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Characteristics of Specific Fuel Consumption on Exhaust Emissions in Diesel Engines Fueled by B20 and B100

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ABSTRACT

The dependence of Indonesian people on diesel fuel is still very high, proven by the increasing amount of diesel fuel consumption yearly. The increase in diesel fuel consumption is a severe problem that must be anticipated because diesel is a fuel that originates from fossils and is non-renewable. In addition to its limited availability, environmental issues are also a matter of concern in the use of diesel fuel because the resulting exhaust emissions can interfere with health and increase global warming. One way to overcome this is to switch from fossil fuels to biofuels, i.e., biodiesel. Although theoretically biodiesel can be used directly as a substitute for diesel fuel, there is very little research on the fuel consumption required for the exhaust emissions produced. Therefore this study aims to determine the correlation between the characteristics of specific fuel consumption (SFC) on exhaust emissions produced in diesel engines using B20 (20% biodiesel + 80% diesel) and B100 (100% biodiesel) fuel. Based on the results of the study, it was found that an increase in SFC resulted in a downward trend in carbon monoxide (CO) and carbon dioxide (CO_2) emissions. In the meantime, the hydrocarbon (HC) emissions and the resulting smoke opacity increased; this was influenced by several factors such as an increase in combustion temperature, increased deposit, and component wear.

Keywords: Biodiesel, exhaust emissions, diesel engine, specific fuel consumption

Introduction

Presently, alternative fuels, especially in internal combustion engines, have become an interesting object to be developed. The use of alternative fuels is inseparable from two global problems, particularly the declining availability of crude oil and the exhaust gas emissions problem, which is increasingly concerning. Considerably high public interest in diesel fuel is indicated by the increase in the consumption of diesel fuel. The fuel oil consumption from 2016 to 2019 continued to increase. In 2016, fuel oil consumption was 97 million barrels per day and increased to 100 million barrels per day in 2019. The consumption increase of diesel fuel is a problem that must be anticipated because diesel is a fuel oil that is processed from crude oil, i.e., fuel made from fossils; thus, it is a non-renewable fuel (Aji et al., 2014). If the consumption of diesel fuel is uncontrolled, the presence of crude oil will decrease and will dry out in 2053 (Kuncahyo et al., 2013).

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Diesel fuel currently used by the public is generally one of the types of fossil fuels that harm the environment and health (Buyukkaya, 2010) because exhaust gas emissions from diesel in the form of CO (carbon monoxide) and HC (hydrocarbon) emissions tend to be still high. The total percentage of CO emissions from burning diesel fuel reaches 4.31%, while the value of HC emissions reaches 135 ppm (Telaoembanoea, 2016). Based on the arising environmental issues and its limited availability, the alternative solution is to diversify fuels.

One of the fuel diversification products that can be used as a substitute for diesel fuel is biodiesel. Biodiesel is a fuel that can be produced from the transesterification process. Biodiesel can be produced by utilizing vegetable oil, animal fat, used cooking oil, and algae; thus, biodiesel can be assumed to be a renewable, biodegradable, non-toxic, and environmentally friendly fuel (Suthisripok & Semsamran, 2018). Biodiesel fuel is appealing to study because of the varying characteristics of biodiesel, influenced by agro-ecological conditions, such as duration of irradiation, rainfall, air temperature, soil type, and soil acidity level (Syukri, 2014).

Saputro et al. (2020) examined the SFC (specific fuel consumption) of the use of B20 fuel (20% biodiesel + 80% diesel) and B100 (100% biodiesel) against operating time. The test was performed for up to 300 operating hours. Based on the study results, the average SFC value produced by the B100 engine was 14.6% higher than the B20 engine. According to Saputro, the higher SFC increase in B100 fueled engines was prompted by the lower energy content of B100 fuel compared to B20. Alloune et al. (2018) conducted a study related to the performance of B30 and B100 diesel engines from Citrullus colocynthis L (CCME). The constant engine speed at 1500 rpm and a dynamometer were used as a load with varying load values. Based on the study results, at low to medium loading (1.1 – 3.5 Kw), the SFC value of the B100 engine was higher than the B30 engine.

Although theoretically biodiesel can be used directly as a fuel, research related to the effect of specific fuel consumption (SFC) on the resulting exhaust gas emissions is still very limited. Based on the differences in the characteristics of biodiesel and the performed test conditions, the purpose of this study is to compare the effect of SFC using B20 and B100 fuels on exhaust emissions produced by diesel engine combustion.

