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Evaluation of Diesel Engine Performance and Exhaust Emission Characteristics using Waste Cooking Oil

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Abstract. The depletion of fossil fuels as well as the rises of greenhouse gases had caused most government worldwide to follow the international energy policies for the use of biodiesel. One of the economical sources for biodiesel production is waste cooking oil. The use of waste cooking oil is more sustainable if they can perform similarly to conventional diesel fuel. This paper deals with the experimental study carried out to evaluate the engine performance and exhaust emission of diesel engine operated by biodiesel from waste cooking oil at various engine speed. The biodiesel used are known as B5, which contains of 5% of waste cooking oil and 95% of diesel fuel. The other one is B20, which contains of 20% of waste cooking oil plus 80% of diesel. Diesel was used as a comparison purposes. The results show that power and torque for B5 give the closest trend to diesel. In terms of heat release, diesel still dominates the highest value compared to B5 and B20. For exhaust emission, B5 and B20 showed improvement in the reduction of NO_x and PM.

Introduction

The extensive usage of diesel engines has led to an increase in demand for diesel fuel, thus causing the decrease of petroleum fuel stocks. Moreover, the consumption of diesel fuel also gives negative effect to the environment by the rises of greenhouse gases. At this point, attention has been given towards the production of biodiesel as an alternative fuel. For example in Malaysia, the government had already mandated the use of B5 nationwide. The transesterification process in biodiesel production ensures that glycerine, catalyst and alcohol are removed from the oil in order to meet the regulation of biodiesel standard, ASTM 6751. One of the reasonable sources of biodiesel is waste cooking oil since it is easy to get and the cost for biodiesel production is 2 to 3 times cheaper than vegetable oils [1].

Many researchers have proved that biodiesel from waste cooking oil can improve exhaust emissions by reducing carbon monoxide, hydrocarbon and particulate matter [2-4]. However, the high viscosity of waste cooking oil still becomes a major problems since it can cause many engine problems such as poor atomization and carbon deposition [5, 6]. In order to overcome these problems, most researchers used a small percentage of waste cooking oil to be blended with diesel fuel and tested for engine compatibility.

In this present study, two types of biodiesel which produced from waste cooking oil were used to evaluate the diesel engine performance and exhaust emissions. These test fuels were compared with ordinary diesel fuel. The engine performance parameters are including indicated power, torque and heat release which based on the experimental data collected from the test engine. The emission parameters such as CO, CO_2, NO_X and PM were measured during the engine performance test.

Materials and Methods

In this study, three test fuels have been used for engine testing, namely diesel, B5 and B20. B5 and B20 were based on biodiesel from waste cooking oil. B5 comprises of 5% waste cooking oil and 95% diesel fuel, and B20 contains of 20% waste cooking oil and 80% diesel fuel.The measurement of the fuel properties was conducted in order to ensure that all biodiesel is complied with ASTM biodiesel standard. The chemical properties of each fuel are shown in Table 1.

Table 1: Chemical properties of test fuels

Parameter	ASTM D6751	Diesel	B5	B20
Density (g/cm^3)	0.88	0.843	0.844	0.851
Cetane Number	> 46	46.6	46.9	48.9
Calorific Value (MJ/kg)	N/A	42.32	42.08	38.67
Kinematic Viscosity at 40°C (mm^2/s)	1.9-6.0	3.718	3.754	3.829
Cloud Point (°C)	N/A	-3	0	0
Pour Point (°C)	N/A	-10	-9	-8

This experimental study was done according to the SAE J1349 standard. A YANMAR TF120 single cylinder, four strokes, naturally aspirated with water cooled diesel engine was used as the test engine. The specifications of the test engine are listed in Table 2. Fig. 1 represents the schematic diagram of the experimental setup. The fuel control unit was placed next to the engine fuel pump and it was separated in two different tanks, called diesel fuel tank and alternative fuel tank. For the dynamometer system, a gear pump was used in order to apply load to the test engine. The data from the engine testing were collected and processed using data acquisition system by TFX Engineering. In addition, the exhaust emission sampling was divided in two parts, which are exhaust gas analyser and filter for particulate matter sampling purpose. Parameters that produced and analysed by this experimental study were engine power, engine torque, heat release and exhaust emission. The engine testing was repeated for three times, and the average value was taken.

