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EXPERIMENTAL STUDY OF THE BIO-ADDITIVES EFFECTS IN BIODIESEL FUEL ON PERFORMANCE, EMISSIONS AND COMBUSTIONS CHARACTERISTICS OF DIESEL ENGINE

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ABSTRACT

Biodiesel is one the most popular bio-derived fuel among the alternative fuels. The biodegradable, environmental friendly and easy resources are causing biodiesel received extra attentions by industries and researchers in addition to solve the future energy crises. Despite years of improvement, the crucial issue in using bio-derived fuels is the oxidation stability, stoichiometric, chemical composition, antioxidants on the degradation and much oxygen compared to diesel. Thus, the improvement of emissions quality from engines fuelled by biodiesel is immediately required to meet the future stringent emission regulations. Instead of using biodiesel itself, the used of biodiesel blended with additive has been experimented extensively aiming the emissions reductions and improving the engine performance. Therefore, this study was executed to analyse the effects of biodiesel mixed with bio-additives on performance, emissions and combustions characteristics of diesel engine. The division of experimental investigation comprises of 1) performance of diesel engine specifically on brake power, brake mean effective pressure and fuel consumption; 2) exhaust gas emissions focussing on CO_2, NOx, HC and CO formations; and 3) combustion characteristics of fuel inside the combustion chamber. Biofuels tested in the study was derived from three different feed stocks i.e. crude palm oil (CPO), jatropha curcas oil (JCO) and waste cooking oil (WCO) at 5, 10, 15 and 20% concentration were blended with selected bio-additive namely Di Methyl Poly Siloxane (DMPS) and D20 palm oil methyl bio-additive formula. Additionally, petroleum diesel namely standard diesel (STD) was examined as well for comparison purpose. A 4-cycle YANMAR TF120ML diesel engine integrated with a 20 HP Eddy-Current dynamometer and mounted with Airrex HG-540 gas analysers are used. Outcomes of the study implied that blended fuels particularly C10+DMPS and J15+DMPS promotes the optimum performance associated with reduction of exhaust emission specially CO gas. Yet, the best alternative fuels were recommended.

Keywords: bio-additive, biodiesel, combustion, diesel engine, emission.

INTRODUCTION

Today, many developed countries have found mass production and commercialisation of bio-energy as a suitable approach to overcome the fossil fuel leakage and environmental pollution problems. Biodiesel was found as an alternative fuel which made using animal fats or vegetable oils. It is non-toxic, biodegradable, contain no aromatics, no sulphur, and the most important thing is it is renewable and proved can significantly reduce exhaust emissions when burned as engine fuel (Khalid, Nursal, Tajuddin, & Hadi, 2016; Tandon, Kumar, Mondal, Vijay, & Bhangale, 2011; Valipour, 2014). Several developed countries have introduced policies encouraging the use of biodiesel fuel (BDF) made from grains, vegetable oil or biomass to replace part of their fossil fuel use in industries in order to prevent environmental degradation by using cleaner fuel as well as to reduce dependence on imported, finite fossil supplies by partially replacing them with renewable, domestic sources (Oguma, Lee, & Goto, 2011). Many researchers and scientists has conducted the study on the effects of bio-additives with BDF blends on engine performance and emissions characteristics. Most of the study reported that bio-additives could produce lower emissions than unleaded diesel on compression ignition (CI) engines (Khalid, Osman *et. al.,* 2013). Besides, researches proved that the using of boost pressure has a great effect on the mixture formation, ignition delay, turbulence, ambient density and ambient pressure, and then affects to the flame propagation, combustion characteristics and emissions elements (Khalid, 2014). Due to this issue, many researches has done to find the solution and one of the effective way to improve BDF properties is by adding or blending it with fuel additive. There are many types of fuel additives found that shows positive result in improving fuel properties such as cetane number, engine performance and combustion and bring down engine emissions.

For that reason, this study has been carried out to investigate the effects of BDF comprises of Crude Palm oil, Jatropha Curcas oil and Waste Cooking oil mixed with bio-additive on performance, emissions and combustions characteristics of diesel engine. Two different products of bio-additive were chosen i.e. Di Methyl Poly Siloxane namely DMPS Power and D20 Palm Oil Methyl Ester booster formula. The DMPS and D20 bio-additives were remarkably beneficial to the fuel economy of CI engine when operated along with BDF (Khalid, 2014). The power produce by these biofuels is depends on the quality and perfection of blends, blending concentration as well as chemical composition of the gas oil. Aside, there are still debates on the advantages and disadvantages offers by

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BDF mixed with bio-additives (Scott, Silverman, & Tatham, 2005; Wirawan, 2007).

The advantages of BDF with bio-additives

Cost: The potential of cost reduction by consuming BDF with bio-additive compared to fossil fuels. Lower carbon emissions: When BDF was burning, they produce less carbon emission and fewer toxins. Availability: Unlike fossil fuels, BDF not required longer period of time to be produced. Moreover, biodiesel are renewable specifically BDF from used frying oil that broadly available every time and everywhere. Economic stimulation and security: Where fossil fuels often travel thousands of miles, BDF gathered locally offering jobs for hundreds and thousands of people (Demirbas, 2008; Demirbas, 2009; Knothe, 2010; Parawira, 2010).

