Applied Mechanics and Materials Vol. 660 (2014) pp 462-467
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doi:10.4028/www.scientific.net/AMM.660.462

Submitted: 07.07.2014
Revised: 23.07.2014
Accepted: 12.08.2014

Experimental Investigation of Emissions Characteristics of Small Diesel Engine Fuelled by Blended Crude Palm Oil

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Keywords: Diesel Engine, Waste Cooking Oil, Biodiesel, Emissions, Alternative

Abstract. Biodiesel is an alternative, decomposable and biological-processed fuel that has similar characteristics with mineral diesel which can be used directly into diesel engines. Crude palm oil (CPO) is one of the vegetable oil that has potential for use as a fuel in diesel engine. However, Biodiesel is also an oxygenated and more density, viscosity meaning it contains influences the emissions production during burning process. Despite years of improvement attempts, the key issue in using crude palm oil fuels is oxidation stability, high viscosity and much oxygen comparing to diesel fuel. Thus, the improvement of performance and emission exhausted from biodiesel fuels is urgently required to meet the future performance and emission regulations. Purpose of this study is to explore how significant the effect of biodiesel blends on the exhaust emission with different speed. The engine speed was varied from 1500-2500 rpm and CPO blending ratio from 5-15 vol% (B5-B15).The emission parameter have been tested in term of opacity, hydrocarbon (HC), nitrogen oxide (NOX), carbon dioxide (CO_2) and oxygen (O_2). Increased blends of biodiesel ratio is found to enhance the combustion process, resulting in decreased the HC emissions and also other exhaust emission element. The improvement of combustion process is expected to be strongly influenced by oxygenated fuel in biodiesel content.

Introduction

In this modern world technology, diesel fuel is very important to fulfill our demand. Many years ago, fossil diesel had been announced as the main source of the world energy. The non stop using of fossil diesel will make the source run out and in order to prevent the crisis of fossil fuel depletion and environment degradation, biodiesel was announce as an alternative. Therefore, the alternative sources of fuel are receiving a lot attention in the automotive industry. The key for this issue is using biodiesel based fuel is oxidation stability [1-3]. However, the application of the BDF in the diesel engines offer not only attractive and more economical fuel but also creates problems of higher emissions compared with petroleum based diesel. BDF diesel engines still have problem of emitting NOx and Particulate Matter (PM) into the atmosphere because of the oxidation stability, cetane number, stoichiometric point, bio-fuel composition and antioxidants on the degradation extremely viscous [4-5]. Thus, the improvement of emissions exhausted from BDF engines is urgently required to meet the future stringent emission regulations. It was reported that the implementation of boost pressure, swirl velocity and injection 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 [6-7]. In Malaysia, the ease of use crude palm oil (CPO) makes it possible for research and development to be conducted. It can be used in diesel engine directly without major modification. From the previous studies state that biodiesel has been proven to be a good solution to help address the problem of global warming. The use of biodiesel as a substitute for diesel fuel will significantly reduce emissions hydrocarbon, carbon monoxide, sulphur dioxide, and particles [7-8].

In this research, the observation with advance monitoring plays an important role in much more understanding about combustion process, combustion characteristics, exhaust emissions and also engine performance. Thus, this work expected will provide more knowledge about oxygenate fuel and its effects on combustion characteristics and emission.

Experiment set up

Fuel- The study used three kinds of BDF derived from CPO which provided by Universiti Tun Hussein Onn Malaysia (UTHM) biodiesel pilot-plant. The particulars of the tested fuels are detailed in Table 1. The fuels tested were a grade II diesel (STD) and blends of B5, B10 and B15 palm oil with the diesel fuel. The ordinary gas oil with the grade II diesel designated as a reference standard fuel (STD). Thus, the results for all the BDF conditions were compared with baseline operating conditions of standard diesel (STD). In this research, the kinematic viscosity of palm oil blend was measured by Viscolite 700 model VL700-T15. The density properties were measured by Metter Toledo Diamond Scale modeled JB703-C/AF. The water content in biodiesel sample measured by Volumetric KF Titrator model v20. The flash point measured by Pensky-Martens PMA 4. The engine fuel consumption is acquired with a precision ONOSOKKI volumetric fuel flow meter, and pegged between the fuel tank and the fuel pump. Measurement data comprised fuel consumption rate (kg/hr) together with the exhaust emissions like hydrocarbon(HC), oxygen(O_2), carbon dioxide(CO_2),carbon monoxide (CO), nitrogen oxides (NOx) and smoke opacity by using autocheck 5 channel gas emission analyzer and dragger MSI. For this research OD, B5, B10 and B15 are used for running under similar engine in a manner similar operation conditions. To compare the difference, the measurement process was repeated for 3 cycles per each condition. Further analysis and presentation of data is based on the average of measurement.

