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EMISSION AND PERFORMANCE CHARACTERISTICS OF WASTE COOKING OIL BIODIESEL BLENDS IN A SINGLE DIRECT INJECTION DIESEL ENGINE

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ABSTRACT

The use of Waste Cooking Oil (WCO) as feedstock, and microwave heating technology are favored to reduce the cost of biodiesel. In order to identify the effect of using biodiesel from WCO Methyl Ester (WCOME) blends on diesel engine emissions and performance, WCOME blends were tested in a single-cylinder Direct Injection (DI) diesel engine at a constant speed of 2500 rpm and with five loads. For comparison, commercial diesel fuel, Petron Diesel Max (PDM), and biodiesel mixture from palm oil (POME) were also used. The performance and emission test results of the five test fuels: PDM, BP10, BP20, BW10, and BW20 were then compared with simulation results created by using GT-Power software. The experimental results indicated that using POME and WCOME blends led to increments in Brake Specific Fuel Consumption (BSFC) of up to 5.9% and reduction in Brake Thermal Efficiency (BTE) of up to 29.3% compare to PDM. These biodiesel blends also increased nitrogen oxide emissions and decreased carbon dioxide, carbon monoxide and hydrocarbon emissions for all engine loads at a constant speed of 2500 rpm. The experimental testing of the cylinder peak pressure demonstrates significant increase with the increase of engine load for the four test fuels. All the simulation graphs show similar trends.

Keywords: Biodiesel; Diesel engine; Emission; Performance; Waste cooking oil

1. INTRODUCTION

Human population growth and economic development are increasing the need for energy. Most energy demand is fulfilled by conventional energy sources such as coal, petroleum, and natural gas. However, limited reserves of fossil materials and environmental considerations are leading researchers to look for alternative energy sources. Biodiesel is a viable alternative fuel for use in compression ignition engines because of its non-toxicity, biodegradability, and renewability.

The use of neat vegetable cooking oils and production processes are factors that affect the cost of biodiesel (Ani et al., 1990). WCO as biodiesel feedstock has been used to reduce the cost of biodiesel. Various authors have investigated the use of WCOME in combination with diesel fuel in diesel engines by blending it with biodiesel. They have assessed the effect of using such combinations on the performance, emissions, injection characteristics, and combustion

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characteristics of diesel engines.

Some researchers have tested WCO and its blends as fuel in diesel engines (Ozsezen et al., 2009; Abu-Jrai et al., 2011; Kalam et al., 2011; Kumar & Jaikumar, 2014), while some have also used WCOME and its blends (Rao et al., 2008; Muralidharan & Vasudevan, 2011; An et al., 2013; Can, 2014; Kathirvel et al., 2016;). Generally, these WCO and WCOME products were blended with commercial diesel fuel. WCO from palm oil can replace diesel fuel for short-term engine running (Kalam et al., 2011). The application of WCOME to diesel engines can reduce operating fuel costs because of the lower price of WCO as the fuel raw material (Motasemi & Ani, 2011; Muralidharan & Vasudevan, 2011; Said et al., 2015).

Ozsezen and Canakci (2011) reported when an engine test was fuelled with Waste (frying) Palm Oil Methyl Ester (WPOME) or Canola Oil Methyl Ester (COME), and not with fuel based on diesel oil (PBDF), the BTE reduced, while the BSFC increased. The methyl esters contained led to a reduction in Carbon Monoxide (CO), unburned hydrocarbons (HC), Carbon Dioxide (CO_2), and smoke opacities. However, these methyl esters increased Nitrogen Oxides (NOx) emissions compared with those of the PBDF over the speed range.

In the present study, the performance, emission, and combustion of a one-cylinder (DI) diesel engine were evaluated using the commercial diesel fuel, PDM, two blends of PDM with POME and two blends of PDM with WCOME. Performance parameters such as BTE, BSFC and exhaust gas emissions were studied at all loads and at constant speed. Combustion parameters such as cylinder pressure and net heat release were also investigated.

2. EXPERIMENTAL SET-UP

A schematic diagram of the engine test bed is shown in Figure 1. An experiment to examine performance was carried out using a four-stroke single-cylinder diesel engine without modification for WCOME and POME blends as fuel. The main engine specifications are presented in Table 1.

