40^{o}C	cSt	7.87	ASTM D 445-97
Pour Point	^{o}C	3	ASTM D 97-85
Cloud Point	^{o}C	9	ASTM D 2500
Flash Point	^{o}C	174	ASTM D 93-00
Sulfur Content	%	0.26	SNI 7431:2008
Sediment Content	%	9.17	ASTM D 473-02
Water Content	%	0.048	ASTM D 1796
Ash Content	%	0.012	ASTM D 482
Densitas	Gr/cm3	0.88	Piknometer
Distilation 90% Complete	^{o}C	410	ASTM D 86
Cetane Index	-	50.30	ASTM D 4737:2011
Lower Heating Value	BTU/lb	18.222	ASTM D 240

Based on the results obtained can be concluded that the nature of biodiesel tested in accordance with Indonesian biodiesel standards.

3.2 Iodine Number Content

Iodine number is expressed by the number of grams of iodine absorbed by 100 g of fat and depends on the amount of unsaturated fatty acids in the oil. Iodine number test results can be seen in table 2.

Tabel 2. Result of iodine number testing

Variants	Results	Test Method
Biodiesel A	60.76	Gravimetry
Biodiesel B	61.93	Gravimetry
Biodiesel C	66.09	Gravimetry

Based on the test results, it can be concluded that the iodine number of biodiesel according to Indonesian biodiesel standard.

3.3 Engine Performance Testing

The experiment aims to find out how much influence the number of iodine on diesel engine performance using diesel engine YANMAR TF 85 MH-in 493 CC Single Cylinder.

3.3.1 The Effect of iodine number on Power

Tests conducted obtained the results that the iodine number does not affect the power generated by the engine at each load level and speed because the power generated by the engine at each load level and speed is relatively the same and there is no significant difference (Fig. 5).

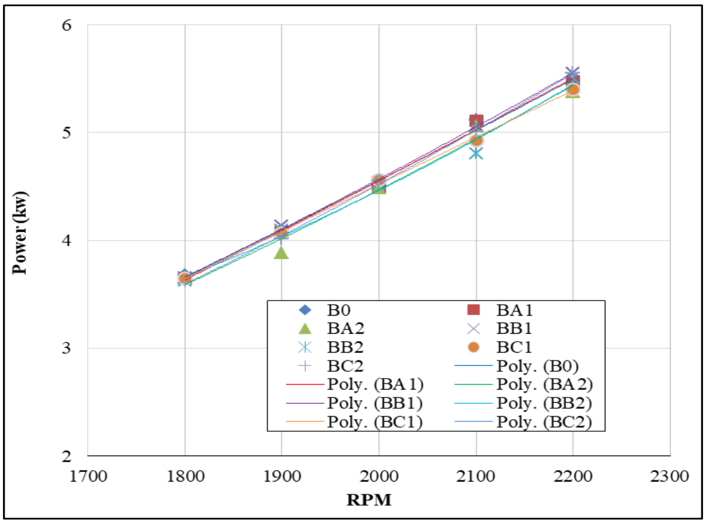


Fig.5. Comparison of maximum power with engine speed on fuel type at maximum load.

From Figure 5 it shows that the increase in power at each level of speed is constantly increased, meaning that there is no power fluctuation from low speed to high speed. Based on the test results, it is concluded that the iodine number does not affect the engine power at each load and each speed, the greater the load used, the greater the power generated along with the increase of the engine load, no power fluctuations at each engine speed.

3.3.2 The Effect of Iodine Numbers on Torque

The torque generated by the engine at the highest load and power in each speeds with different fuel variants is shown in figure 6.