Table 1: Properties of the tested fuels

Fuel type	Properties			
	Density (g/cm³)	Kinematic Viscosity (Cp)	Flashpoint (°C)	Water Content (ppm)
STD	0.833736	3.0	80.0	79.6
B5	0.837048	3.0	91.5	120.1
B10	0.837664	2.9	92.0	158.6
B15	0.840428	3.0	93.5	219.0
B20	0.841172	3.1	94.5	294.7
B25	0.841716	3.0	97.0	363.3
B30	0.845852	3.2	97.5	397.1
B35	0.844816	3.4	99.5	426.9
B40	0.848236	3.2	100.0	558.0

Table 2: Engine specifications

Engine Specification	
Model	Hatz Diesel Engine 1B30
Type	Air-cooled four stroke diesel engine
Combustion system	Direct injection
Number of cylinder	1
Bore/Stroke	80/69 mm
Displacement	347 cm³
Sense of rotation on power take-off side	left
Engine oil pressure at oil temperature of 100°C	2.5 bar at 3000 rpm
Maximum torque	17.Nm
Weight	40 kg

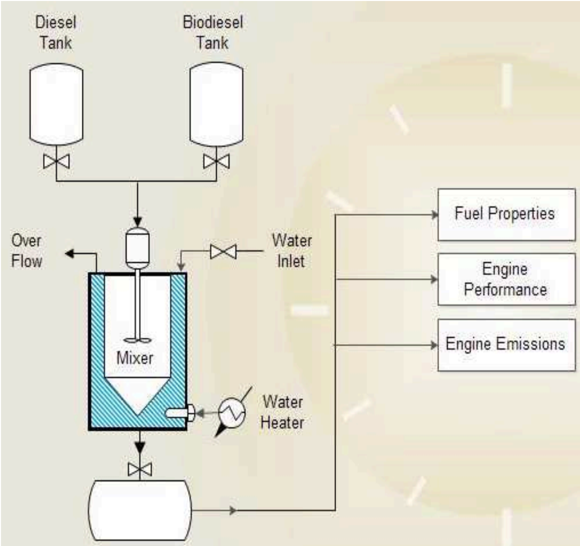

Figure 1: Blending process of producing biodiesel

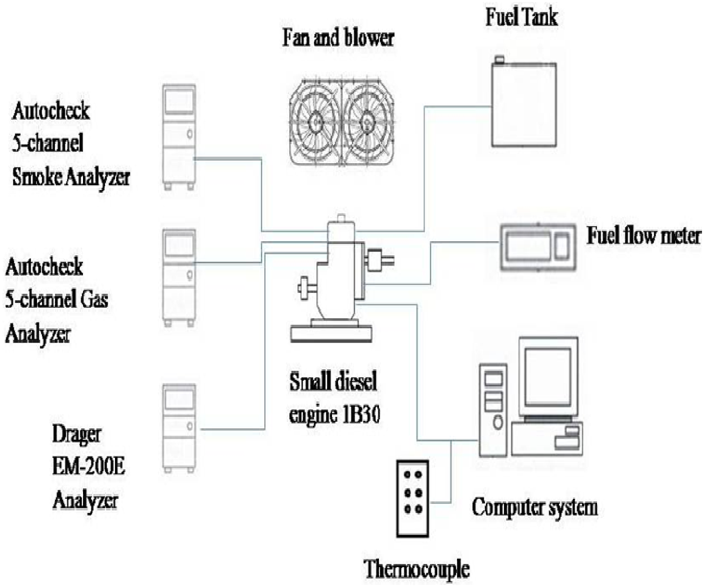

Figure 2: Schematic Diagram of Experiment Setup

A block diagram of blending process and schematic view of blending process are shown in Fig.1. The purified palm oil methyl ester was then blended with STD in various concentrations for preparing biodiesels blend. During blending process, the laboratory scale blending machine was operated at 60^0C and the mixture was stirred at 70^0C for 1 hour. The rotating blade speed was adjusted to maintain the same speed at 270 rpm.