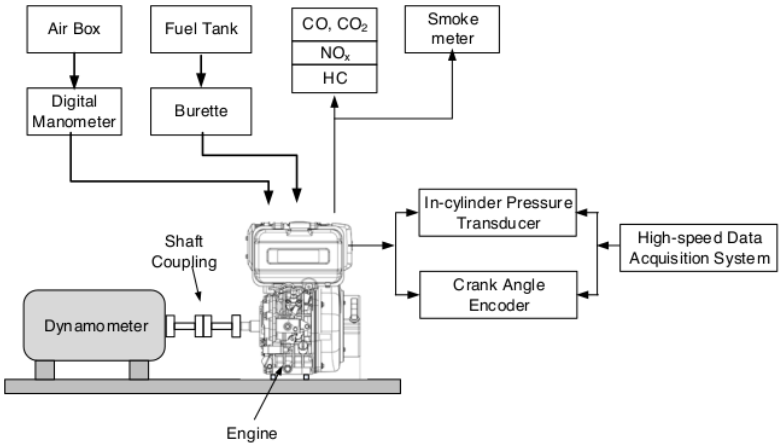

Figure 1 Schematic diagram of the engine test set-up

The experimental testing was carried out in the Automotive Laboratory of Universiti Teknologi Malaysia (UTM) for a variety of diesel fuels: PDM, and the test fuels BP10, BP20, BW10, and BW20. The major properties of these fuels were tested in the Laboratory Centre, UTM, for the diesel and blends listed in Table 2.

Fuel consumption was measured by determining the time taken by the diesel engine to consume a certain amount of fuel. The engine's RPM was also monitored by using a tachometer. The engine was coupled to an eddy current dynamometer and temperature was measured using a thermocouple. A pressure transducer was placed inside the cylinder head to measure the pressure inside the cylinder.

Table 1 Specification of the test engine

Parameter	Value
Model	Yanmar L70N6
4 stroke, vertical cylinder diesel	
No. of cylinders	1
Bore x stroke	78×67 mm
Displacement	0.320 liters
Continuous rated output	4.4 kW @ 3600 rpm
Max Rated output	4.9 kW @ 3600 rpm

Table 2 Properties of test fuels

	PDM	BP10	BP20	BW10	BW20
Percentage of blend (% v/v)	0.00	3.23	13.98	3.30	14.30
Carbon (wt %)	85.43	85.04	84.98	84.53	83.09
Hydrogen (wt %)	13.98	13.99	14.04	13.97	14.00
Nitrogen (wt %)	0.36	0.38	0.36	0.38	0.34
Sulfur (wt %)	0.10	0.02	0.02	0.04	0.04
Oxygen (wt %)	0.13	0.57	0.59	1.08	2.53
Calorific value (MJ/kg)	45.488	45.311	44.624	44.016	43.801
Density at 15ºC, (kg/L)	0.830	0.832	0.835	0.835	0.855
Kinematic viscosity at 40ºC (mm^2/s)	3.02	3.95	3.13	3.15	3.43

A card for the computer-based data-acquisition system SPECTRUM (MI.3112CA) was installed on a DEWE-5000 portable data-acquisition system to collect and analyze the results. A TELEGAN emission analyzer was used to measure exhaust gas emissions. All tests were carried out with PDM fuel in order to provide baseline data and then the fuel was switched to BP10, BP20, BW10, and BW20 fuels.

3. RESULTS AND DISCUSSION

3.1. Engine Performance

Figure 2a shows the effect of Brake Mean Effective Pressure (BMEP) on BSFC for PDM, POME blends and WCOME blends at 2500 rpm engine speed. It is observed that BSFC for all biodiesel blends was higher than for PDM for all loads. For the same BMEP, higher consumption is needed for the biodiesel blends than for PDM. This reflects the heating values of both biodiesel blends which are lower than for PDM. Tests for the BW20 fuel could be operated on two loads only because the engine stopped on the load of 7 Nm and 2500 rpm. The engine stopped due to poor combustion of the injected fuel resulting from its high viscosity and density (Kumar & Jaikumar, 2014). The calorific value of the biodiesel blends is lower than PDM due to their oxygenated nature. The amount of the expected increments in the BSFC results can therefore be explained by the low calorific value of the biodiesel blends (Can et al., 2017). The minimum BSFC for all loads was 316.4, 358.7, 371.6, and 387.9 g/kWh for PDM, BP10, BP20, and BW10, respectively. All of the minimum BSFCs were obtained at BMEP 1.23 bar.

