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(2) Since you are the corresponding author for the paper "EMISSION AND PERFORMANCE CHARACTERISTICS OF WASTE COOKING OIL BIODIESEL BLENDS IN A SINGLE DIRECT INJECTION DIESEL ENGINE", please choose another author as the corresponding author for this paper

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Thank you for your contribution to IJTech and looking forward to a good collaboration in the next future.

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Author(s) : N.H. Said, F.N. Ani, M.F.M. Said

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Dear Editor,

Please find enclosed copy of our manuscript entitled "Emission and performance characteristic of waste cooking oil biodiesel blends in a single DI Diesel engine" by Nur Hamzah Said, Farid Nasir Ani and Mohd. Farid Muhamad Said. We would like to submit this manuscript to International Journal of Technology as an original research papers. We the authors declare that the submitted manuscript is the original research paper of ours and has not been published previously in any form nor presently it is under consideration for publication elsewhere except that for this Journal and that its publication is approved by all the authors. We the authors of the manuscript also mutually agree to submit our work in International Journal of Technology.

This article has been presented at 2nd International Tropical Renewable Energy Conference (i-TREC) on 2-3 October 2017.

We will appreciate your effort in processing our manuscript to your Journal.

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EMISSION AND PERFORMANCE CHARACTERISTIC OF WASTE COOKING OIL BIODIESEL BLENDS IN A SINGLE DI DIESEL ENGINE

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ABSTRACT

The use of waste cooking oil (WCO) as feedstock and microwave heating technology are favor to reduce the cost of biodiesel. In order to know the effect of using biodiesel from WCO methyl ester (WCOME) blends on diesel engine emissions and performance, WCOME blends was tested in a single cylinder direct injection (DI) diesel engine at constant speed 2500 rpm and 5 loads. For comparison also used commercial diesel fuel Petron Diesel Max (PDM) and biodiesel mixture from palm oil (POME). The performance and emission test results of five test fuels PDM, BP10, BP20, BW10 and BW20 then compared with the simulation results by using the GT-Power software. The experimental results indicated that using POME and WCOME blends led to increment in brake specific fuel consumption (BSFC) up to 5.9% and reduction in the brake thermal efficiency (BTE) up to 29.3% compare to PDM. These biodiesel blends also increased NO_x emissions and decreased CO_2, CO and HC emissions for all engine loads at the constant speed of 2500 rpm. The experiment of the cylinder peak pressure increase significantly with the increase of engine load, for four test fuels. All the simulation graphs show the similar trend compared to experiment.

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

1. INTRODUCTION

The need for energy is increasing with human population growth and economic development. Most of the energy demand is fulfilled by conventional energy sources like coal, petroleum and natural gas. However, the limited reserves of fossil materials and environmental consideration are forcing researchers to look for alternative energy sources. Biodiesel is a viable alternative fuel used in compression ignition engines because of its non-toxic, biodegradability and renewability. Neat vegetable cooking oils and production process are factors that affect the cost of biodiesel (Ani et al., 1990; Williams & Ani, 1990). The use of WCO as biodiesel feedstock were used to reduce the cost of biodiesel. Various authors have investigated the use of WCOME in combination with diesel fuel in diesel engine such as blending with biodiesel. They assessed effect of using these combinations on performance, emission, injection characteristics and combustion characteristics of diesel engine.

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Some researchers have been testing on diesel engines using WCO and its blends as fuel (Abu-Jrai et al., 2011; Kalam et al., 2011; Ozsezen et al., 2009; Senthil Kumar & Jaikumar, 2014). Some studies also used WCO methyl ester and its blends (An et al., 2013; Can, 2014; Kathirvel et al., 2016; Muralidharan & Vasudevan, 2011; Rao et al., 2008), generally these WCO and WCOME were blended with commercial diesel fuel. The WCO from palm oil can replace diesel fuel for short-term engine running (Kalam et al., 2011). The application of WCO methyl ester on diesel engines can reduce operating cost of fuel, because the WCO as raw material has lower price (Motasemi & Ani, 2011; Muralidharan & Vasudevan, 2011; Said et al., 2015).
Ozsezen & Canakci (2011) reported that the engine test machine was fuelled with WPOME or COME and not based on diesel oil (PBDF) reduced the BTE, while the BSFC increased. Meanwhile, the methyl esters causes the reduction of carbon monoxide (CO), unburned hydrocarbons (HC), carbon dioxide (CO_2) and smoke opacities. However, these methyl esters increased nitrogen oxides (NO_x) emissions compared with those of the PBDF over the speed range.