The disadvantages of BDF with bio-additives

Lower output: BDF offer a lower energy output than fossil fuels, which means a larger amount of BDF requires yielding the same energy. Production Carbon Emissions: It is not about the production nor use of BDF but the efforts to cultivate the feedstock plants consists of fertilizers activities, nitrate processes and the operation of machineries have shown that occasionally creates equally or even more greenhouse gasses (GHG) than the fossil fuels. Increase food price and shortages (mostly for bio-ethanol): Food prices may rise associated with foods shortages due to the growing demand for BDF (Demirbas, 2008; Lin, Cunshan, *et al.,* 2011; Quigley, 2007).

Biodiesel fuel (BDF) blending process

The BDF (CPO, JCO and WCO) was obtained from biodiesel pilot plant in University Tun Hussein Onn Malaysia. The BDF is then blended with different 5 vol.%, 10 vol. %, 15 vol. % and 20 vol.% of biodiesel. Each blended fuels are prepared in 5 liters per batch. A specifics ratio of bio-additive then will be drop into each class of biodiesel blend during experiment. To run blending process, blending machine was set to operate at 70°C and the mixture of biodiesel was stirred for one hour. This blending machine used a rotating blade for stir process, basically the rotating speed was set to maintain at 270 rpm. Figure-1 shows the blending machine that provided in the automotive laboratory.

a) Mixer motor

b) Diesel oil tank

c) Biodiesel oil tank

d) Rotating blade

e) Blending chamber

f) Control panel switch board

g) Hot water discharge pipe

h) Temperature sensor

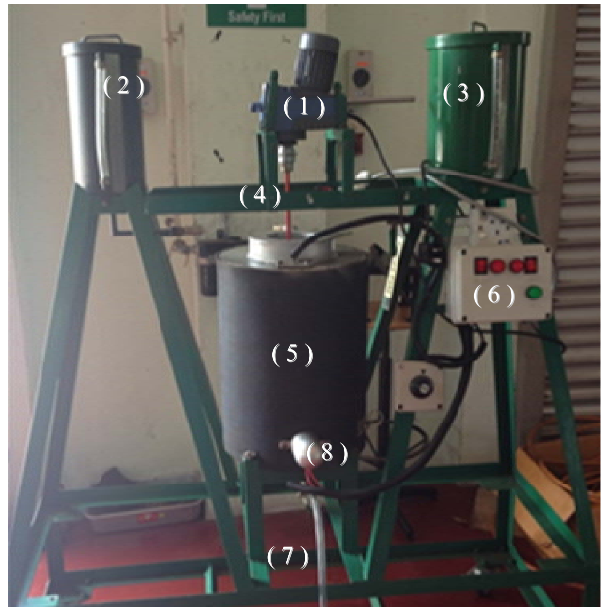

Figure-1. Laboratory scale blending machine.

On other hand, the standard diesel (STD) used in the experiment is premium grade Euro II diesel that obtained from Malacca PETRONAS Refinery. The BDF with variant blending ratio was blended along with main bio-additive tested i.e. DMPS additive. In additions, a comparative studied also been carried out with the blends of C20 fuel with DMPS additive (C20+DMPS) and secondly with D20 booster additive (C20+D20).

Bio-additive used in the experiment

The optimal ratio of bio-additive in BDF depends on types of fuel used and on the different engine operating conditions. In general, the Crude Palm Oil (CPO), Waste Cooking Oil (WCO) and Jatropha Curcas Oil (JCO) have potency to be used as alternative fuel that may reduce the total exhaust emission especially CO_2 gas from the internal combustion engine. Despite the fact, the additional of DMPS bio-additive or D20 booster additive in biodiesel was claimed as environment friendly and might increase about 20% to 35% power of engine.

DMPS power descriptions

Main bio-additive used in this experiment is Di-Methyl Poly Siloxane (DMPS) which is an innovative product invented and patented in Republic of Korea on 18th August 1989 under patent no. 28930. DMPS is an organic base fuel additive to sustain the green and healthy of earth, protect our planet and prolong the use of our limited fuel resources. The organic DMPS additive truly boost up power without any mechanical alteration to machineries or engines, instead protect the mechanism and power up for better mechanical performance. DMPS fuel addictive when combust with diesel, it will increases the oxygen molecules that enables more complete combustion

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of fuel (burns the fuel more effectively) in the combustion chamber thus reduces the production of CO and HC gases. In addition, the burns of DMPS also led the creation of natural silicon in which helps to lubricate the engine cylinder walls that reducing the friction between the piston and the cylinder walls. Thus, it will enhance life span of the engine. The properties of DMPS power bio-additive is demonstrates in Table-1.

Table-1. DMPS properties (Khalid, 2014).

Properties	Unit	Parameter
Density	kg/m^3	965
Kinematic viscosity at 25°C	cST	2.79
Carbon residue %	% wt.	0.03
Cetane index	g/cm^3	46
Specific density		0.966 – 0.977
Visual appearance		Clear, colourless, viscous liquid

D20 booster racing formula description

The second product of fuel additive used in this experiment is D20 booster additive which is a product of Palm Oil Methyl Ester (POME) base provided by D20 Resources Sdn Bhd. The properties of D20 booster additive is tabulates in Table-2 based on measurements conducted in Automotive Laboratory in Universiti Tun Hussein Onn that intended specially for automotive application (Khalid, 2014).

Table-2. D20 booster additive properties (Khalid, 2014).