Figure 2b shows that the maximum BTE for all loads is 25.0%, 22.2%, 21.2% and 21.1% for PDM, BP10, BP20, and BW10 fuels respectively. All of the maximum BTEs were obtained at BMEP 3.69 bar. The BW10 fuel performance was 29.3% lower than the PDM, at BMEP 3.69 bar. The reduction in BTE is largely as a result of poor combustion of the fuel injected, due to high viscosity and density (Kumar & Jaikumar, 2014). Figure 3 shows the comparison between simulations and experiments for BSFC and BTE versus BMEP. This simulation was performed using GT-SUITE V6.0 software.

Both of the simulation results were quite close to the experimental results for all the fuel tests. BSFC for the experiment was 1% higher than the BSFC simulation, while the BTE of the experiment was 0.6% lower than the BTE simulation. All the simulation graphs indicate a similar pattern in comparison with the experiments.

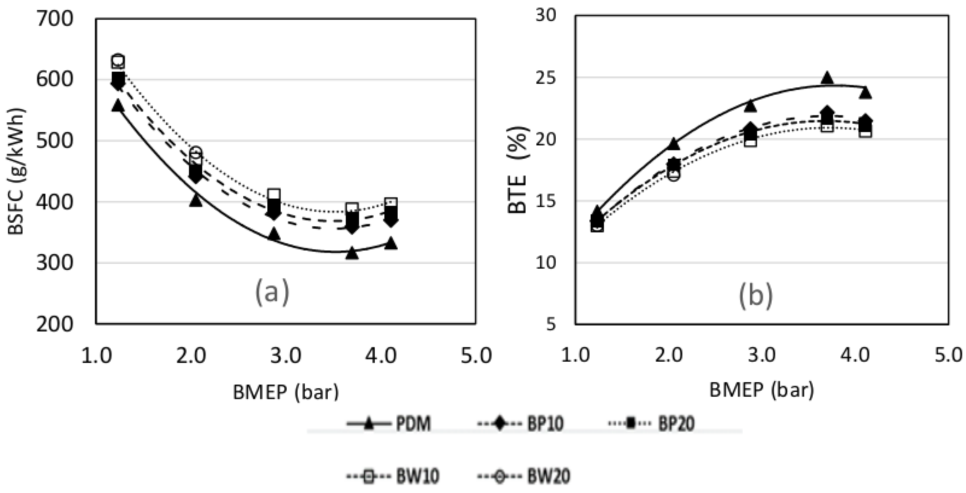

Figure 2 Experiment results for (a) BSFC; and (b) BTE for five fuel tests at 2500 rpm

3.2. Engine Performance Statistical Analysis

BSFC and BTE statistical analysis were conducted on the collected experimental data for loads at constant speed. Analysis of variance (ANOVA) was used to indicate the level of significance of the load effects on BSFC and BTE. In this analysis, DF represents the degree of freedom, F value represents the probability distribution in repeated sampling, and p-value represents the weight of significance (Ott & Longnecker, 2010). From the ANOVA analysis result, p-value maximum for all fuels is 0.00803; since p-value is less than 5%, the BMEP can be stated to have a significant effect on BSFC. Similarly, BTE has a p-value maximum of 0.00972 and this means that BMEP has a significant effect on BTE.

A quadratic polynomial regression model was applied using the characterization of the relationship between BMEP and BSFC, and between BMEP and BTE. Parameters of the model were estimated using a least square method. The data were analyzed using the computer program OriginPro, which is appropriate for performing these calculations.

The output statistics indicate that R square (COD) minimum of the relationship between BMEP and BSFC for all fuels is 0.99078. Similarly, for BMEP and BTE, R square minimum is 0.99028. This indicates that a quadratic regression model can be used.

