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Performance and emission characteristics of binary mixture of poppy and waste cooking biodiesel

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Abstract

An experimental study was conducted on a compression ignition (CI) engine using neat diesel and binary mixture of poppy and waste cooking (PWC) biodiesel-diesel blends. Biodiesel-diesel blends of B5, B10 and B20 for PWC were used in this investigation. The experiment was conducted for different engine speed (1200 rpm-2400 rpm) and load (25%, 50%, 75% and 100%). The speed of the engine was varied from 1200 rpm to 2400 rpm with 200 rpm interval. The performance of the engine output is presented in terms of brake power (BP), torque, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE). The emission characteristics, such as nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) are also presented in this study. The results indicate that BP increases with increase in speed up to the maximum speed of 2400 rpm, whereas, BSFC decreases initially up to 1400 rpm and then increases up to the maximum speed of 2400 rpm at full load condition. On the other hand, torque and BTE initially increases up to 1400 rpm, and then, decreases with increase in speed up to the maximum speed of 2400 rpm. The results revealed that BP, torque, BSFC and BTE are lower in biodiesel blends in comparison to diesel. The engine performance and emission characteristics are compared with diesel. The results revealed that the use of biodiesel-diesel blends led to the significant reduction in carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) emissions in comparison to conventional diesel at full load condition. On the other hand, increase in nitrogen oxides (NOx) is observed in using biodiesel blends over the diesel.

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Keywords: Poppy and Waste Cooking Biodiesel; BP; BSFC; BTE; NO_x; CO; HC and PM

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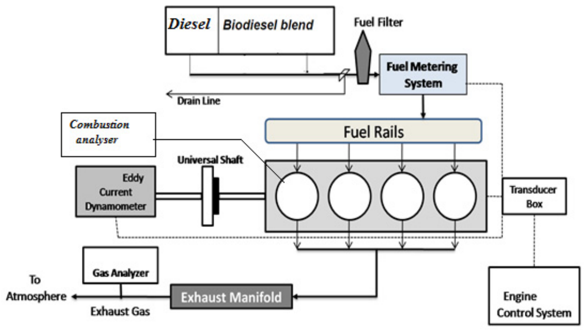
1. Introduction

Numerous studies have been conducted to explore alternative renewable fuel resources and how to use the energy in the most efficient way [1]. One of the principal ways to overcome the dependency on fossil fuel is to use biodiesel in CI engines [2-10]. It has the higher flash point, lubricity, cetane number and oxygen content, although it has the higher viscosity, pour point, lower calorific value and volatility, lower oxidation stability in comparison to diesel. Also, it has good ignition ability due to its high cetane number in comparison to diesel [11]. It is generally accepted that biodiesel-diesel blends up to B20 could be used in existing diesel engines. In terms of engine performance, most of the studies showed that biodiesel-diesel blends decrease in BP and increase in fuel consumption compared to diesel [12]. Several researchers showed that increase in the percentage of biodiesel in the blend resulted in a decrease in power [13]. Overall, biodiesel-diesel blends could be considered as a prospective future transportation fuel. Although many studies have been conducted on engine performance and emission characteristics using different feedstocks, but no or very few studies have been conducted using binary mixture of poppy and waste cooking (PWC) biodiesel. The purpose of this chapter is to analyse the performance characteristics using PWC biodiesel-diesel blends. The use of biodiesel-diesel blends in CI engines leads to the reduction in CO, HC and PM emissions during the combustion process [14]. These results could be explained by low aromatic content and presence of high oxygen content [15]. Researcher showed that biodiesel-diesel blends in CI engines decreases CO, HC and PM emission significantly in comparison to diesel [16]. Most of the studies from the available literature reported that biodiesel-diesel blends increase NO_x emission in comparison to diesel [13, 17]. Researcher showed that EGT is higher in biodiesel-diesel blend compared to diesel [18]. Researcher showed that CO_2 emission is higher in biodiesel blends in comparison to diesel [12].

2. Experimental Setup for Engine Testing

A four-cylinder, four-stroke, liquid-cooled diesel engine was used for the experimental investigation. The experiments were conducted at the thermodynamics laboratory at Central Queensland University, Australia. The engine test bed which was used for the experiment is shown in Fig. 1(a). A schematic diagram of the engine test rig is shown in Fig. 1(b).

(a)



(b)

Fig. 1. (a) Engine test bed for experiment; (b) Schematic diagram of the engine test rig

The test rig is directly coupled to the eddy current dynamometer. An eddy current dynamometer built in auto controller system was used to determine the engine performances and speed. The detailed specifications of the engine test rig and operating condition is presented in Table 1.