Material and Methods

Experimental set-up

This study used two units of the same type of engine, i.e., the Kubota diesel engine of RD 65 DI NB series with a cylinder volume capacity of 376 CCs and using the same lubricant, i.e., Pertamina Meditran SX Bio SAE 15W-40. Each engine was used to power four halogen lamps with a total power of 4 kW and served as an engine loader. Shaft power was measured by dividing the total load output power by the generator efficiency. Both engines used two different fuels, specifically B20 and B100 fuel. A schematic image of the testing tool can be seen in Figure 1.

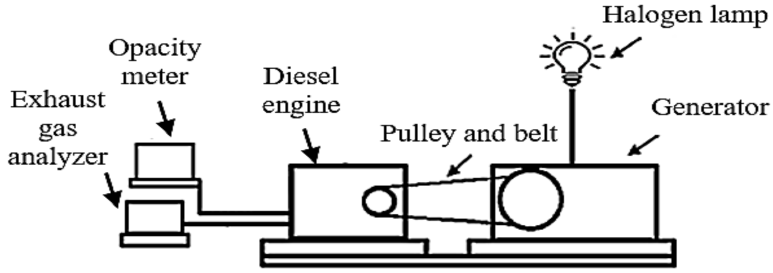

Figure 1. Schematic diagram for experiment

The equipment in Figure 1 was then connected to supporting equipment such as a burette to measure fuel consumption per unit time, an rpm sensor to measure engine speed, equipment to measure current and voltage, and a digital infrared thermogun to measure engine components temperature. Furthermore, to measure fuel emissions used an exhaust gas analyzer with the Tecnotest brand, the Stargas 898 model, and to measure the smoke opacity used the Texa opacity meter, the Opabox autopower model. Measurement of fuel consumption using a manual technique with a burette with a capacity of 20 ml, then measured the time the engine spent 20 ml of fuel using a stopwatch. The cylinder block temperature was measured using a digital infrared thermogun by shooting infrared rays directly at the engine components.

Fuel Characteristics of B20 and B100

The fuel used in this research was B20 and B100 fuel. B100 is pure biodiesel fuel from Crude Palm Oil (CPO) which is a product of PT. Pelita Agung Industri, while B20 is a fuel mixture consisting of 20% palm oil biodiesel and 80% diesel fuel which is a product of PT. Pertamina. The physical and chemical properties of B100 and B20 fuels are presented in Table 1.

Table 2. Fuel specification standards

No	Test Parameters	Test Method	Unit	B100 Test Result	B20 Test Result
1	Density at 40 °C	ASTM D 1298-12b	kg m^{-3}	862.4	-
2	Density at 15 °C	-	kg m^{-3}	-	845.7
3	Kinematic viscosity at 40 °C	ASTM D 445-06	mm^2/s	4.53	2.92
4	Cetane numbers	ASTM D6980-12	Min : 51	61	56.7
5	Flash point	ASTM D 93-02	°C	177	65
6	Distillation temperature 90%	ASTM D 1160-06	°C	350	344
7	Color	ASTM D 1500	Colour ASTM	1	1.1
8	Methyl ester levels	Calculation	% (mm^{-1})	98.24	-
9	FAME content	-	% v/v	-	20
10	Water content	ASTM D 6304	ppm	267	159.63

Result and Discussion

Carbon monoxide

The results of the carbon monoxide (CO) emission test on specific fuel consumption (SFC) is shown in the graph in Figure 2. Based on the analysis results, it was found that the trend of CO emissions in B20 and B100 engines had decreased along with the increase in SFC. The average value of CO emissions produced by the B100 engine was 16% lower than the B20 engine when idle at 1000 RPM. The B20 engine had an average CO emission value of 590 ppm vol, and the B100 engine had an average CO emission value of 500 ppm vol.