Test parameter	Method	Unit	Results
Kinematic viscosity at 100°C	ASTM D445-06	mm^2/s	8.283
Kinematic viscosity at 40°C	ASTM D445-06	mm^2/s	40.17
Viscosity index (calculate)	ASTM D2270	-	187.8
Water content	ASTM D6304	ppm wt.	711
Total base number	ASTM D2896	mgKOH/g	0.01
Flash point, COC	ASTM D92	°C	318
Fire point	ASTM D92	°C	346
Density at 15°C	ASTM D1298	g/ml	0.915
Pour point	ASTM D97	°C	6
Cloud point	ASTM D97	°C	10
Sulphated ash	ASTM D874	mass %	0.001
Appearance	Visual	Clear dark yellow	

EXPERIMENTAL SETUP

Testing apparatus and procedure

Facilities and equipment of this study are set up in Marine Engineering Department's Laboratory in Ungku Omar Polytechnic, Ipoh. Fuels was tested using a small marine diesel engine, model TF120-ML with 0.638 litre capacity, single cylinder, horizontal type, 4-cycle engine with water and air-cooled system made by Yanmar Motor as in Figure-2 integrated with a 20 HP DYNOMITE^{tm} Eddy-Current Dynamometer. The engine was design with compact dimensions and in all applications with a power requirement up to 8.8 kW at 1 hour due to its low weight. Table-3 indicated specification of the engine. The testing apparatus set up has been arranged as in Figure-3. The dashed line shows the link connection from main particular sensor attached with the engine to encoder/data acquisition system (DAQ) and connect to a Supervisory Control and Data Acquisition unit (SCADA) which computerise monitored.

Figure-2. Yanmar diesel engine TF12ML.

Table-3. Test engine specification.

Item	Specification
Engine Model	TF120-ML
Type	1 cylinder, Horizontal, water-cooled and air-cooled, 4 stroke
Combustion System	Direct injection
Aspiration	Natural aspiration
Cyl. Bore x Stroke	92 mm x 96 mm
Displacement	0.638 litre
Max Output Power	12 Ps (8.8 kW) at 2400 rpm
Lubrication System	Complete enclosed forced lubricating system
Electrical System	Alternator, 12 V-45 W
Fuel Tank Capacity	11 litre

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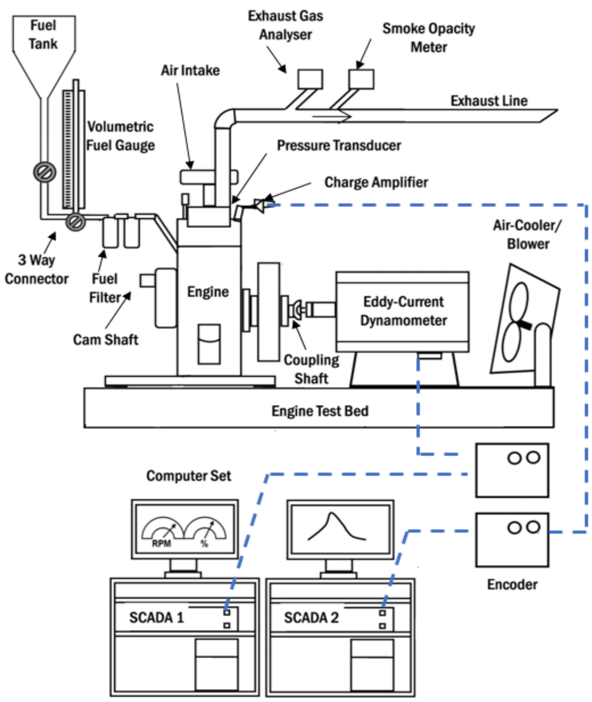

Figure-3. Schematic of experimental setup.

The operating parameters such as loads exerted during engine operation and engine speeds are controlled manually by user while the overall operation of engine will automatically monitored by set of SCADA unit. The DEWESOFTv7.11 software is used to monitor the input parameters and measure the performance of the engine while the DYNO-MAX 2010 software is used to analyse the combustion characteristics. For this research, all biodiesel fuels (BDF) types and standard diesel (STD) are used for running under similar manner of engine operation under dynamometer loads at 0%, 50% and 90% loads condition. The maximum load i.e. 100% will not be considered in the test operation to avoid the exhausted and failure of the engine as the precaution. The other parameter in this experiment is the various running speeds of the engine which will be simulated at 800, 1200, 1600 and 2000 rpm. To enhance the accuracy of results, the data measurement and recording process was repeated for 3 cycles per each test condition.

The parameters measured with respect to engine performance consists of engine torque, brake power (BP), fuel consumption rate (FC) and brake mean effective pressure (BMEP). While the combustion analysis parameters consists of cylinder pressure data, volume and heat release are used to plot Pressure-Volume (P-V) diagram as well as Pressure-Crank Angle (P-CA) diagram and heat release rate (HRR) from fuel combusted inside the combustion chamber of the engine. In conjunction, the measurements of exhaust gas emissions comprised carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NOx) and hydrocarbon (HC) using Airrex HG-540 model exhaust gas analyser.

RESULTS AND DISCUSSIONS

All data obtained from the experiment was analysed. Based on the experiments, there are eleven variation of fuels were tested consists of standard diesel fuel (STD), C5+DMPS (5% CPO biodiesel fuel blended with DMPS bio-additive), C10+DMPS, C15+DMPS, C20+DMPS, C20+D20, J5+DMPS (5% JCO biodiesel fuel blended with DMPS bio-additive), J10+DMPS, J15+DMPS, W5+DMPS (5% WCO biodiesel fuel blended with DMPS bio-additive), W10+DMPS and W15+DMPS. These biodiesel blends and standard diesel were analysed corresponding to engine performance, exhaust emissions and combustion characteristic and be compared to STD.