A Coriolis-type flow meter (Model: CMF025M319NQEIEZZZ) was used to measure the fuel flow rate. The engine fuel system was adjusted by using two different tanks with nozzle systems to the main fuel supply line. An initial engine run was conducted with diesel before starting the test with different biodiesel-diesel blends.

Table 1. Test engine specifications

Model	Kubota V3300	Model	Kubota V3300
Type	Vertical, 4 cycle liquid cooled diesel	Intake system	Natural aspired
No. of cylinders	4	Output:	
		Gross intermittent (kW/rpm)	54.5/2600
		Net continuous (kW/rpm)	44.1/2600
Total displacement (L)	3.318	Rated Torque (N.m/rpm)	230/1400
Bore × Stroke (mm)	98 × 110	Compression ratio	22.6

A Coriolis-type flow meter (Model: CMF025M319NQEIEZZZ) was used to measure the fuel flow rate. The engine fuel system was adjusted by using two different tanks with nozzle systems to the main fuel supply line. An initial engine run was conducted with diesel before starting the test with different biodiesel-diesel blends.

3. Biodiesel-Diesel Blend

Blending of PWC (80% poppy and 20% waste cooking) methyl esters with diesel was first prepared at different ratios (5%-20% by volume) using a magnetic stirrer (IKA C-MAG HS7) and a shaker (IKA KS 130) at 2000 rpm and 600 rpm for 30 min, respectively. Specifically, the biodiesel-diesel blends of B5, B10 and B20 PWC methyl ester was used to run the experiment, where, B5, B10 and B20 indicates 5% biodiesel and 95% diesel, 10% biodiesel and 90% diesel, and 20% biodiesel and 80% diesel, respectively.

4. Results and Discussion

The variation in brake power (BP), torque, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) with engine speed for binary mixture of poppy and waste cooking (PWC) biodiesel at B5, B10 and B20 and at full load condition is presented in Fig. 2 (a), (b), (c) and (d), respectively. Fig. 2(a) shows that the engine BP output for all blends over the entire range of engine speed increases with increase in speed. It can be seen from Fig. 2(a) that the BP decreases with increase in biodiesel-diesel blend level at all engine speeds. The maximum BP is obtained at B5 compared to B10 and B20 for all blends. This is because of the higher heating value, lower density, as well as the lower viscosity of B5 blended fuel. It has been observed that the properties of the blended fuel influence the combustion system. The lower BP in blended fuels compared to diesel could be attributed to the lower calorific values, higher densities and viscosities. In addition, the lower BP in all biodiesel blends in comparison to diesel is due to the formation of the poor mixture, higher viscosity and density [18].

It can be seen from Fig. 2(b) that the torque increases initially with an increase in speed up to reach the maximum level at 1400 rpm and then decreases continuously until the maximum speed of 2400 rpm for all blending conditions. The higher torque accomplished at B5 is due to the lower density and viscosity, and higher calorific value of the fuel. As expected, it can be seen from Fig. 2(b) that the engine torque of the diesel is higher than those of B5, B10 and B20 for all samples inspected which are due to the lower density and viscosity, and the higher calorific value.

Initially, at full load condition, the BSFC decreases from 1200 rpm to 1400 rpm, then increases with increase in speed up to the maximum speed of 2400 rpm as shown in Fig. 2(c). The decrease in BSFC is due to the better physical and chemical properties of fuel which assisted in improving combustion at low engine speeds. On the other hand, at high speeds, the friction heat losses occur and combustion deteriorates which increases the BSFC. The lowest fuel consumption at B5 is due to the lower viscosity and density, and higher calorific value. In addition, the increase in BSFC at B10 and B20 is because of the short ignition delay. Moreover, the higher BSFC of B10 and B20 could be attributed to due to the volumetric effect of constant fuel injection rate and to their higher viscosity values. Generally, using biodiesel-diesel blends resulted in higher BSFC than that of diesel, as biodiesel has higher density and lower calorific value compared to diesel. The use of biodiesel-diesel blend initially increases BTE up to 1400 rpm and then decreases over the entire range of speed. At higher speeds, the BTE decreased due to lack of sufficient air which caused uneven combustion of fuel.