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

2. EXPERIMENTAL SET-UP

The schematic diagram of the engine test bed is shown in Figure 1. An experiment to examine the 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 given in Table 1.

The experimental test was done in the Automotive Laboratory in Universiti Teknologi Malaysia (UTM) for a variety of fuels such as diesel fuel PDM, BP10, BP20, BW10 and BW20. The major properties of these fuels were tested in the Laboratory Centre UTM for the diesel and blends are 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 is coupled to an eddy current dynamometer, the temperatures measured by using a thermocouple. A pressure transducer was placed inside the cylinder head to measure the pressure inside the cylinder.

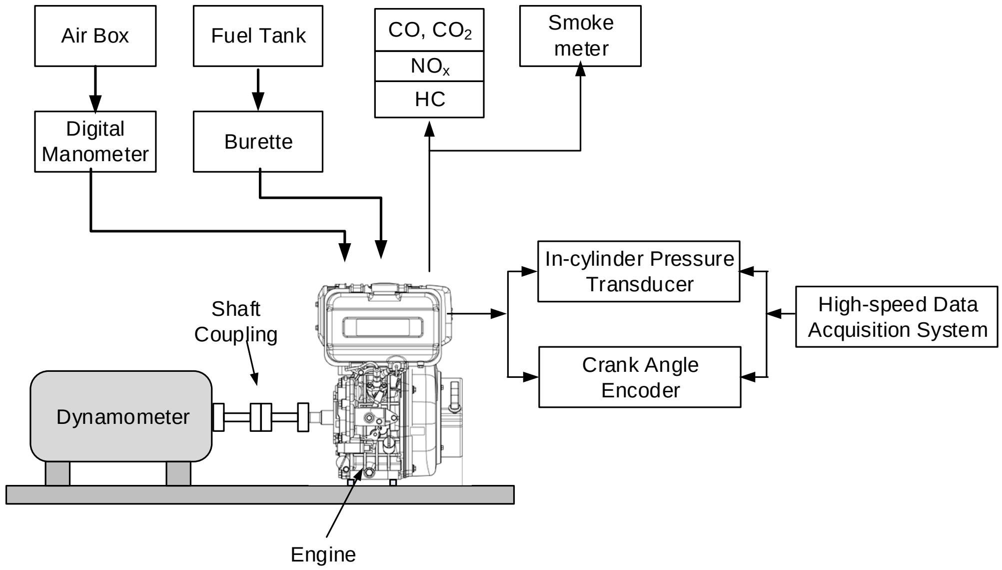

Figure 1 Schematic diagram of the engine test set-up

Table 1 Specification of the test engine

Parameter	Value
Model	Yanmar L70N6
4 stroke, vertical cylinder diesel	
No. of cylinder	1
Bore x stroke	78 x 67mm
Displacement	0.320 litre
Continuous Rated output	4.4kW @3600 rpm
Max Rated output	4.9kW @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 15 ºC, (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

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

3. RESULTS AND DISCUSSION

3.1. Engine Performance

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

In Figure 2 (b) shows, the maximum BTE for all loads is 25.0%, 22.2%, 21.2% and 21.1% for fuel of PDM, BP10, BP20 and BW10, respectively. All of the maximum BTE was obtained at BMEP 3.69 bar. The BW10 fuel decreased by 29.3% compared to 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 (Senthil Kumar & Jaikumar, 2014).. Figure 3 shows the comparison between simulation and experiment of BSFC and BTE versus BMEP. This simulation was performed using the GT-SUITE V6.0 software.

Compared to the experimental results, both of the simulations were quite close for all fuel tests, BSFC of experiment 1% higher than BSFC simulation, while BTE of experiment 0.6% lower than BTE simulation. All the simulation graphs indicate the similar pattern with the experiment.