The x-axis of graph plotted indicates the blending proportion of 0, 5, 10, 15 and 20% by volume. For an example WCO at 5% concentration also denoted as W5 in the analysis and discussion. Further discussion are comprised the analysis through engine speed of 1200 and 2000 rpm at 50% (medium) and 90% (maximum) dynamometer loads condition for performance and emissions investigations. Whilst the analysis on fuels combustion represents by experimental results under 0% load condition at 800 rpm engine speed and 90% load conditions during 2000 rpm engine speed.

Figure-4 shows the performance BDF blends at 50% load condition. During low speed the variation of torque, brake power, fuel consumption rate and brake mean effective pressure were not much different through engine speed between 800 rpm and 1200 rpm. In overall, J10+DMPS exhibit a significant reduction of fuel consumption along with lower engine performance. Aside, W10+DMPS demonstrates better engine performance compared to that of STD with about comparable fuel consumption.

As the speed and load increased, the consuming of BDF was slightly reduces the engine torque under full rated load as illustrates in Figure-5. However, it is noticed that the experimental results particularly on engine performance is not proportional with the increment of the BDF blending proportion, for example under 2000 rpm at 90% loads, C10 yields better performance than C15 while C15+DMPS exhibits better performance than C10+DMPS. These results suggest that the fuel composition directly affecting the combustion quality with considering the external factors such as operating conditions. Graph in Figure-5 also shows all BDF promotes lower fuel consumption rate as compared to that of petro-diesel i.e. STD due to the improvement of the ignitibility and combustion process in the cylinder. In other hand, the increasing of BDF ratio and booster additive will increase the fuel consumption respectively at all engine speeds. It is proven with the highest fuel flow rate for all speeds were at C10, J15 and W10 blends of booster additive.

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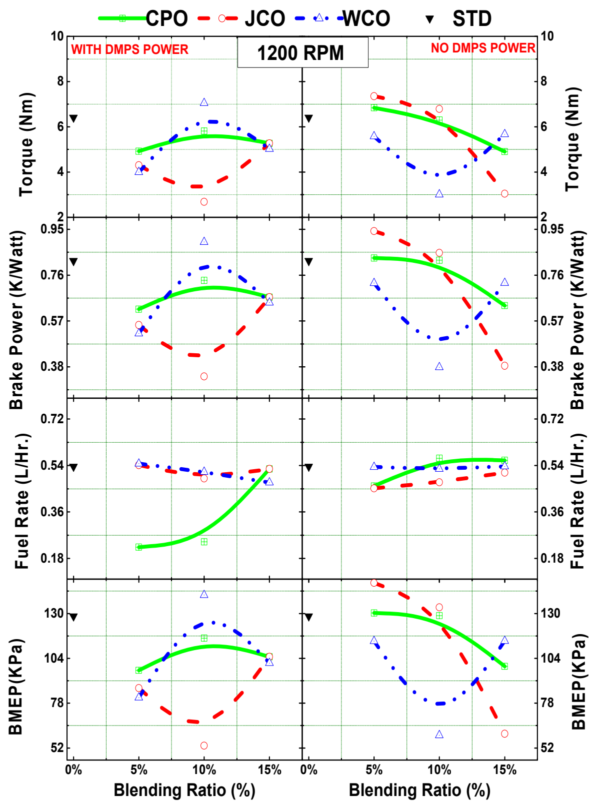

Figure-4. Performance with blending ratio at load 50% in low speed setup.

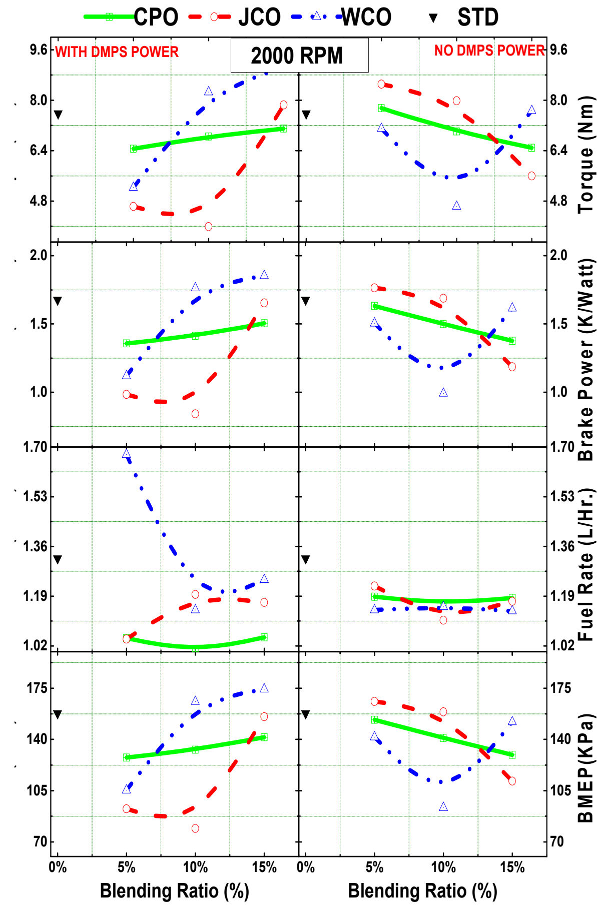

Figure-5. Performance with blending ratio at load 90% in high speed.