Table 2: Engine specifications

Description	Specification
Engine model	YANMAR TF120
Number of cylinders	1
Bore x Stroke (mm)	92 x 96
Displacement (L)	0.638
Compression ratio	17.7
Continuous output (HP)	10.5 HP at 2400 RPM
Rated output (HP)	12 HP at 2400 RPM

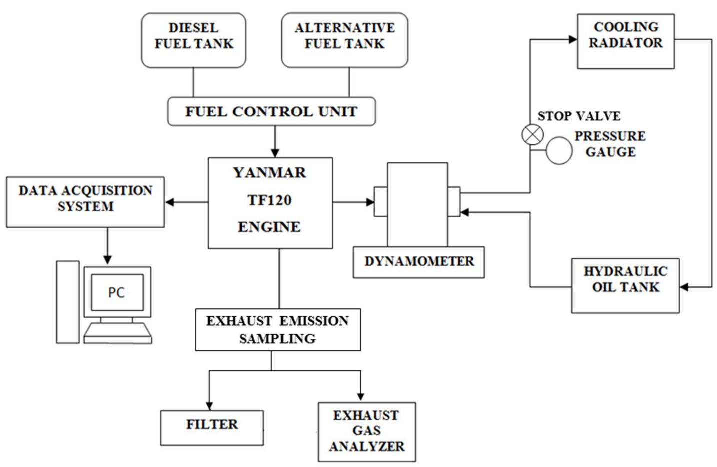
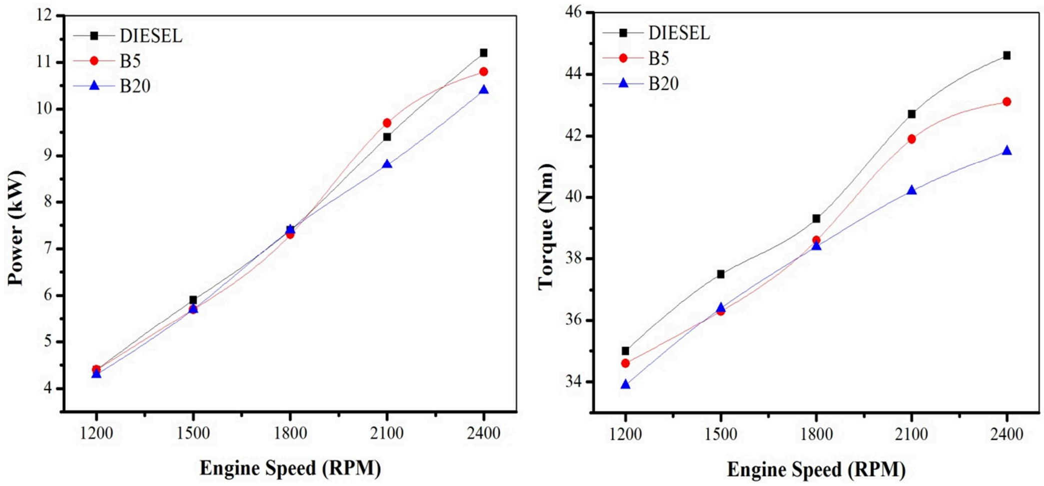