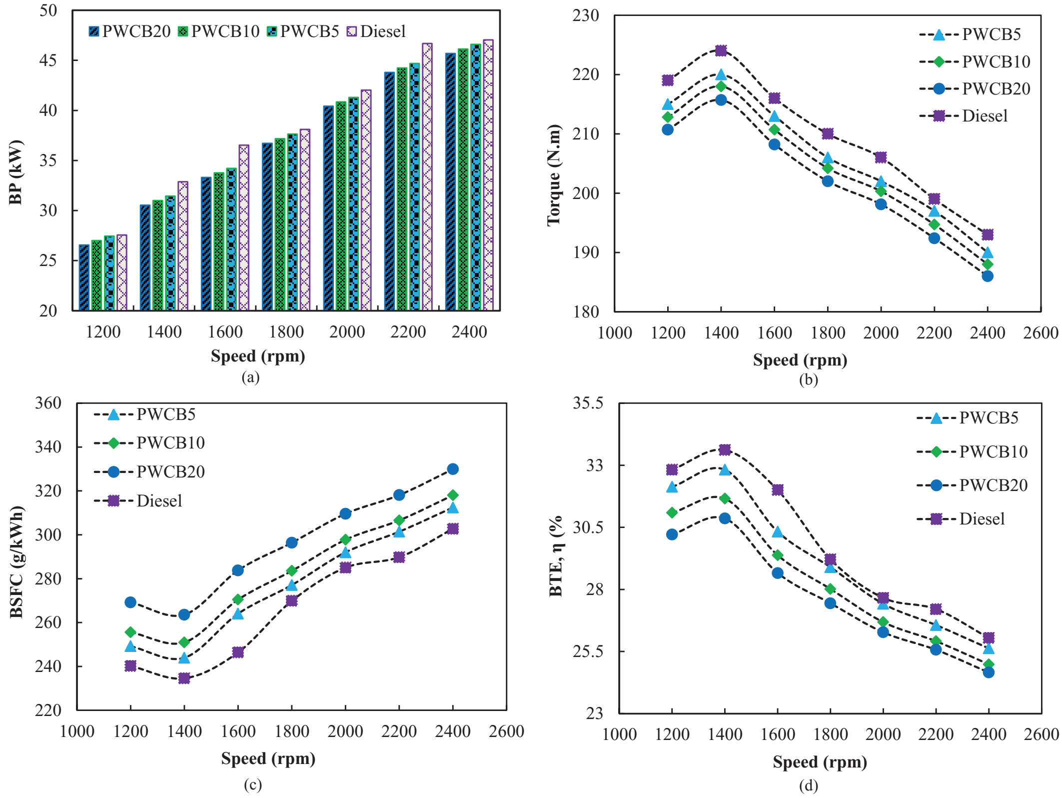


Fig. 2. Variation in (a) BP; (b) torque; (c) BSFC and (d) BTE with engine speed

As seen from Fig. 2(d), the BTE decreases with increase in the level of biodiesel blends from B5 to B20. As expected, the higher BTE is observed at B5 compared to B10 and B20. The reason for higher BTE is due to the higher calorific value and lower fuel consumption as compared to B10 and B20. In addition, this could be explained due to the lower viscosity and increases volatility which leads to improved air-fuel mixing and resulted in better combustion [19]. Generally, petro-diesel shows the higher BTE than biodiesel-diesel blend which is because of the higher calorific value, lower density and viscosity.

Fig. 3 (a), (b), (c) and (d) shows the variation in NO_x, CO, HC and PM emission with respect to speed for PWCB at 100% loading condition. The NO_x increases with increase in speed for the entire range of engine speed (1200 rpm-2400 rpm). The decrease in NO_x emission at B5 could be demonstrated by the effect of fuel properties on combustion phenomenon and exhaust emission. For instance, the higher CN at B5 initiated a shorter ignition delay, which resulted in lower combustion temperature and pressure and consequently, it led to producing less NO_x formation. It can also be seen that the NO_x emission for PWCB at B5, B10 and B20 are higher than those of diesel. This could be due to the leaner air/fuel ratio of blends as biodiesel is an oxygenated fuel and contains 12% more molecular oxygen which increases in combustion temperature and causes better combustion [20]. The CO emission decreases with increase in speed for all biodiesel blends as shown in Fig. 3(b). This could be attributed to the better air-fuel mixing process and/or the increases of the fuel-air equivalence ratio with the increases in engine speed [21]. The CO emission decreases with an increase in the concentration of biodiesel that is biodiesel blend level from B5 to B20. The CO emission decreases with an increase in the concentration of biodiesel that is biodiesel blend level from B5 to B20. This is because an increasing rate of oxygen content in the air-fuel mixture with an increase in biodiesel blend level assisted in improving combustion [22].