Aside, there are some similarities between neat biodiesel oil and BDF whereby they present some physicochemical or properties differences with diesel fuel such as higher density, viscosity, water content, acid value and lower of flash point that may affects the performance of engine durability such as atomisation of fuels entering the combustion chamber, injector choking, filter gumming, stuck in piston ring and engine deposit. Hence, improvement must be taken such as preheating the fuels and refining the blending process to ensure the biofuels are suitable to be used in diesel engine (Mustaffa, Khalid, Sies, Zakaria, & Manshoor, 2013).

Figure-6 shows the emission BDF blended with DMPS bio-additive under 50% load condition through 1200 rpm engine speed. The variation of HC, CO_2, CO and NOx were not much different at lower engine speed. However, the formation of those gas emissions by BDF with DMPS is getting higher compared to STD through 1200 rpm engine speed. From the experiment, is was observed that the combustions of BDF mixed with DMPS bio-additive significantly reduce the CO, CO_2 and HC emissions with slightly increase the formation of NOx relative to that of STD specifically for 5% blending concentration. Apart from that, all types of emissions except CO is noticed higher than that of STD for all BDF added with booster additive.

Figure-7 indicates the emissions produced by BDF through 2000 rpm engine speed under 90% dynopack rated load. The production of CO emission by diesel fuel is significantly lower compared to BDF fuels. The NOx emissions produced also higher during 2000 rpm engine speed for loads conditions. It also observed that the higher formation of NOx emissions were under maximum load exerted except for JCO blended with DMPS bio-additive. This is due to reason the oxygenated of biodiesel blends improved the fuel-air mixing (Anand, Kannan, Nagarajan, Velmathi, 2010). The increase of BDF blending ratio with booster additive is found to increase the NOx emission. This behaviour could be associated with the influences of booster additive and higher oxygen content in high blending ratio thus influences the combustion process. In conjunction, the emission of CO_2 and HC is observed to increase slightly by the increasing of rated load for all fuels and engine speeds. High injection pressure of fuel will produce low CO after combustion due to the behaviour of biodiesel fuel has high oxygen content. The more oxygen content in BDF, the more CO_2 to NOx will be emitted with the addition of CO emission reductions.

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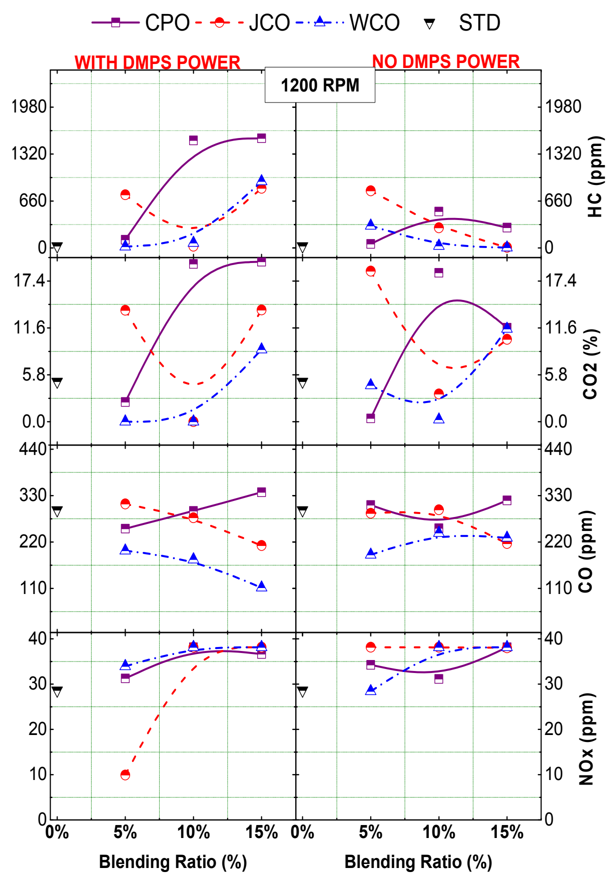

Figure-6. Emission with blending ration at load 50% in low speed.

Aside, the higher blends of BDF have more oxygen content, which result more complete combustion and directly decrease carbon-monoxide (CO) emission (Khalid, Anuar *et. al.,* 2014).

Comparative studies of combustion characteristic for added bio-additive with BDF (CP20)

Figure-8 to Figure-11 indicates the characteristic of fuel combustion inside the combustion chamber by CP20 and STD fuels under conditions of 0% load through 800rpm engine speed and maximum rated load of 90% through maximum engine speed of 2000rpm. The studies involve three types of different CP20 blend fuels that consists of original CP20 and CP20 that mixed with two different bio-additive, CP20+DPMS and CP20+D2O. The graph of combustion characteristics plotted encompasses the P-V diagram of engine cylinder and heat release rate (HRR) diagram.

P-V diagram load condition

By referring to P-V diagram as per Figure-8, the results of combustion characteristics without load condition by BDF for combustion of original CP20 blends and STD, the maximum peak pressure has been recognised. CP20 with both bio-additive shows the rise of overall peak pressure as the engine speed increased from lower speed in Figure-8 to high speed of 2000 rpm under 90% dynamometer load exerted as depicts in Figure-9.