Fig. 1: Schematic diagram of the experimental setup

Result and Analysis

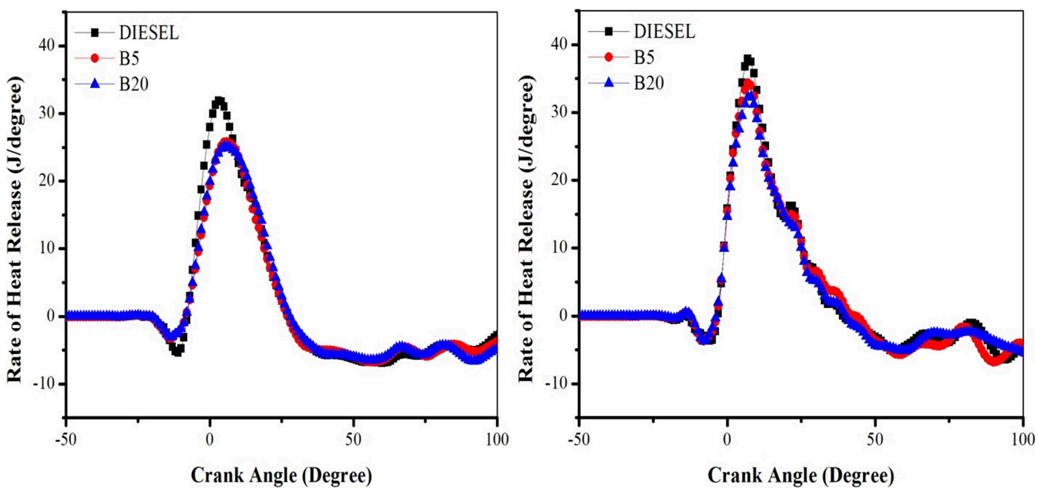
A comparison of the engine power and torque produced by all test fuels is represents in Fig. 2(a) and (b). As seen in the figure, power and torque for all test fuels shows a linear increase as the speed increases. Thus, all test fuels were marked the maximum power and torque value at engine speed of 2400 rpm. With the increase in biodiesel blends ratio, it can be seen that the power and torque produced is lower compared to diesel, which is in agreement with the literature [7-9]. This is obviously because of the chemical properties of biodiesel, especially the lower calorific value of B5 and B20 as compared with diesel.

The results of heat release produced by all test fuels at lowest and highest engine speed are shown in Fig. 3(a) and (b). This figure shows that B5 and B20 have identical combustion stages similar to diesel. However, it can be seen that the heat release increase as the engine speed increase. The location of peak of heat release also delayed and shifted away from TDC with the increment of the engine speed. Moreover, compared to the other test fuels, diesel marked the highest heat release at 1200 rpm and 2400 rpm engine speeds, with the value of 31.9 J/degree and 37.9 J/degree respectively. The lower heat release by B5 and B20 is due to their lower volatility of 0.57% and 8.62% respectively as compared to diesel.



(a) (b)

Fig. 2: (a) Power values for all test fuels, (b) Torque values for all test fuels



(a) (b)

Fig. 3: (a) Heat release rate at 1200 rpm, (b) Heat release rate at 2400 rpm

The comparison of gases emission and particulate matter distribution for all test fuels at various engine speed is shown in Fig. 4(a), (b), (c) and (d). Considering the NOx emission as seen in Fig.

4(a), the usage of B5 and B20 instead of diesel, resulted in small different of 0.2% to 5.7% as the engine speed increase. However, at lowest engine speed of 1200 rpm, NOx produced by B5 and B20 are higher than diesel. This phenomenon might have happened because of structural oxygen content of biodiesel, that improved the oxidation of nitrogen and raised the combustion temperature [10]. The CO emission results are shown in Fig. 4(b). The CO emissions for B20 had a significant increased from about 42% to 83% when engine speed increase as compared to diesel. B5 also produced higher CO than diesel, however at 1800 rpm, the emission is similar with diesel. The increase of CO emission by biodiesel blends might be due to the high viscosity and poor spray characteristics of biodiesel, thus leading to incomplete combustion. For CO_2 emissions as can be seen in Fig. 4(c), B5 and B20 released higher CO_2 as compared to diesel. This is obviously because of average carbon content per energy of biodiesel which is higher than diesel. The other significant emissions from diesel engines are PM emission which can contribute to serious human health effect and environment pollution. The PM concentration of all test fuels can be seen in Fig. 4(d). Overall, as the engine speed increase, PM concentration is also increase. B5 seems to have similar results with diesel with a small variance. However, there is a significant reduction of 20% by B20 as compared to diesel at 2400 rpm engine speed. This is due to the high oxygen content of B20 which caused a reduction in soot formation and thus enhanced soot oxidation [11].