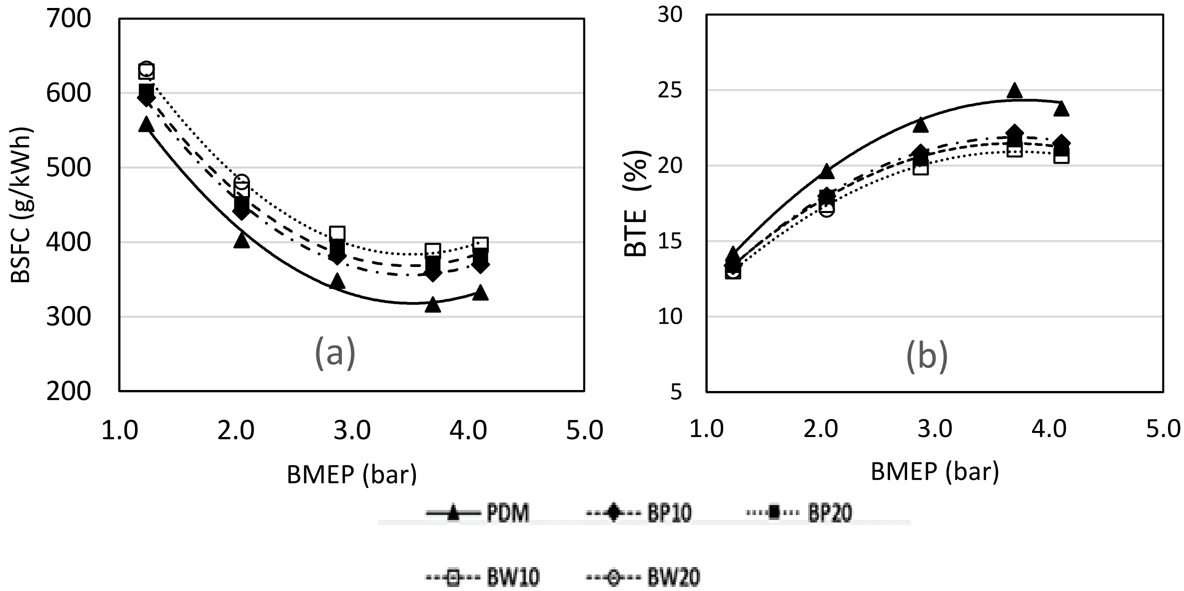

Figure 2 Experiment of BSFC and BTE for five fuel tests at 2500 rpm

3.2. Engine Performance Statistical Analysis

The BSFC and BTE statistical analysis were conducted on the collected experimental data for loads at constant speed. The analysis of variance (ANOVA) was used to indicate the level of significance of the load effects on the 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 has a significant effect on BSFC. Similarly, BTE, p-value maximum is 0.00972. This means that BMEP has a significant effect on BTE.

A quadratic polynomial regression model has been applied using the characterisation of the relationship between BMEP and BSFC, and also BMEP and BTE. Parameters of the model were estimated using a least square method. The data were analysed using computer program OriginPro that performs these calculations.

The output statistic indicated 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.