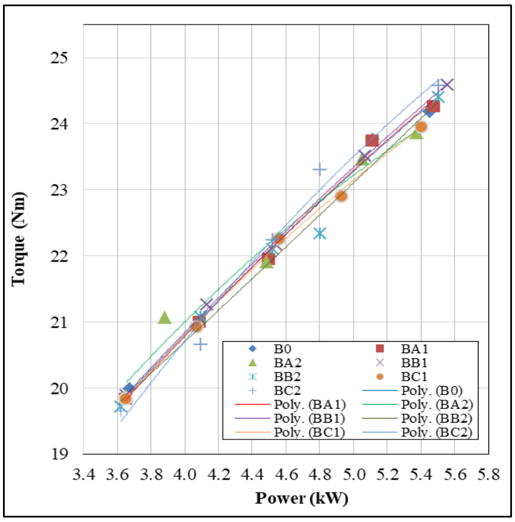


Fig.6. Comparison of power with torque to fuel type at maximum load

From Figure 6 it is seen that the iodine number does not affect the torque generated by the engine at the highest load in each speed with the various fuel variants available because the torque generated by the engine is relatively the same.

From the result of experiment, it can be concluded that the iodine number in each fuel variant does not affect the torque at each load and every speed rate generated by the engine, there is an increase of torque at each load level along with the increase of engine power and speed, no fluctuation at each load level and each speed of engine.

3.3.3 The Effect of Iodine Numbers on SFOC

Experimental results performed with various variants of the fuel to SFOC are as shown in Fig. 7. For comparison, the maximum power taken is power at maximum load (5000 watts) at each speeds.

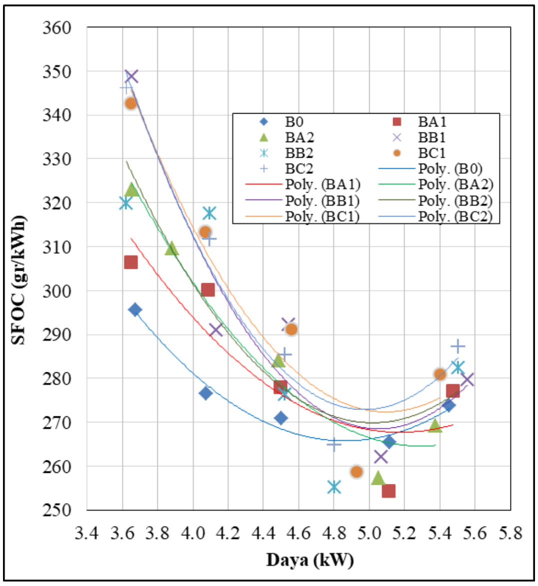
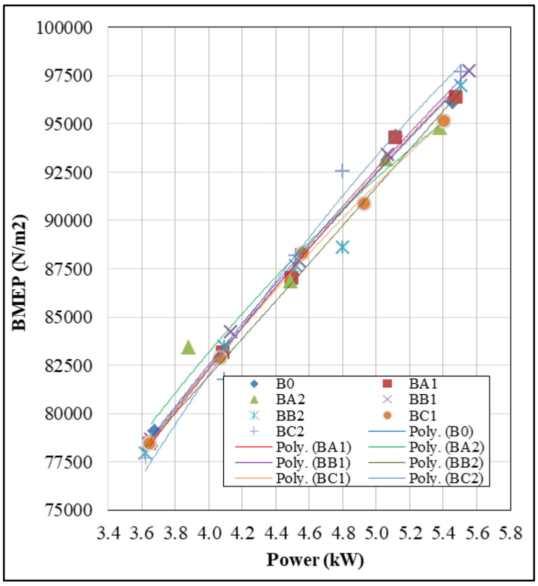


Fig.7. Comparison of power with torque to fuel type at maximum load

From Figure 7 it is seen that iodine numbers significantly affect SFOC at maximum load (5000 watts) at 1800 rpm, 1900 rpm, 2100 and 2200, whereas in 2000 rpm iodine numbers do not affect SFOC because it is relatively the same between each type of fuel variant used. The Figure 7 also shows that there are significant differences in SFOC from BB1, BC1 and BC2 fuels to other fuel types at 1800 rpm, an increase of 25.71 g/kwh to BB2 and BC2, 42.19 g/kwh to BA1 and 53.06 g/kwh to B0. From the experimental results it can be concluded that the greater the power generated by the engine the smaller the SFOC, the iodine number affects SFOC on certain engine speed.