A schematic view of the emission test and summarizes the engine specification including the operating parameter shown in Fig. 2 and Table 2, respectively. The tested engine that used is small diesel engine, Hatz diesel engine 1B30 with 1 cylinder engine. This engine 1B30 series was design with compact installation dimensions and in all applications with a power requirement up to 8 kW due to its low weight. The maximum torque is 17.5 Nm. For this experiment, the running speeds were simulated at 1500, 2000, and 2500 rpm. Measurements data comprised fuel consumption rate (kg/hr) together with the exhaust emissions like hydrocarbon(HC), oxygen(O_2), carbon dioxide(CO_2),carbon monoxide (CO), nitrogen oxides (NOx) and smoke opacity by using autocheck 5 channel gas emission analyzer and dragger MSI. For this research OD (standard diesel), W5, W10 and W15 are used for running under similar engine in a manner similar operation conditions. To compare the difference, the measurement process was repeated for 3 cycles per each condition. Further analysis and presentation of data is based on the average of measurement.

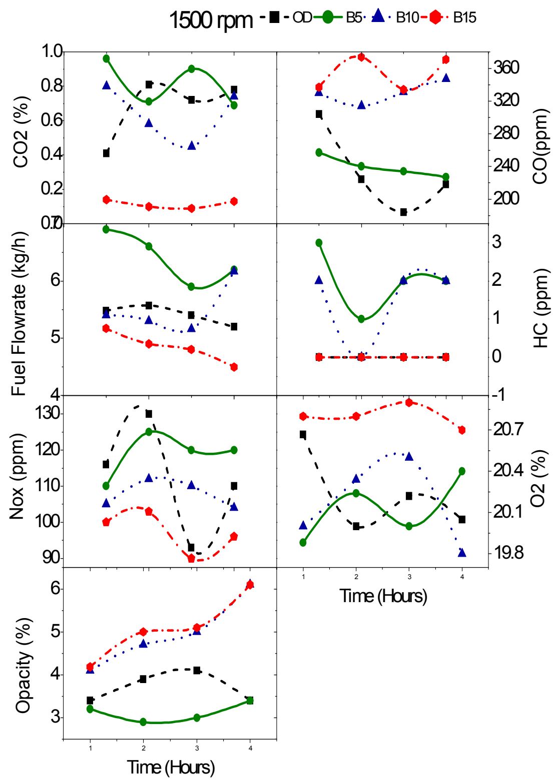

Figure 3 : Engine emission during 1500 rpm using OD and biodiesel blend (B5,B10,B15)

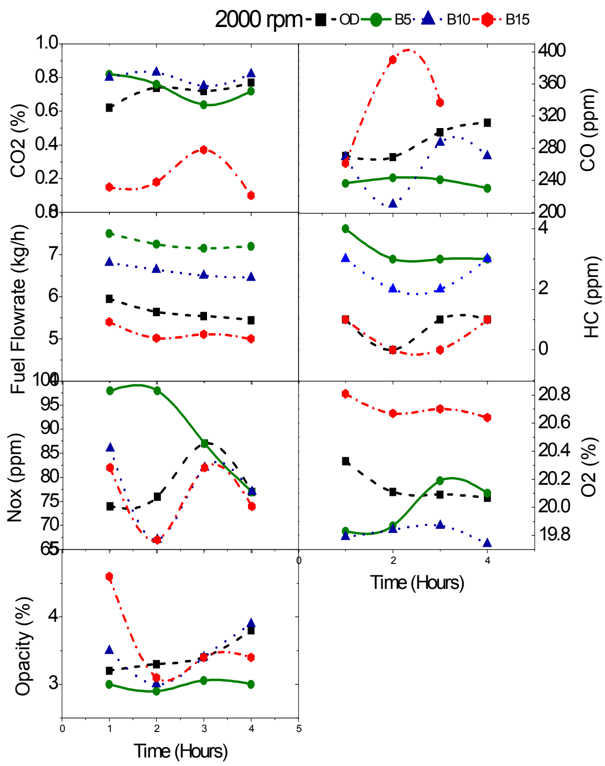

Figure 4: Engine emission during 2000 rpm using OD and biodiesel blend (B5,B10,B15)

Result and Discussion

The emission characteristic on different blending ratio and engine speed was investigated first. Figure 3 shows the relationship between the emission characteristic of Ordinary Diesel (OD), B5, B10 and B15 with 1500, 2000, and 2500 rpm of engine speed which is run in small diesel engine. Refer to figure 5, the increasing of blending ratio for all engine speed will decrease the HC and smoke opacity respectively. It is because the increasing of blending ratio will weaken the fuel ignitibility and prolong ignition delay as well. This circumstances results in lower combustion temperature and pressure. Thus the lower HC emission and smoke opacity is strongly related to lower combustion temperature. It is also found that NOx emission is increase inversely proportional with the blending ratio. It seems that the low viscosity of fuel due to the higher temperature enhance the fuel-air premixing thus influence the higher NOx. From the plotted graph show the result of increasing on O2 and decreasing on CO2 and CO with the increasing of blending ratio.