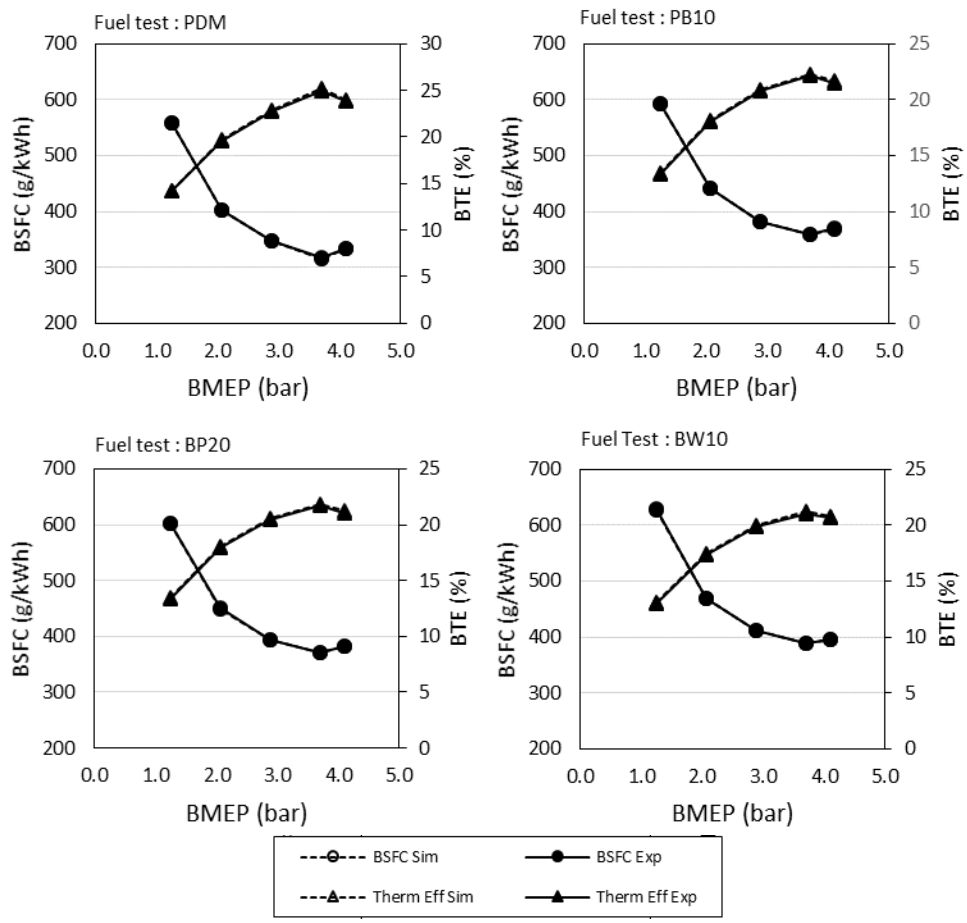

Figure 3 Experiment and simulated data of BSFC and BTE for four fuel tests at 2500 rpm.

3.3. Exhaust Emission

The engine exhaust gas constituents measured are CO_2, CO, unburned hydrocarbon (HC) and NO_x. All of the emissions concentrations were expressed in percent or ppm. The 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 shows that the CO emissions for biodiesel blends decreased compared with PDM for all loads. According to the data 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 emission can be attributed to high oxygen content in the biodiesel blend (Rao et al., 2008). In the figure of CO_2 emission concentration for PDM and biodiesel 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 low carbon content in the biodiesel blends.

For all of the engine loads, all biodiesel blends show lower HC than PDM. The NOx emissions from diesel engine are usually a combination of Nitric oxide (NO) and NO_2. The NO is the predominant among the oxides 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 were higher than for the PDM fuel; this is caused by contains oxygen in fuel increasing significantly. This result agrees well with some studies (Abdullah et al., 2014; Muralidharan & Vasudevan, 2011).

