International Journal of Smart Grid and Clean Energy

Experimental study on performance of the diesel engine fuelled by *cerbera odollam* oil biodiesel blends

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Abstract

Cerbera odollam is a plant species commonly found in coastal areas, especially in Aceh, Indonesia. Based on traditional processes, *carbera odollam* seeds are potentially capable of producing oil. The objective of this research is to examine the effects of specific fuel consumption, power generation and the thermal efficiency on diesel engine performance based on different ratios of diesel and *Cerbera odollam* seeds oil blends (B-0, B-10, B-20 and B-30) under high speed rotation of the diesel engine. The result showed that, at relatively low rotational speeds of the engine (2000 rpm to 2500 rpm), there are no significant effects on fuel consumption (for each type of fuel). In addition, the experimental results revealed that, when the rotational speed exceeds 2500 rpm, the specific fuel consumption significantly increases. The power generation increases when the engine rotation increases. It was found that the diesel and *Cerbera odollam* seeds oil blends are superior at relatively lower rotational speed, while the pure diesel fuel excels at a rotational speed of 3500 rpm. In addition, the thermal efficiency of diesel and blended diesel decreases when the engine rotation increases.

Keywords: Biodiesel, cerbera odollam seeds, power, specific fuel consumption, thermal efficiency.

1. Introduction

The dependence of people on fossil fuel as the main source of energy is increasing, while its stock is diminishing. Consequently, depending on worldwide supply, the world price of oil goes up and sometimes fluctuates. This tendency may affect energy stability from the fossil fuel viewpoint, thus, urging researchers to seek out solutions for alternative non fossil fuel. To address this issue, the Indonesian government has issued a policy on the development of alternative fuel to tackle the energy crisis and solve the problems related economic revival of the society. One of the emerging solutions is to find new renewable energy sources derived from biomass, commonly called bio-fuel or biodiesel. Biodiesel is a promising alternative fuel for diesel engine. It is defined as the mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats and alcohol with or without a catalyst. Biodiesel is renewable, biodegradable non-toxic, portable, readily available and eco-friendly [1].

A number of researchers have conducted studies on the conversion of vegetable-based fuel into biodiesel. Havendri A. [2] stated that biodiesel was much more 'greener' (environmentally friendly) since its fumes released into the air will be absorbed by plants for the process of photosynthesis. Therefore, biodiesel should be capable of diminishing the exhaust emissions without sacrificing the performance of the engine. From the previous study [3], it was reported that *pangium edule* seeds could be adopted as a new source of biodiesel since it has similar characteristics with other vegetable based oil for biodiesel. Therefore, to the best of the author's knowledge, limited studies on the possibility of *cerbera odollam* oil as a potential non-edible oil feed stock for biodiesel production have been reported [4]. Diesel engine performance by using biodiesel from *hevea barsiliensis* seeds and its blend with diesel

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doi: 10.12720/sgce.7.4.297-302

oil (DEX) has also been reported [5]. The experiment was performed by using diesel engine under a low speed rotation of less than 2600 rpm.

In this study, the authors would like to examine the effect of the mixture variation of *cerbera odollam* oil with diesel oil (DEX) and the variation of engine rotation on fuel consumption, the power being generated and the thermal efficiency of the diesel engine under a high speed rotation (more than 2500 rpm).

2. Experimental Procedures

2.1. Biodiesel production

Biodiesel has been produced by a three-step process namely, degumming, esterification and transesterification. The first step is called the degumming process. In this process, there is about 0.7 % (vol.) of phosphoric acid. (H_3PO_4, 20% concentration) was added to crude c*erbera odollam* oil at a temperature of 70 ℃ for 30 minutes in a glass beaker. This mixture was separated by density separation in a separation funnel resulting in the phosphate compounds dropping down at the bottom of the container. The second process is called acid esterification. In this process, the sample of crude *Cerbera odollam oil* (CCCO) was mixed with 1:8 molar ratios of methanol and the mixture was stirred at a speed of 300 rpm. Then, hydrochloric acid (HCl) was added to the sample drop by drop using a connected pipe to the flask. The amount of HCl catalyst added was 1% (v/v). During the reaction, the mixture was stirred at a constant speed of 300 rpm using a magnetic stirrer for 3 hours at 65^{o}C. The last process is called transerterification. In this process, *Cerbera odollam* esterified oil (COEO) was mixed with 29.76 gr of methanol while stirring at a speed of 300 rpm. Then, 2 gr of KOH of the alkaline catalyst used in this process was diluted, added to the oil and maintained at 60^{o}C for 2 hours.