3.3.4 The Effect of Iodine Numbers on BMEP

From the experimental results it was found that iodine number did not affect BMEP at each load and speed with iodine variant on each type of fuel because it was relatively the same. Figure 8 shows the BMEP at the maximum load at each speed level, showing that both at low speed (1800 rpm) and at maximum speed (2200 rpm) there is no difference in each type of fuel used. In the picture, it is also seen that the higher the speed, the greater the BMEP. The relatively constant increase of BMEP means no change in the increase of any given level of rotation.



Figu.8. Comparison of power with BMEP to fuel type at maximum load

From the experimental results it can be concluded that the iodine number does not affect the BMEP at each load level and engine rotation rate, there is an increase in BMEP along with increasing engine speed, the increment is relatively constant.

3.3.5 The Effect of Iodine Numbers on Thermal efficiency

The experimental results are as shown in figure 9 which shows the thermal efficiency generated by the engine at the load, and the maximum power by using the iodine number variant on different types of fuel.

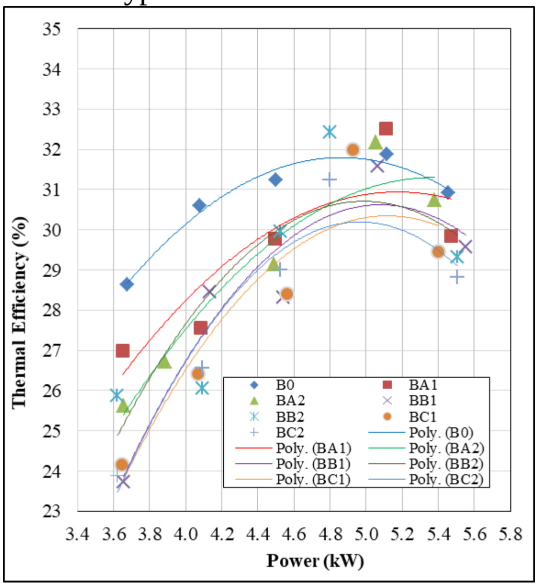


Fig.9. Comparison of power with thermal Efficiency to fuel type at maximum load

In figure 9 it can be seen that the iodine number affects thermal efficiency at each load and speed level, this can be seen from the magnitude of the thermal efficiency at each load level and the rotation is relatively different. From the figure it can also be seen that from RPM 1800 to 2100 there is an increase in thermal efficiency, while from 2100 rpm to 2200 rpm there is a decrease. Of the various types of fuel used, the BA1 fuel type produces the greatest thermal efficiency at 1800 rpm compared to other types of fuel while at the maximum rpm (2200 rpm) BA2 fuel type produces the greatest thermal efficiency. From the experimental results, it can be concluded that the iodine number influences the thermal efficiency, thermal efficiency fluctuation from 2100 rpm to 2200 rpm, BA1 fuel produces the greatest efficiency at 1800 rpm and at 2200 rpm the greatest efficiency is produced by BA2.

4. CONCLUSION

After conducting the experiment and based on the data found it can be concluded as follows:

- The iodine number does not affect power, torque, and thermal efficiency of the engine.
- The iodine number simply affects SFOC at certain load and spin levels.
- The greater the load, the greater the power generated by the engine as the engine speed increases.
- There is an increase in torque at each load level along with increasing power and engine speed.
- The larger the power the SFOC generates the smaller as the engine spins.
- Increased BMEP along with increasing load and engine speed.
- No fluctuations in power, torque and BMEP at each rotation level, whereas in SFOC and thermal efficiency fluctuations occur

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