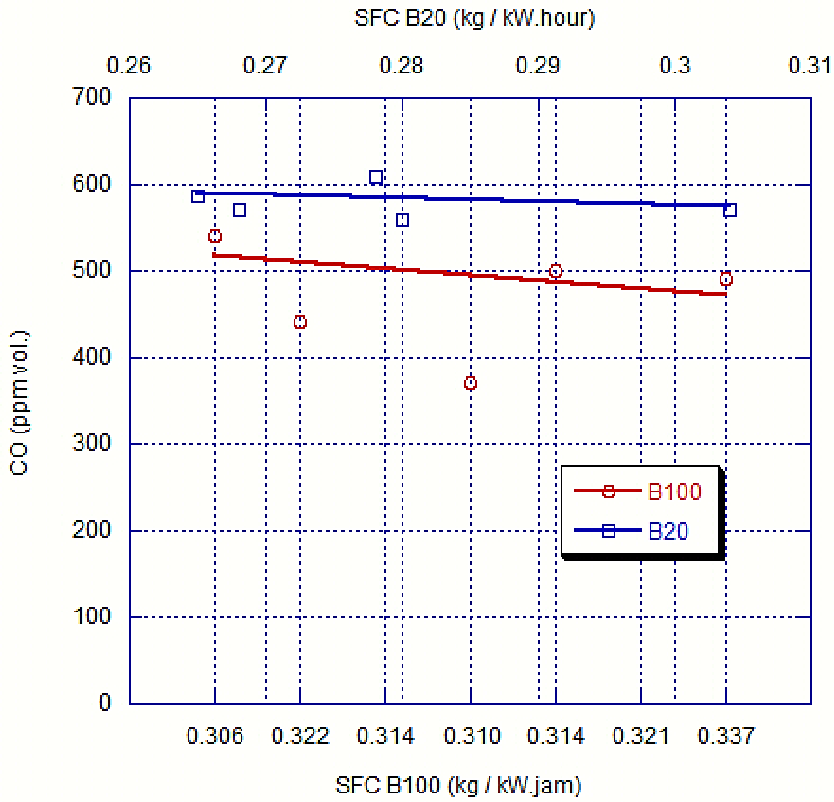

Figure 2. Graph of carbon monoxide emission against specific fuel consumption.

Based on Figure 2, the decrease in CO emissions to SFC in both fuels occurred due to better combustion due to increasing temperatures. The average cylinder block temperature of both engines reached 130 °C. The oxygen (air) entering the combustion chamber reacted with the fuel in an optimum amount (stoichiometry), then under these stoichiometric conditions, the pressure increased, resulting in a higher combustion temperature. When injected into the combustion chamber, the high temperature made the fuel undergo complete combustion due to atomization or very fine droplets burning completely. In addition, the higher oxygen content in B100 fuel reached 11% wt (Suthisripok & Semsamran, 2018), causing the oxygen content in the combustion chamber to become richer. Oxygen played a vital role in producing complete combustion; thus, more CO was oxidized to CO_2 and produced CO emission reduction trend than B20 fuel. Analysis of CO emissions under full load conditions with a rotation of 2200 rpm was not performed because the measuring instrument was unable to take readings at low CO.

Hydrocarbon

The hydrocarbon emissions (HC) test results against specific fuel consumption (SFC) are shown in the graph in Figure 3. Based on the analysis result, the result shows that the trend of HC emissions in engines with B20 and B100 fuel had increased along with the increase in SFC. The average value of HC emissions produced by the B100 engine was 34% lower than the B20 engine at a full load of 2200 RPM. The B20 engine had an average CO emission value of 181 ppm vol, and the B100 engine had an average CO emission value of 136 ppm vol.

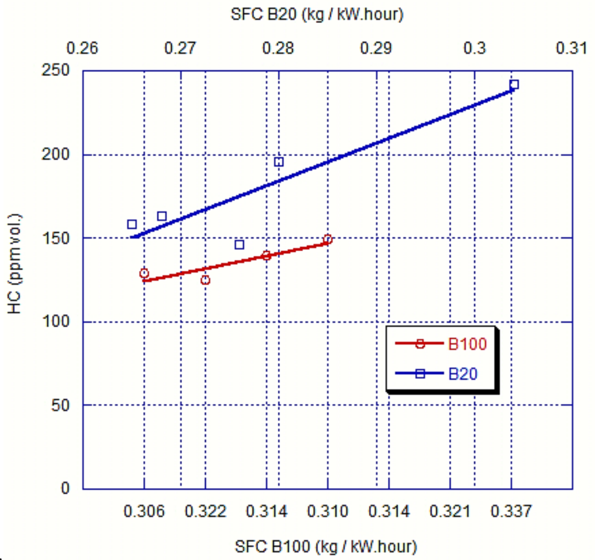

Figure 3. Graph of hydrocarbon emission against specific fuel consumption.