The properties of the produced biodiesel derived from *Cerbera odollam* oil i.e. viscosity, density, flash point, acid value, oxidation stability, FAME content and heating value have been tested. Table 1 summarises the physicochemical characteristics of *Cerbera odollam* oil's biodiesel.

Table 1. Physicochemical properties of *Cerbera odollam* oil

Property	COME	Limit ASTM D6751	Limit EN 14214
Kinematic viscosity at 40^{o}C (mm^2/s)	847.9	880	860-900
Density at 15^{o}C (kg/m^3)	3.1578	1.9−6.0	3.5−5.0
Acid value (mg KOH/g)	0.4	Max. 0.5	Max. 0.5
Heating value (MJ/kg)	40.490	35	−
Flash point (℃)	214.0	Min. 130	Min. 101
Oxidation stability (h)	6.35	3	6
FAME content (%)	97.77	−	96.5

To test the engine performance, a measuring glass in which the blended biodiesel and diesel oil (DEX) would be supplied into the fuel tank was used. Its specific aim was to pinpoint the effect of fuel consumption rate on engine performance. The experiment for fuel consumption could be simultaneously conducted along with the engine power test. To obtain the output power of the diesel engine through the measurement of the voltage and amperage from a generator which was connected to the engine via a V belt, a specific methodology was applied. Fig. 1 illustrates the scheme of the testing tool for engine performance.

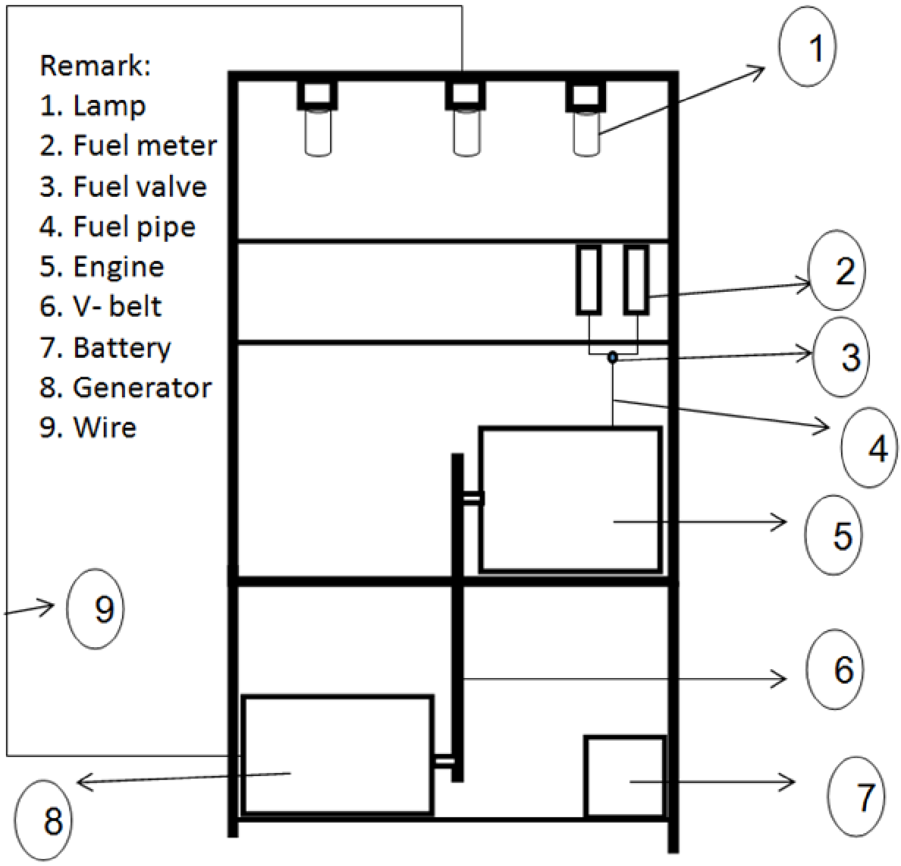


Fig.1. The scheme of testing tool for engine performance.