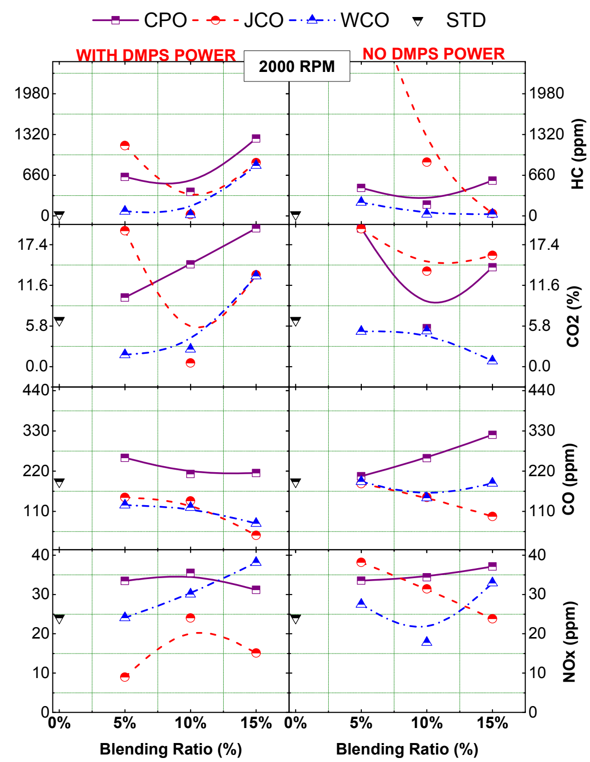

Figure-7. Emission with blending ration at load 90% in high speed.

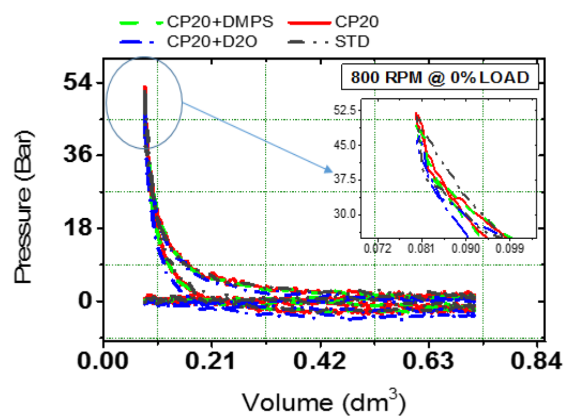

Figure-8. P-V diagram without load.

Aside, by referring to Figure-8, the original CP20 showed a maximum peak among other fuels tested. STD gas oil also yields the same results as the original CP20 during zero load condition engine operation. As the engine speed and load increased, both CP20 with bio-additive shows that the peak pressure rise significantly and reaches

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around 67.6 bar pressure at the point of volume 0.081 dm^3 as demonstrates in Figure-9.

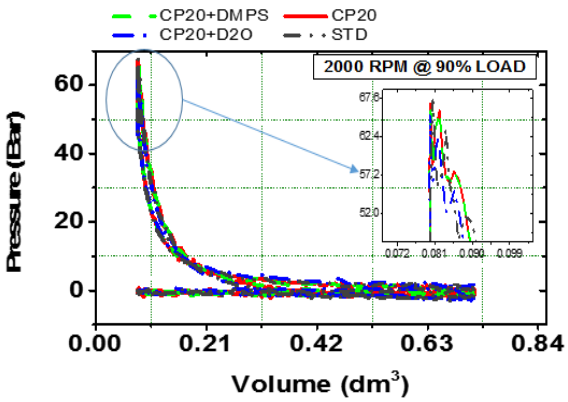

Figure-9. P-V diagram with load.

Heat release rate (HRR) load condition

As seen in Figure-10, the start of combustion (SOC) timing by CPO with DMPS is remarked as earliest among other fuels tested but it is also remarks that CPO+DPMS exhibits the highest of maximum cumulative heat release around 70 $kJ.m^3$ at 7^0CA bTDC during 800 rpm engine speed under 0% rated loads. The highest of HHR peak value is however leads by CP20 as the load increased to 90% as shows in Figure-11, but the peak HHR by that of STD is observed somewhat equal to CP20 blends as engine speed was increased to 2000 rpm. With increase in duration of combustion the heat release rate also increased due to possibility of complete combustion.

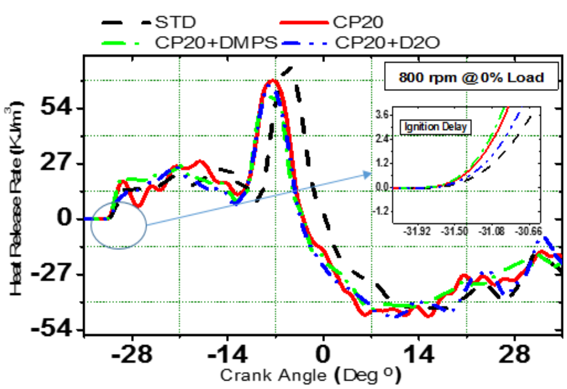

Figure-10. Heat release rate without load.

CONCLUSIONS

The study has been completed using CPO, JCO and WCO biofuels at 5, 10, 15 and 20% concentration blended with bio-additive (CP5+DMPS, CP10+DMPS, CP15+DMPS, CP20+DMPS, CP+D20, JC5+DMPS, JC10+DMPS, JC15+DMPS, WC5+DMPS, WC10+DMPS and WC15+DMPS) along with STD diesel in order to examine the engine performance, exhaust gas emissions and combustion characteristics of diesel engine.