Based on Figure 3, the increase in HC emissions to SFC in both fuels was caused by several factors, such as the wear of engine components and a decrease in combustion temperature. The wear factor on the components will cause the compression pressure of the diesel engine to decrease, where there is an air leak when the compression system is working. The reduced compression pressure will make the compressed air in the cylinder have no significant power pressure to generate heat in the combustion chamber; thus, engine cylinder temperature will decrease. The decrease in temperature will result in incomplete combustion, where the air and fuel are not completely burned at the end of the combustion process. In addition, the more fuel that is injected into the combustion chamber, the more air-poor combustion will occur. The result of incomplete combustion will leave unburned fuel and usually occurs in fuel surrounding the combustion chamber walls, which have a low temperature. The unburned fuel in the combustion process was then removed in a raw fuel condition; thus, it would be read as HC emissions in the exhaust gas analyzer. Fuel that reacts with heat will form another hydrocarbon element that is then released with the exhaust gases.

Carbon dioxide

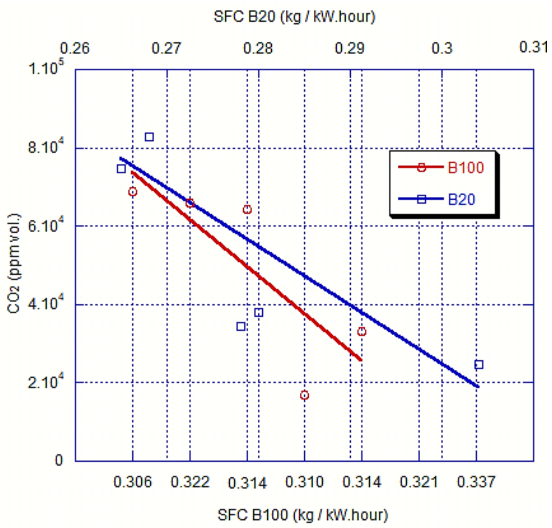

Figure 4. Graph of carbon dioxide emission against specific fuel consumption.

The testing results of carbon dioxide (CO_2) emissions against specific fuel consumption (SFC) are shown in the graph in Figure 4. Based on the analysis results, the results show that the trend of CO_2 emissions in engines with B20 and B100 fuel has decreased along with the increase in SFC. The average value of CO_2 emissions produced by the B100 engine was 36% lower than the B20 engine at a full load condition of 2200 RPM. The B20 engine had an average CO emission value of 5.7 x 10^4 ppm vol, and the B100 engine had an average CO emission value of 5 x 10^4 ppm vol.

Based on Figure 4, the trend of CO_2 emissions in both fuels decreased along with the increase in SFC. The more fuel injected into the combustion chamber has the potential for incomplete combustion. That is influenced by the wear factor on the components, which will cause the compression pressure of the diesel engine to decrease, where there is an air leak when the compression system is working. The reduced compression pressure will make the compressed air in the engine cylinder not have a significant power pressure to generate heat in the combustion chamber; therefore, the engine cylinder temperature will decrease. The decrease in temperature will result in incomplete combustion, where the air and fuel are not completely burned at the end of the combustion process. In addition, more fuel that is injected into the combustion chamber will cause poor combustion of air (oxygen). Thus oxygen does not react enough with the C element (carbon), resulting in incomplete combustion, characterized by a decrease in CO_2 emissions.

Smoke Opacity

The results of the smoke opacity test on specific fuel consumption (SFC) are shown in the graph in Figure 5. Based on the analysis results, the results show that the trend of smoke opacity in engines with B20 and B100 fuel increased along with the increase in SFC. The B20 engine had an average absorption coefficient value of 8 x 10^5 ppm vol, and the B100 engine had an average smoke opacity value of 7 x 10^5 ppm vol.