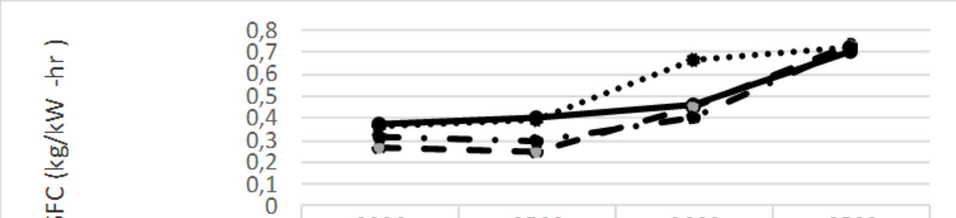
3. Results and Discussion

3.1. The effect of rotational speed on fuel consumption

Specific fuel consumption (brake specific fuel consumption - bsfc) is defined as the amount of fuel consumed by an engine to generate a power of 1 kW for one hour. Bsfc is a standard for the fuel consumption of an engine, usually counted in fuel mass unit per output power unit. The results of the experiment showed that the fuel consumption profile of blended biodiesel for different speed rotation may be as shown in Fig. 2.

Fig. 2 shows that, in general, there is a correlation between the fuel consumption rate and engine rotation. The specific fuel consumption increases by increasing the engine's rotational speed. On the rotation of 2000 to 2500 rpm, there were no significant effects on the correlation between the different blended biodiesel types and fuel consumption. It was found that the ratio of biodiesel in diesel fuel significantly affects the specific fuel consumption on the rotation of more than 2500 rpm.

This research shows that the addition of 20 % *cerbera odollam oil* to diesel fuel (B-20) and (B-30) has the tendency to save specific fuel consumption of the engine at 2500 rpm due to the kinematic viscosity of the oil. This fact has been reinforced by Murni [6] who argued that the lower the kinematic viscosity of a fuel, the greater the fuel consumption would be.



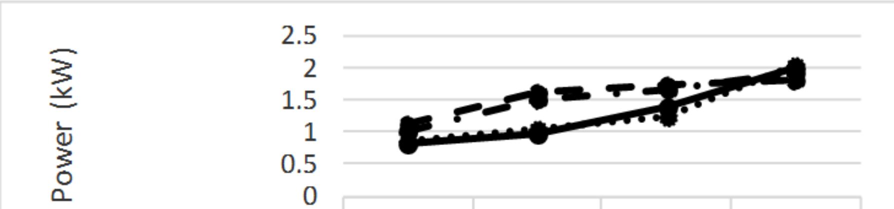
	2000	2500	3000	3500
Pertamina Dex	0,373	0,405	0,465	0,7
B-10	0,368	0,398	0,668	0,726
B-20	0,271	0,246	0,451	0,732
B-30	0,318	0,295	0,4	0,724

Fig. 2. The profile speed rotation engine (rpm) and specific fuel consumption (kg/kW hour) for diesel fuel (B-0) and blended biodiesel (B-10), (B-20) and (B-30).

3.2. The effect of blended biodiesel on generated power.

Power generated by an engine can be defined as the comparison between output power by the generator (voltage and amperage product) divided by product multiplied between the engine's indicators (conversion from thermal energy to power) by generator efficiency connected to an a-c single phase generator [7]. The experimental results in Fig. 3 show that the engine rotation affects the engine's power generation. In this case, the results show that the power generation increases with the increases of the engine rotation.

In this study, it was found that by adding the amount of *cerbera odollam oil* around 20% into diesel fuel (B-20), there was a slight tendency towards lower performance of the engine at 3000 rpm compared to the pure diesel consumption. This might have been caused by the pure diesel fuel that has higher caloric values than the one with 20% biodiesel mixture. Table 1 confirms this.