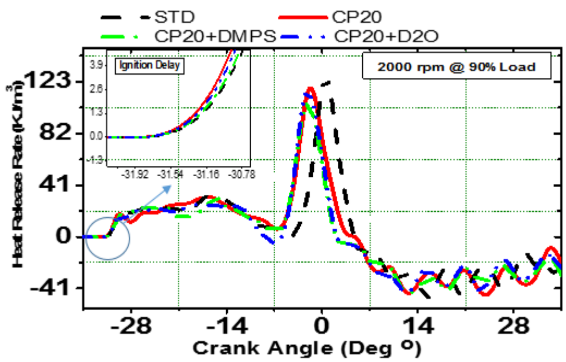

Figure-11. Heat release rate with load.

The experiment was conducted under various engine speed 800, 1200, 1600 and 2000 rpm by increasing of engine operation load at 0, 50 and 90%. The conclusion based on the experimental study were lay emphasis on results of fuel tests that optimised the engine performance, combustion characteristics and exhaust gas emissions and are explicated as follows:

(1) The mixtures of biodiesel with DPMS bio-additive promotes better fuel consumption along with slight reduction in exhaust emission mainly at higher engine speed while the biodiesel fuel and D20 (palm oil base) booster additive blends was proved to help enhancing the fuel combustion quality and yet improve the performance of diesel engine.
(2) The increased of BDF blending ratio is remarked to decrease the emissions of HC, CO and CO_2 throught range of engine speeds due to the weakening of fuel ignitibility and prolong the ignition delay. Whereas, this circumstance leading to the low combustion pressure and temperature inside the engine which directly contributes to lowering the HC emission.
(3) BDF at higher blending proportion was noticed to have high oxygen content that may resulting to almost complete combustion as well as promotes lower exhaust emissions.
(4) The NOx emission starts to increase at low engine speed, but gradually decrease proportional to the increment of engine speed. Volumetric efficiency, combustion delay and temperature arising caused by the hyperactive of fuels energy are factors that affecting the formation of NOx emission. Therefore, NOx can be reduced by the increasing the engine speed or use the higher engine speed for operation.
(5) As an alternative, the BDF at 10 to 15% blending ratio blended with DMPS bio-additive is recommended to use in diesel engine as it demonstrates the better outcomes of engine performance accompanied by lower emissions.

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NOMENCLATURE

CO Carbon monoxide
CO_2 Carbon dioxide
D20 Bio-additive product brand
HC Hydrocarbon
NOx Oxides of Nitrogen
rpm Revolution per minute (rotational speed unit)

ABBREVIATIONS

BDF Biodiesel fuel
BMEP Brake mean effective pressure
BP Brake power
BSFC Brake specific fuel consumption
bTDC Before top dead centre
C10 10% crude palm biodiesel blends fuel
*C10+DM*PS 10% CPO fuel blended with DMPS additive
C15 15% crude palm biodiesel blends fuel
C15+DMPS 15% CPO fuel blended with DMPS additive
C20 20% crude palm biodiesel blends fuel
C20+D20 20% CPO fuel blended with D20 additive
C20+DMPS 20% CPO fuel blended with DMPS additive
C5+DMPS 5% CPO fuel blended with DMPS additive
CI Compression ignition
CP20 20% crude palm biodiesel blends fuel
CP20+D20 20% CPO fuel blended with D20
CP20+DMPS 20% CPO fuel blended with DMPS additive
CPO Crude palm biodiesel oil
DAQ Data acquisition system
DMPS Di Methyl Poly Siloxane bio-additive
FC Fuel consumption
GHG Greenhouse gases
HP Horsepower (power unit)
HRR Heat release rate
J10+DMPS 10% JCO fuel blended with DMPS additive
J15 15% jatropha biodiesel blends fuel
J15+DMPS 15% JCO fuel blended with DMPS additive
J5+DMPS 5% JCO fuel blended with DMPS additive
JCO Jatropha cursas biodiesel oil
P-CA Pressure-Crank Angle
POME Palm Oil Methyl Ester
P-V Pressure-Volume
SCADA Supervisory Control and Data Acquisition
SOC Start of combustion
STD Standard diesel (fossil diesel)
W10 10% waste cooking biodiesel blends fuel
W10+DMPS 10% WCO fuel blended with DMPS additive
W15+DMPS 15% WCO fuel blended with DMPS additive
W5 5% waste cooking biodiesel blends fuel
W5+DMPS 5% WCO fuel blended with DMPS additive
WCO Waste cooking biodiesel oil

REFERENCES

Agarwal, A. K., & Dhar, A. 2009. Performance, Emission and Combustion Characteristics of Jatropha Oil Blends in a Direct Injection CI Engine. SAE Technical Paper, 4970: 2009-01-0947.

Anand, R., Kannan, G. R., Nagarajan, S., & Velmathi, S. 2010. Performance Emission and Combustion Characteristics of a Diesel Engine Fueled with Biodiesel Produced from Waste Cooking Oil. SAE Technical Paper: 2010-01-0478.

Baumgarten, C. 2005. Mixture Formation in Internal Combustion Engines. Hannover: Springer-Verlag Berlin Heidelberg New York.

Demirbas, A. 2008. Biodiesel : A Realistic Fuel Alternative for Diesel Engines. Trabzon Turkey: Springer-Verlag London Limited.