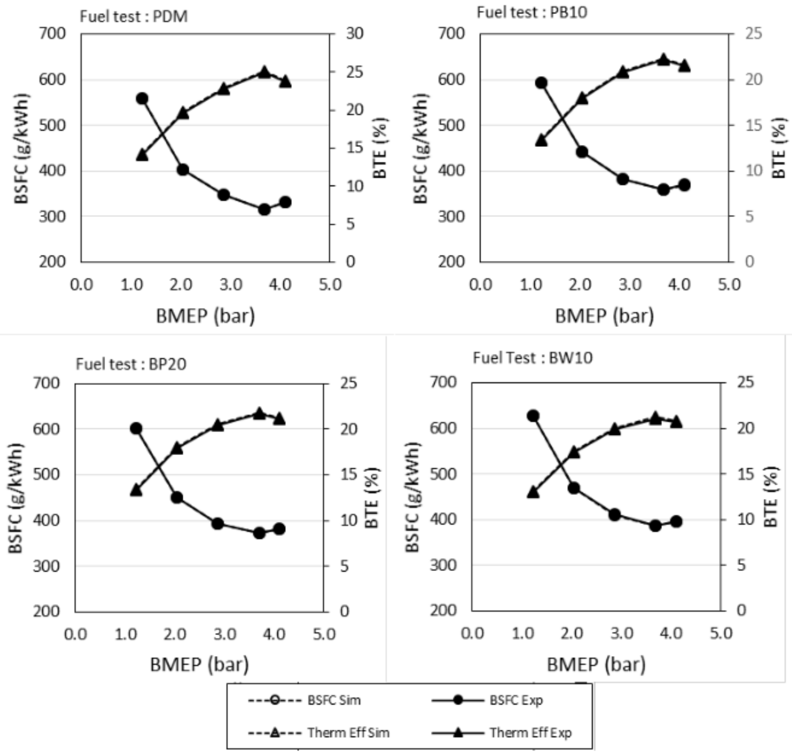

Figure 3 Experimental and simulated data for BSFC and BTE for four fuel tests at 2500 rpm

3.3. Exhaust Emissions

The engine exhaust gas constituents measured are CO_2, CO, HC, and NO_x. All of the emission concentrations are expressed in percentages or ppm. CO is an intermediate product of hydrocarbon fuel combustion. As the fuel burns, it produces CO, most of which oxidizes to CO_2. The CO, CO_2, HC, and NO_x emissions for all loads are shown in Figure 4. It can be seen that the CO emissions from the biodiesel blends were lower than from PDM for all loads. According to the data shown in Figure 4, PDM has the highest CO emissions for all loads, followed by BP10, BP20, and BW10. The CO emissions increase with increasing load for all fuels. The increase of CO emissions can be attributed to the high oxygen content in the biodiesel blends (Rao et al., 2008). Comparison of the CO_2 emission concentration figure for PDM with the biodiesels shows that all the biodiesel blends tend to reduce the CO_2 emissions for all loads. The decrease in the CO emissions is caused by the lower carbon content of the biodiesel blends.

For all of the engine loads, all biodiesel blends show lower HC than PDM. The NO_x emissions from diesel engines are usually a combination of nitric oxide (NO) and nitrogen dioxide (NO_2). NO is the predominant oxide of nitrogen usually produced inside the engine cylinder. The NO emissions are due primarily to the oxidation of molecular nitrogen. The NO_x emissions for biodiesel blends are higher than for PDM; this is caused by the significantly higher oxygen level in these fuels. This result agrees well with some previous studies (Abdullah et al., 2014; Muralidharan & Vasudevan, 2011).