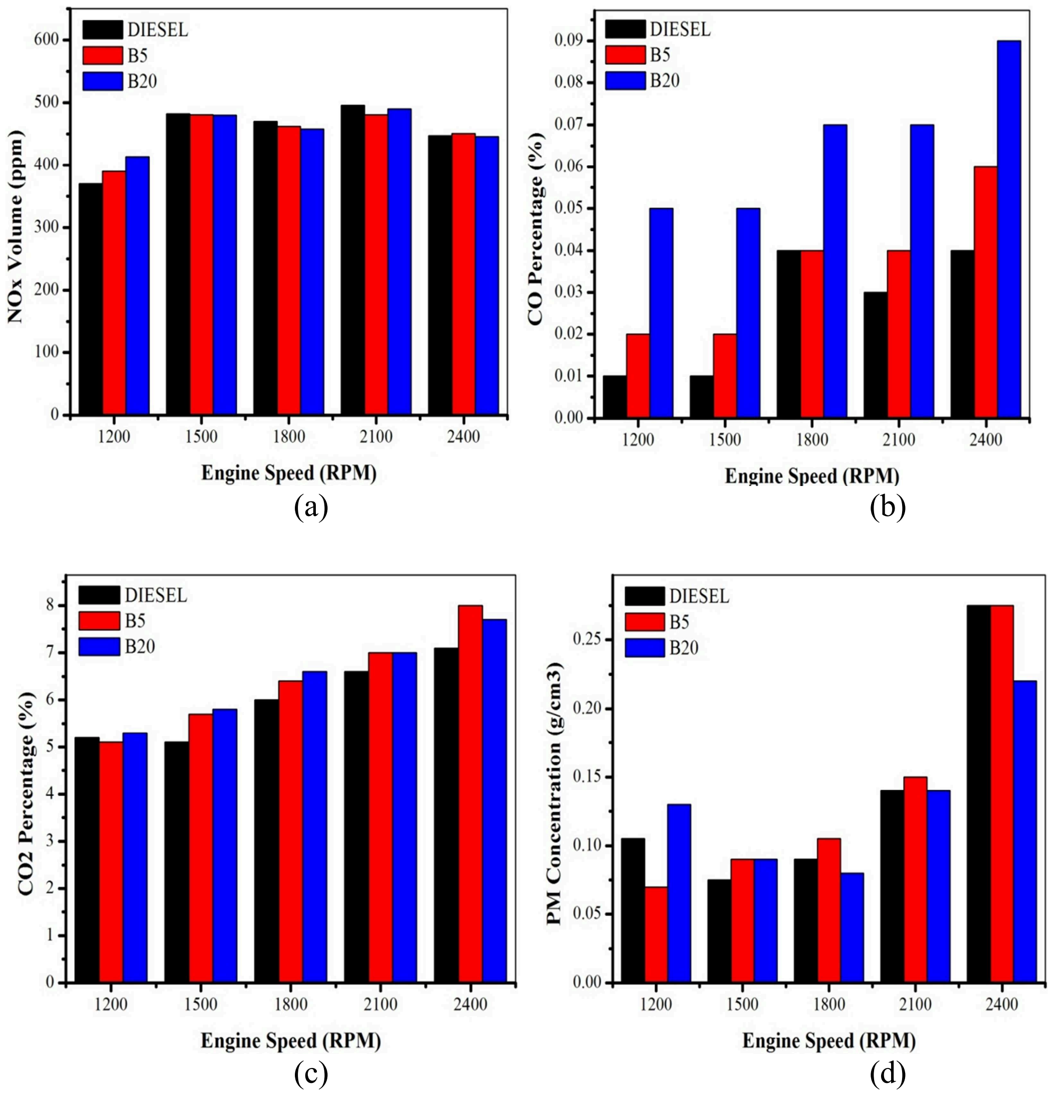


Fig. 4: (a) NO_x emissions at various engine speeds, (b) CO emissions at various engine speeds, (c) CO_2 emissions at various engine speeds, (d) PM emissions at various engine speeds

Conclusion

The engine performance and exhaust emission characteristics of diesel and biodiesel blends derived from waste cooking oil (B5 and B20) were compared. The experimental result showed that the power and torque characteristics for biodiesel blends were almost similar with diesel. For heat release, both B5 and B20 indicated a lower heat release as compared to diesel. Moreover, B5 also showed a close resemblance with diesel in terms of exhaust emissions. These results indicate that biodiesel blends can be used as a diesel substitute without any modification on the engine.

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