Demirbas, A. 2009. Progress and recent trends in biodiesel fuels. Energy Conversion and Management, 50(1), 14–34.

Dinesh, S., Kumar, L., Patel, P., & Nikul, K. 2000. Performance And Emission By Effect Of Fuel Additives For Ci Engine Fuelled With Blend Of Biodiesel And Diesel - A Review Study. Journal of Engineering Research and Studies, 3(4), 5-8.

Keating, E. L. 2007. Applied combustion. (L. L. Faulkner, Ed.) (Second Edi.). Columbus, Ohio: Press, CRC Group, Taylor & Francis.

Khalid, A. 2014. Effects of Booster Racing Formula on Performance and Emissions Characteristics of Diesel Engine Fuelled by Biodiesel Derived from Palm Oil, Applied Mechanics and Materials, 5(2), 1-6.

Khalid, A., Anuar, M. D., Ishak, Y., Manshoor, B., Sapit, A., Leman, M., & Zaman, I. 2014. Emissions Characteristics of Small Diesel Engine Fuelled by Waste Cooking Oil. MATEC Web of Conferences, 13(6), 1-6.

Khalid, A., Jaat, M., Zaman, I., Manshoor, B., & Ali, M. F. M. 2013. Effect of Preheated Fuel on Mixture

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Formation of Biodiesel Spray. Applied Mechanics and Materials, 393, 493-498.

Khalid, A., Mudin, A., Jaat, M., Mustaffa, N., Manshoor, B., Fawzi, M. A. M., Ngali, M. Z. 2014. Effects of Biodiesel Derived by Waste Cooking Oil on Fuel Consumption and Performance of Diesel Engine. Applied Mechanics and Materials, 554, 520-525.

Khalid, A., Nursal, R. S., Tajuddin, A. S. A. & Hadi, S. A. 2016. Performance and Emissions Characteristics of Alternative Biodiesel Fuel on Small Diesel Engine. Journal of Engineering and Applied Sciences, 11(12), 7424-7430.

Khalid, A., Osman, S. A., Jaat, M., Mustaffa, N., Basharie, S. M., & Manshoor, B. 2013. Performance and Emissions Characteristics of Diesel Engine Fuelled by Biodiesel Derived from Palm Oil. Applied Mechanics and Materials, 315, 517-522.

Khalid, A., Tamaldin, N., Jaat, M., Ali, M. F. M., Manshoor, B., & Zaman, I. 2013. Impacts of Biodiesel Storage Duration on Fuel Properties and Emissions. Procedia Engineering, 68, 225-230.

Knothe, G. 2010. Biodiesel : Current Trends and Properties. Journal of Top Catal, 53, 714-720.

Lin L, Cunshan Z, Vittayapadung S, Xiangqian S, Mingdong D. (2011). Opportunities and challenges for biodiesel fuel. Applied Energy, 88(4), 20-31.

Mofijur, M., Masjuki, H. H., Kalam, M. A., & Shahabuddin, M. 2013. Experimental study of additive added palm biodiesel in a compression ignition engine, Energy Science and Research, 30(2), 737-748.

Mohammadi, P., Nikbakht, A. M., Tabatabaei, M., & Farhadi, K. 2012. A Novel Diesel Fuel Additive to Improve Fuel Properties and to Reduce Emissions. International Journal of Automotive Engineering, 2(3), 156-162.

Mustaffa, N., Khalid, A., Sies, M. F., Zakaria, H., & Manshoor, B. 2013. Performance and Emissions of Preheated Biodiesel on a Compression Ignition (CI) Engines. Applied Mechanics and Materials, 291-295.

Oguma, M., Lee, Y. J., & Goto, S. 2011. An overview of biodiesel in Asian countries and the harmonization of quality standards. International Journal of Automotive Technology, 13(1), 33-41.

Parawira, W. 2010. Biodiesel production from Jatropha curcas : A review. Scientific Research and Essays, 5(14), 1796-1808.

Quigley, R. 2007. Biodiesel : The good, the bad … and additives. Biofuels biodiesel: additives, 2, 70-72.

Scott, J., Silverman, I., & Tatham, S. 2005. Cleaner Diesel Handbook: Bring Cleaner Fuel And Diesel Retrofits Into Your Neighborhood, New York, USA: Environmental Defense.

Shahabuddin, M., Masjuki, H. H., Kalam, M. A., Mofijur, M., Hazrat, M., & Liaquat, A. M. 2012. Effect of Additive on Performance of C.I. Engine Fuelled with Bio Diesel. Energy Procedia, 14, 1624-1629.

Tandon, A., Kumar, A., Mondal, P., Vijay, P., & Bhangale, U. D. 2011. Tribological Issues Related to the Use of Biofuels: A New Environmental Challenge. British Journ. of Environment & Climate Change, 1(2), 28-43.

Valipour, A. 2014. A Review on Effect of Fuel Additives on Combustion, Performance and Emission Characteristics of Diesel and Biodiesel Fuelled Engine. International Journal of Application or Innovation in Engineering & Management (IJAIEM), 3(1), 266-273.

Venkateswar, R. P., Appa, B. V. R. & Radhakrishna, D. 2012. Experimental Analysis of DI Diesel Engine Performance. Iranica Journal of Energy & Environment, 3(2), 109-117.

Wirawan, S. S. 2007. Future biodiesel research in Indonesia, Asian Science & Technology Seminar, Jakarta. From: www.jst.go.jp/asts/asts_j/files/ppt/16_ppt.pdf.