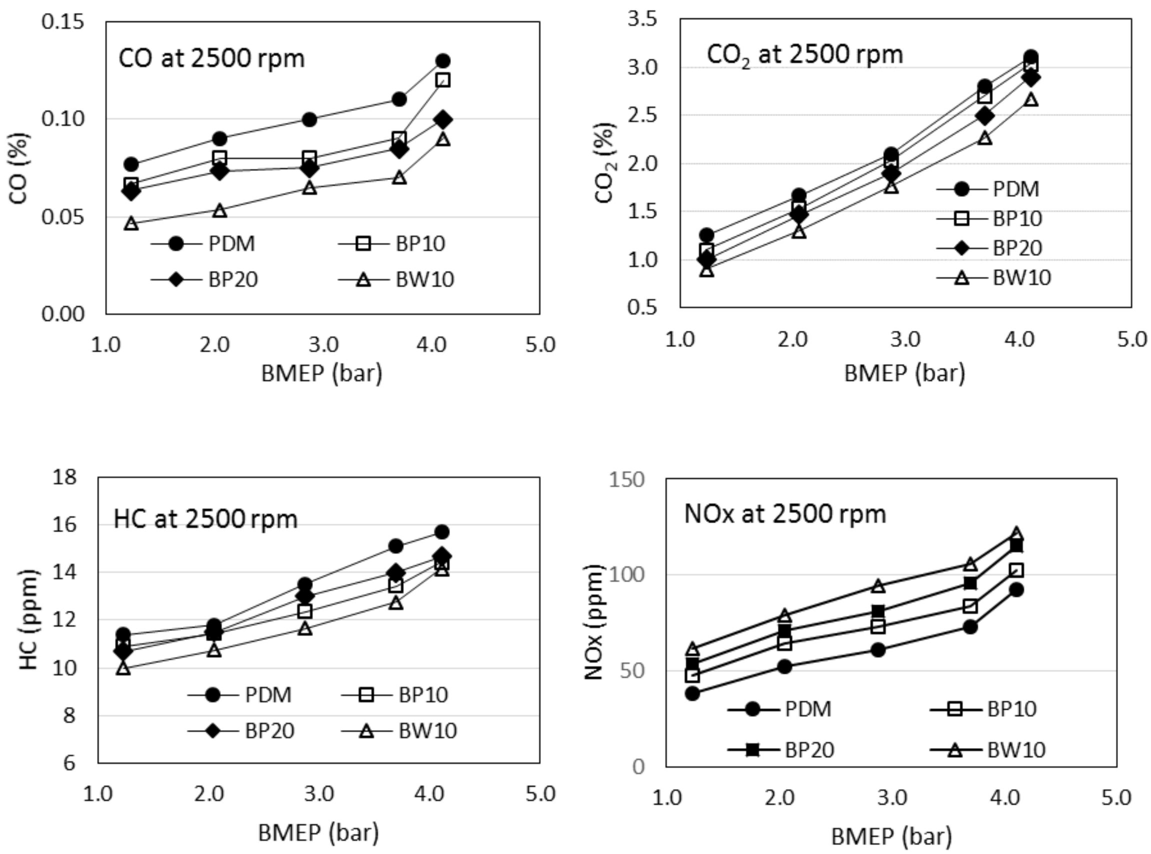

Figure 4 The variation of CO, CO_2, HC and NO_x with engine BMEP at 2500 rpm engine speed

3.4. Combustion Characteristic

The peak cylinder pressure is shown in Figure 5. This graph indicated that the peak cylinder pressure increase with increasing load. The peak cylinders pressure of biodiesel blends BP10, BP20 and BW10 are lower than PDM for all loads, while for BW20 is less than PDM 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 (Can et al., 2017; Rao et al., 2008).

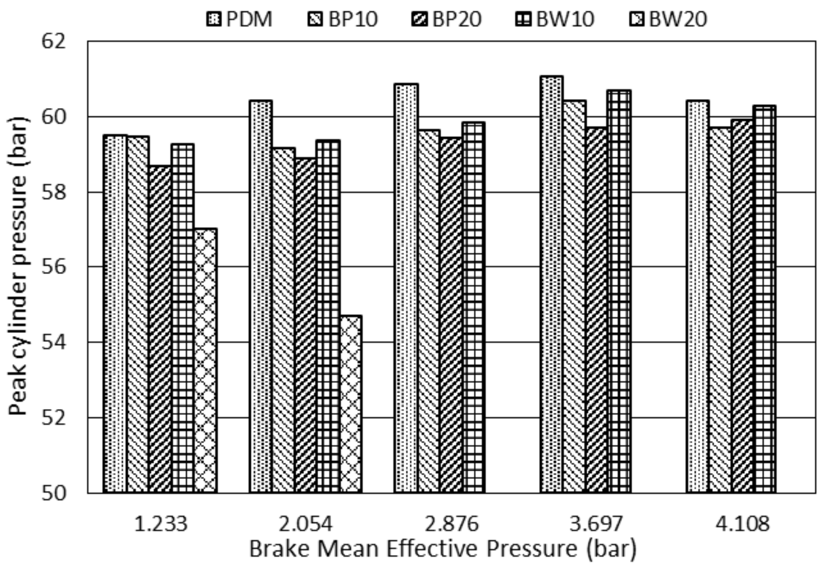

Figure 5 Comparison PDM and biodiesel blends on peak pressure cylinder at 2500 rpm engine speed

4. CONCLUSION

The WCOME and POME fuel blends were successfully investigated in single-cylinder diesel engine without modification. The maximum of BTE for all load is in the order of PDM > BP10 > BP20 > BW10. While the maximum BSFC for all load is in the order of BW20 > BW10 > BP20 > BP10 > PDM.

Compare to PDM; the biodiesel blends tend to reduce the CO, CO_2, and HC emissions for all loads. Instead NO_x increase with usage biodiesel blends. The peak cylinder increase with increasing load. The peak cylinders pressure for BP10, BP20 and BW10 are lower than PDM for all loads.

5. ACKNOWLEDGEMENT

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