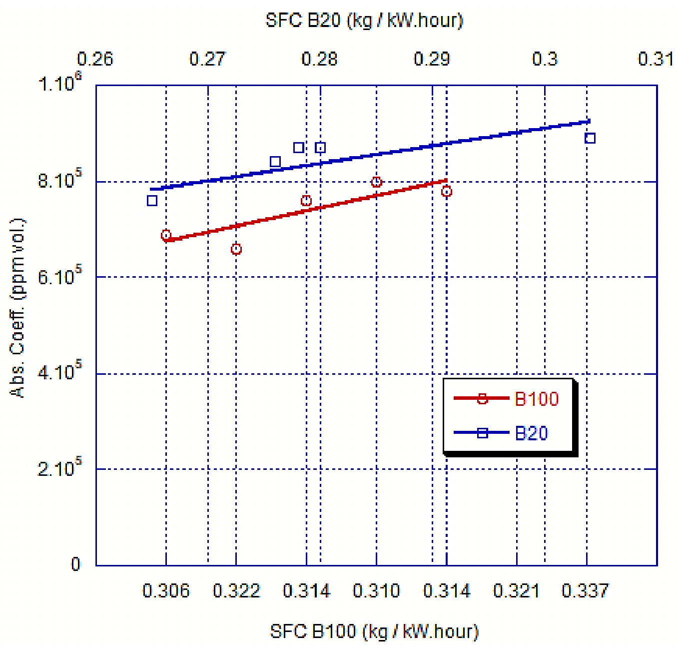

Figure 5. Graph of smoke opacity emission against specific fuel consumption.

Based on Figure 5, the trend of smoke opacity in both fuels progressed with the increase in SFC. Biodiesel fuel has a higher viscosity and density value than diesel fuel. Based on Table 1, the density value of B100 fuel was 862.4 kg/m^3, and the viscosity value was 4.53 mm^2/s. Higher values of viscosity and density will result in poor atomization and larger droplet size. During the combustion process, when the fuel is sprayed into the cylinder in the form of fine liquid droplets when the conditions in the cylinder are at high temperature and pressure, it will cause the grains to evaporate. However, decomposition will occur if the fuel grains that occur due to spraying are too large or if several grains are collected together. This is due to the heating of the air at high temperatures, yet evaporation and mixing with the air in the cylinder cannot happen completely, especially at times when too much fuel is sprayed, resulting in poor combustion of air (oxygen) and the formation of solid carbons (angus). When there is too much angus, the exhaust gas emerging from the engine will be black, pollute the air, and be such an eyesore for the view.

Conclusion

Based on the performed research result, an increase in specific fuel consumption (SFC) results in a downward trend in exhaust gas emissions such as carbon monoxide (CO) and carbon dioxide (CO_2) emissions. In contrast, in hydrocarbon emissions (HC) and smoke opacity, there is an increasing trend. The trend of decreasing exhaust emissions can be influenced by the increased combustion temperature factor and better combustion. While the increase in exhaust emissions can be influenced by wear and tear on the components, which will cause the compression pressure of the diesel engine to decrease; thus, the engine cylinder temperature will decrease and make combustion less complete.

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References

Aji, S., Kusmaningrum., & Herni M, F. (2014). Optimisasi keuntungan menggunakan linear programming di PT Pertamina Refinery Unit (RU) VI Balongan. *Journal of Institut Teknologi Nasional, 1*(3), 1-5.

Alloune, R., Balistrou, M., Awad, S., Loubar, K., & Tazerout, M. (2018). Performance, combustion and exhaust emissions characteristics investigation using *Citrullus colocynthis L.* Biodiesel in DI Diesel Engine. *Journal of the Energy Institute*, *91*, 434–444. Doi: 10.1016/j.joei.2017.01.009

Buyukkaya, E. (2010). Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics, Fuel, 89(10), 3099-3105. Doi:10.1016/j.fuel.2010.05.034

Kuncahyo, P., M. Fathallah, A. Z., & Semin. (2013). Analisa prediksi potensi bahan baku biodiesel sebagai suplemen bahan bakar motor diesel di Indonesia, *Jurnal Teknik POMITS, 2*(1), 62-66. Doi: 10.12962/j23373539.v2i1.3156

Saputro, W., Sentanuhady J., Majid A. I., Prasidha W., N, Gunawan N. P., & Raditya T. Y. (2020). Karakteristik Unjuk kerja mesin diesel menggunakan bahan bakar B100 dan B20 Dalam Jangka Panjang,. *Journal of Mechanical Design and Testing* , 2(2), 125–136. Doi: http://dx.doi.org/10.22146/jmdt.v2i2.55523

Suthisripok & Semsamran. (2018). The impact of biodiesel B100 on a small agricultural diesel engine, *Tribology International*, 128, 397-409. https://doi.org/10.1016/j.triboint.2018.07.042

Syukri, M. N. (2014). *Karakteristik kelapa sawit sebagai bahan baku bioenergi*. Bogor: IFMM (Insan Fajar Mandiri Nusantara)

Telaoembanoea, F. (2016). Penelitian kandungan gas buang yang beracun pada mesin diesel 2500 CC yang menggunakan bahan bakar solar dan bahan bakar biosolar. *Jurnal Warta, 50,* 117-125. Doi: https://doi.org/10.46576/wdw.v0i50.202