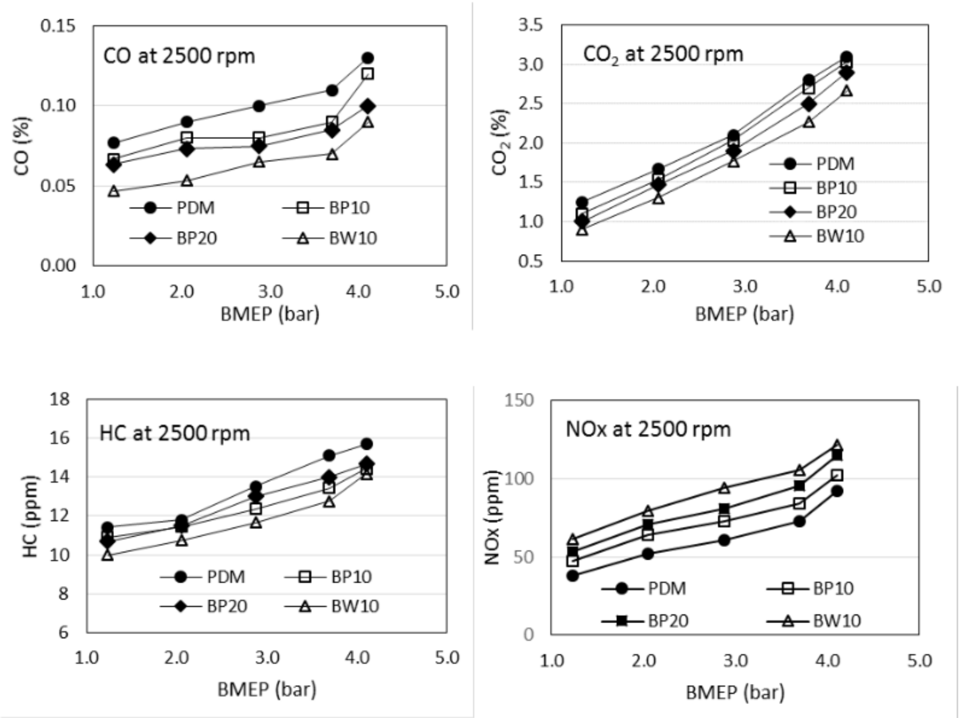

Figure 4 The variation of CO, CO_2, HC, and NO_x with engine BMEP at 2500 rpm engine speed

3.4. Combustion Characteristic

The peak cylinder pressure is shown in Figure 5. This graph indicates that peak cylinder pressure increases with increasing load, but decreases at maximum load.

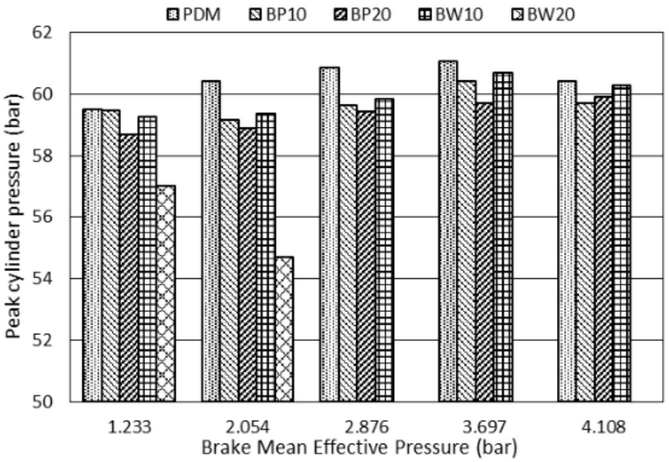

Figure 5 Comparison of PDM and biodiesel blends in peak pressure cylinder at 2500 rpm engine speed

The peak cylinder pressure of biodiesel blends BP10, BP20, and BW10 are lower than PDM for all loads, while BW20 is lower for two loads only. The oxygen content of both biodiesel blends, which results in better combustion, may also result in lower peak pressure compared to PDM (Rao et al., 2008; Can et al., 2017).

4. CONCLUSION

The WCOME and POME fuel blends were successfully investigated in single-cylinder diesel engines without modification. The maximum of BTE for all load is obtained in the use of PDM as fuel, then BP10, BP20 and BW10. While the minimum BSFC for all load is obtained in the use of PDM as fuel, then BP10, BP20, BW10 and BW20.

In comparison to PDM the biodiesel blends tend to reduce the CO, CO_2, and HC emissions for all loads. There is no NO_x increase with the use of biodiesel blends. The peak cylinder pressure increases with increasing load. The peak cylinder pressures for BP10, BP20, and BW10 are lower than PDM for all loads.