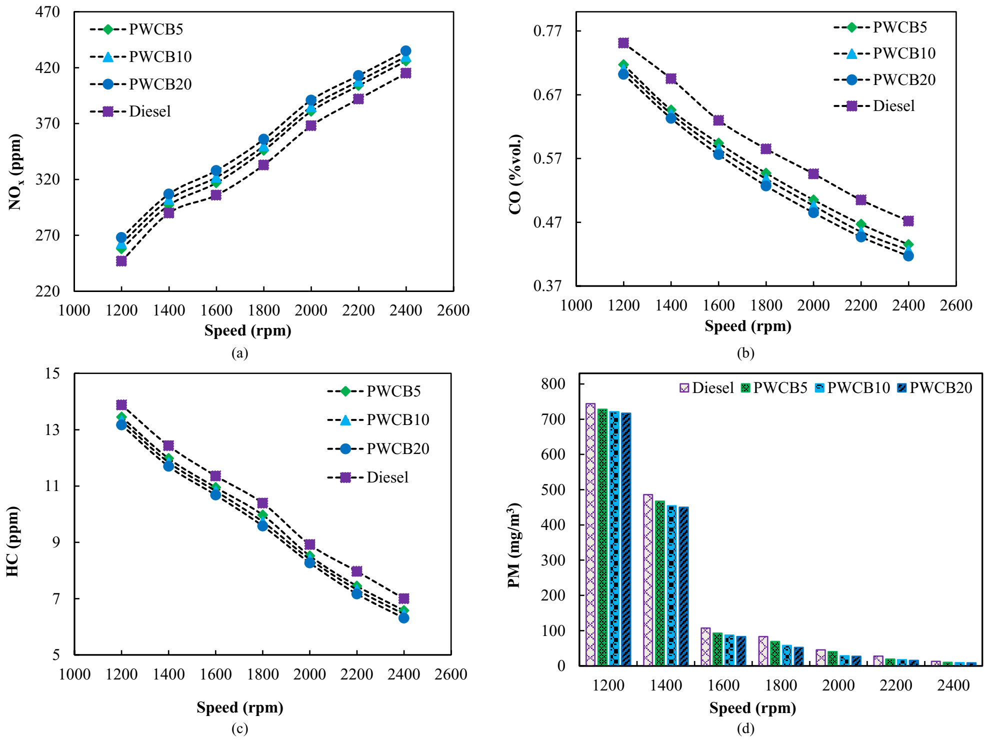


Fig. 3. Variation in (a) NOx; (b) CO; (c) HC and (d) PM with engine speed

The CO emission decreases with an increase in the concentration of biodiesel that is biodiesel blend level from B5 to B20. This is because an increasing rate of oxygen content in the air-fuel mixture with an increase in biodiesel blend level assisted in improving combustion [22]. Furthermore, the higher CN at B20 initiated the shortening of ignition delay which restricted the formation of less over-lean zones and therefore, improved the combustion process.

The HC emission decreases with increase in speed over the entire range of engine speed (1200 rpm-2400 rpm). At low engine speed, the ignition delay is longer which is due to the slow swirling velocity of air and therefore, higher HC emission is produced. In addition, the higher HC emission at low engine speed is because of its high fuel density and viscosity as these factors critically impacted the fuel atomisation and ignition in the combustion chamber. Fig. 3 (c) exhibits the variation in HC emission with increase in the percentage of biodiesel in the blend (B5, B10 and B20) for all fuels tested. This could be attributed to the presence of higher CN which shortens the ignition delay, and ultimately restricted the formation of over-lean regions. Biodiesel blended fuels show the lower HC emission in comparison to diesel. The PM emission decreases dramatically with the increase in speed up to the maximum speed of 2400 rpm. At low engine speed, the PM is significantly higher which is due to the incomplete combustion and burning of heavy lubricating oil. This occurs in the fuel-rich zone in the cylinder at high temperatures and pressures. In contrast, the PM decreases intensely at higher engine speed which could be explained in relation to combustion with biodiesel where fuel bounded oxygen enhanced fuel oxidation in these regions and as a result it led to a reduction in PM . Fig. 3 (d) indicates that with an increase in the concentration of biodiesel in the blend the PM emission reduces for all samples tested.

5. Conclusion

The use of biodiesel led to slightly reducing engine power mainly due to the reduction in heating value of biodiesel compared to diesel over the entire range of engine speeds (1200 rpm-2400 rpm) for PWCB but there exists power recovery through increaseing biodiesel fuel consumption. Engine torque decreases with increase in speed except 1400 rpm when the engine is fuelled with biodiesel-diesel blend instead of diesel for all biodiesel feedstocks. The maximum torque is obtained at 1400 rpm. The BSFC increases with increase in engine speed when using biodiesel-diesel blend instead of diesel for all blends (B5, B10 and B20) of PWC. The BTE decreases when the engine is fuelled with biodiesel-diesel blend instead of diesel over the entire range of engine speeds except 1400 rpm. The NO_x emission increases with increase in speed when using biodiesel in comparison to diesel for all biodiesel-diesel blends (B5, B10 and B20). Over the entire range of engine speeds, CO and HC emission reduces when using biodiesel-diesel blends compared to diesel. The PM emissions are significantly reduced compared to diesel with increase in speed when biodiesel-diesel blend is used instead of diesel.

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