There is a relation which can be conclude that high blends of biodiesel have more oxygen content, which result more complete combustion and directly decrease CO2 and CO emission. It is proven that B15 is the lowest CO2 and CO emission. From the flow rate graph, the result shows B15 is the lowest flow rate compare with OD, B5 and B10. This can be concluded that, the B15 is more economical and less fuel consumption. The emission characteristic with different periods of time was investigated and discussed from Figure 4 and Figure 5 which is measured from 1st hour, 2nd hour, 3rd hour and 4th hour period of time. The fuels tested are OD, B5, B10 and B15. As seen in Figure 4, the emission of HC is negligibly small and lower for B15 with different period of time compared to OD. The reduction of smoke opacity may attributed to its oxygen content of the injected fuel at high injection pressure, thus more oxygen content will produce more C to CO, then decrease the smoke emission indirectly while increase the CO emission when engine speed increases. NOx emission is depending on the volumetric efficiency, combustion delay and temperature arising from high activation energy. It will decrease as the engine speed increase because the increased of volumetric efficiency and shorter ignition delay inside the combustion chamber. In Figure 4 and Figure 5, B15 have the lowest HC emission and also lowest CO_2

emissions under all engine speed conditions. The NOx emission start increasing at 1500 rpm of engine speed, but will decreases after 2000rpm and 2500 rpm. However, higher blends will result in higher NOx emission such as B5 and B10 at 1500 rpm and 2000rpm meanwhile OD has the moderate NOx emission among the tested fuels. The B15 shows the lowest at HC, NOx and CO2emission among other sample biodiesel at all engine speed conditions. On the other hand, the B15 shows the higher value for CO and Smoke Opacity emission at 1500 rpm and 2000 rpm of engine speed. The trend starts decreasing and show the lowest value at 2500 rpm of engine speed. Nevertheless the trend of CO and Smoke Opacity shows the decreasing from 1500 rpm to 2500 rpm.

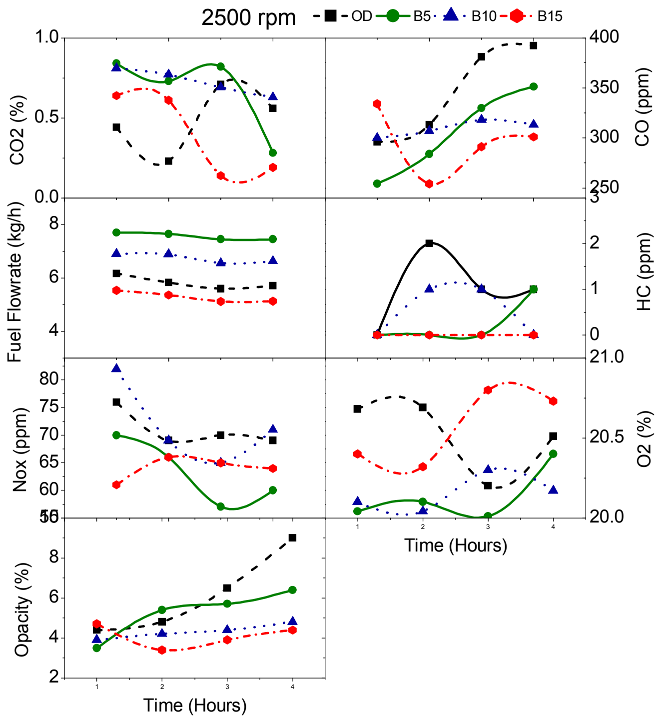

Figure 5 Engine emission during 2500 rpm using OD and biodiesel blend (B5,B10 B15)

Conclusion

In this research, the WCO biodiesel with different blending ratio (W5,W10,W15) are obtained in diesel engine and engine speed was adjusted at 1500, 2000, 2500 rpm. The summary as follows:

1. Engine emissions promotes the reduction of NOx and CO2 emission and higher in O2 in the range 5% to 15 % of blends due to more oxygen present during combustion, thus the combustion will become more complete and in oxygenated fuel.
2. Smoke Opacity, HC, CO, CO2 emissions and temperature is lower for high blends of WCO (B15), and decrease as the engine speed increases.

Acknowledgements

The authors also would like to thank the Ministry of Higher Education, Malaysia for supporting this research under Research Acculturation Grant Scheme (RAGS) Vot. R025 and Fundamental Research Grant Scheme (FRGS) vot.1054.

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