5. ACKNOWLEDGEMENT

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6. REFERENCES

Abdullah, M.A., Ani, F.N., Hassan, M., 2014. Performance and Emission of a Common Rail Passenger Car Engine Fuelled with Palm Oil Biodiesel. *Applied Mechanics and Materials*, Volume 564, pp. 66–71

Abu-Jrai, A., Yamin, J.A., Al-Muhtaseb, A.H., Hararah, M.A., 2011. Combustion Characteristics and Engine Emissions of a Diesel Engine Fueled with Diesel and Treated Waste Cooking Oil Blends. *Chemical Engineering Journal*, Volume 172(1), pp. 129–136

An, H., Yang, W.M., Maghbouli, A., Li, J., Chou, S.K., Chua, K.J., 2013. Performance, Combustion and Emission Characteristics of Biodiesel Derived from Waste Cooking Oils. *Applied Energy*, Volume 112(0), pp. 493–499

Ani, F.N., Lal, M., Williams, A., 1990. The Combustion Characteristics of Palm Oil and Palm Oil Ester. *In:* Proceedings of Third International Conference on Small Engines and their Fuels for Use in Rural Areas, London, 12 November, United Kingdom

Can, Ö., 2014. Combustion Characteristics, Performance and Exhaust Emissions of a Diesel Engine Fueled with a Waste Cooking Oil Biodiesel Mixture. *Energy Conversion and Management*, Volume 87(0), pp. 676–686

Can, Ö., Öztürk, E., Yücesu, H.S., 2017. Combustion and Exhaust Emissions of Canola Biodiesel Blends in a Single Cylinder DI Diesel Engine. *Renewable Energy*, Volume 109, pp. 73–82

Kalam, M.A., Masjuki, H.H., Jayed, M.H., Liaquat, A.M., 2011. Emission and Performance Characteristics of an Indirect Ignition Diesel Engine Fuelled with Waste Cooking Oil. *Energy*, Volume 36(1), pp. 397–402

Kathirvel, S., Layek, A., Muthuraman, S., 2016. Exploration of Waste Cooking Oil Methyl Esters (WCOME) as Fuel in Compression Ignition Engines: A Critical Review. *Engineering Science and Technology, an International Journal*, Volume 19(2), pp. 1018–1026

Kumar, M.S., Jaikumar, M., 2014. A Comprehensive Study on Performance, Emission and Combustion Behavior of a Compression Ignition Engine Fuelled with WCO (Waste

Cooking Oil) Emulsion as Fuel. *Journal of the Energy Institute*, Volume 87(3), pp. 263–271Motasemi, F., Ani, F.N., 2011. The Production of Biodiesel from Waste Cooking Oil using Microwave Irradiation. *Jurnal Mekanikal (Journal of Mechanical)*, Volume 32(1), pp. 61–72

Muralidharan, K., Vasudevan, D., 2011. Performance, Emission and Combustion Characteristics of a Variable Compression Ratio Engine using Methyl Esters of Waste Cooking Oil and Diesel Blends. *Applied Energy*, Volume 88(11), pp. 3959–3968

Ott, R.L., Longnecker, M., 2010. *An Introduction to Statistical Methods and Data Analysis* (6th Edition). Belmont, CA, USA: Brooks/Cole, Cengage Learning

Ozsezen, A.N., Canakci, M., 2011. Determination of Performance and Combustion Characteristics of a Diesel Engine Fueled with Canola and Waste Palm Oil Methyl Esters. *Energy Conversion and Management*, Volume 52(1), pp. 108–116

Ozsezen, A.N., Canakci, M., Turkcan, A., Sayin, C., 2009. Performance and Combustion Characteristics of a Di Diesel Engine Fueled with Waste Palm Oil and Canola Oil Methyl Esters. *Fuel*, Volume 88(4), pp. 629–636

Rao, G.L.N., Sampath, S., Rajagopal, K., 2008. Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking Oil Methyl Ester and Its Diesel Blends. *World Academy of Science, Engineering and Technology*, Volume 13, pp. 551–557

Said, N.H., Ani, F.N., Said, M.F.M., 2015. Review of the Production of Biodiesel from Waste Cooking Oil using Solid Catalysts. *Journal of Mechanical Engineering and Sciences*, Volume 8, pp. 1302–1311

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