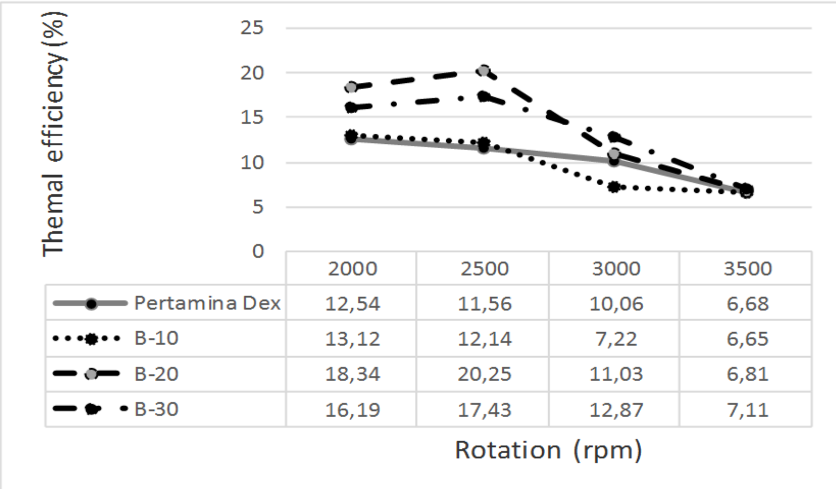
	2000	2500	3000	3500
Pertamina Dex	0.821	0.969	1.409	2.005
B-10	0.853	1.049	1.234	2.048
B-20	1.135	1.634	1.759	1.81
B-30	1.008	1.517	1.656	1.916

Fig. 3. The profile of the effect of engine rotation (rpm) on generated power (kW) diesel fuel (B-0) and blended diesel (B-10), (B-20) and (B-30).

3.3. The effect of blended biodiesel on thermal efficiency.

Thermal efficiency is defined as the caloric efficiency of fuel converted into mechanical rotation. Thermal efficiency (η_{th}) can be measured through the ratio of output power toward caloric values of the fuel used [8]. Fig. 4 shows the profile of thermal efficiency from the calculation of different biodiesel mixture towards different engine rotation.

Fig. 4 shows that the thermal efficiency of the diesel engine (using pure and blended diesel fuels) decreases when its rotational speed increases. This is evidence that for diesel fuel (B-0) was lower than mixed diesel fuel (B-10, B-20 and B-30) on rotations from 2000 rpm to 2500 rpm. The down-grading of the thermal efficiency is suspiciously caused by the amount of its thermal energy in the form of caloric values carried out by diesel fuel (B-0), far greater than the other two mixed diesel fuel.



	2000	2500	3000	3500
Pertamina Dex	12,54	11,56	10,06	6,68
B-10	13,12	12,14	7,22	6,65
B-20	18,34	20,25	11,03	6,81
B-30	16,19	17,43	12,87	7,11

Fig. 4. The Correlation of engine rotation (rpm) to the thermal efficiency (%) generated for diesel fuel of types (B-0), (B-10) and (B-20).

4. Conclusions

An experimental study on the performance of diesel engine fuelled by *Cerbera odollam oil* (Bintaro) and diesel mixture was carried out. The major findings of this study are summarised as follows:

1. The effect on the different blended diesel fuels does not significantly affect the specific fuel consumption at low rotational speeds of the engine from 2000 rpm to 2500 rpm. However, there is a significant increase at rotations of more than 2500 rpm.
2. The power generation is increased by increasing the engine rotation. However by adding the amount of cerbera odollam oil around 20% into diesel fuel (B-20), there is a slight tendency towards a downward performance of the engine at 3000 rpm compared to the pure diesel consumption.
3. The thermal efficiency of the diesel engine (fuelled with diesel and blended diesel) decreases by increasing the engine rotation. This is evidence that for diesel fuel (B-0) was lower than mixed diesel fuel (B-10, B-20 and B-30) on rotations from 2000 rpm to 2500 rpm.

Acknowledgements

The authors graciously acknowledge the financial support provided by Syiah Kuala University, Banda Aceh, Indonesia through the Penelitian Professor No.: 04/UN11.2/PP/PNBP/SP3/2017. Our gratitude also goes to the bachelor students and magister student who assisted in the conduct of the research.

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