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INVESTIGATION ON CHARACTERISTICS OF POME BLENDED DIESEL ENGINE

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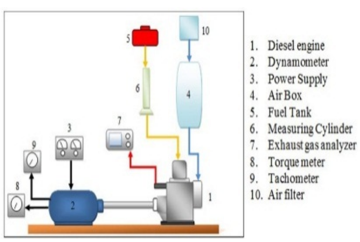
Graphical abstract



Abstract

The sudden increase in fuel prices due to diminishing petroleum resources and the pollution resulting from its use has resulted in research into alternative fuels such as biodiesel. In addition, the faster combustion and high temperature in the combustion chamber which results from petroleum diesel fuel leads to higher nitrogen oxide (NOx) and Particulate Matter (PM) emissions. Therefore, this research was conducted to investigate the effect of using palm oil methyl ester (POME) blends as alternative fuels on the performance and emission of a compression ignition engine. The performance of POME blends and diesel were compared by manipulating the load of the engine at 1800 rpm. The results obtained show that fuel consumption rate is higher for the POME blends compared to the diesel fuel and increases as the POME concentration increases. The increment of brake specific fuel consumption and the reduction of CO emission exhibit a relation to the increase in percentage of POME. This is mainly contributed by the higher oxygen content of POME which promotes complete combustion of the blends. However, efficient combustion from the blends as compared to diesel fuel resulted from higher oxygen content and cetane number leads to significant increase in exhaust temperature. This in turn increases NOx emissions since using POME blends is highly related to high temperature of combustion chamber. The experimental results proved that POME in compression ignition engine is a possible substitute to diesel.

Keywords: Palm oil methyl ester, blended, biodiesel, cetane number, diesel engine

1.0 INTRODUCTION

Increase in petroleum demand has recorded almost double increment due to development, modernization and industrialization. This has led to the reduction of petroleum that the main cause of the increase in petroleum prices [1]. The extensive use of petroleum such as gasoline and diesel also led to serious global warming and pollution caused by the gas emitted from its use. In order to overcome this problem the researchers have initiated effort towards renewable energy sources such as biodiesels. One of their main focuses in alternative fuel (AF) study is Palm Oil Methyl Esters (POME) [2]. This is due to Malaysia has a large quantity of palm oil and the largest palm oil exporter over the past few years.

Since then, POME had been repeatedly tested as a diesel replacement in a wide range of vehicle that operates on compression ignition engine or diesel engine. In these studies, it was found that POME could give a significant effect to the performances of the engines. A.S. Ramadhas et al. [3] reported that fuel consumption might increase as the biodiesel blends increase due to reduce in calorific value. The research done by H. Sharon et al. [4] which conducted an experiment on emission gases from B100, B75, B50, and B25 biodiesel at constant rated speed of 1500 rpm with variable loads comes out with the conclusion that is NOx emission increase as the biodiesel blends increase due to their higher exhaust temperature as compare to diesel fuel. A.S. Ramadhas et al. [3] proved that any increase in biodiesel concentration will cause significant increase in exhaust gas temperature. Most of them agreed that the main reason of increase in exhaust temperature with increase in the percentage of POME in the blends is due to the increase in oxygen content and cetane number.

Previous researchers have developed many methods for biodiesel production from crude palm oil. Biodiesel is a generic name for fuel which results from transesterification of a vegetable oil. In general, crude palm oil is converted to methyl ester through direct esterification of fatty acids or transesterification of triglyceride and glycerol as byproduct [5]. MPOB has developed a process that converts crude palm oil into methyl ester, which is used as a conventional diesel fuel substitute [6]. The transesterification of vegetable oils aims to ensure the quality of biodiesel by lowering its viscosity and enhancing other physicochemical properties. Faster combustion and high temperature in the chamber leads to higher oxides of nitrogen (NOx) and Particulate Matter (PM) emissions when using diesel fuel. Alternatively, biodiesel such POME has a high potential to become an additive to petroleum diesel fuel or operate as a standalone fuel to totally substitute diesel fuel itself for the reduction of emissions as well as improving the performance of diesel engine.

Thus, an experimental work using diesel engine test bed operates with different composition of POME blended diesel as well as diesel fuel was carried out to compare its characteristic. Moreover, the temperature profile in combustion chamber, engine performance and emissions were also determined. The results may contribute to an improvement in order to reduce the use of fossil fuel and switch to a renewable alternative fuel. As a contribution to automotive industry, the emissions of NOx and CO may be reduced to some acceptable level.

2.0 METHODOLOGY

2.1 POME Blend Preparation.

Commercial diesel fuel is compared with 4 types of POME blended biodiesel which are the B20 (blend of 20% POME and 80% diesel), B15 (blend of 15% POME and 85% diesel), B10 (blend of 10% POME and 90% diesel), B5 (blend of 5% POME and 95% diesel). The commercial grade diesel fuel used had an elemental composition by weight of 87.2% carbon, 12.8% hydrogen and 0.0225% sulphur. Blends were prepared on a volume basis at 25°C for 1 litre. Although blend preparation on a weight basis has the advantage that weight fraction does not change with temperature, the common practice in the fuel industry is to carry out the mixing process on a volume basis at the ambient temperature. For this reason, the option selected in this work was to use blending rules as a function of volumetric fractions.

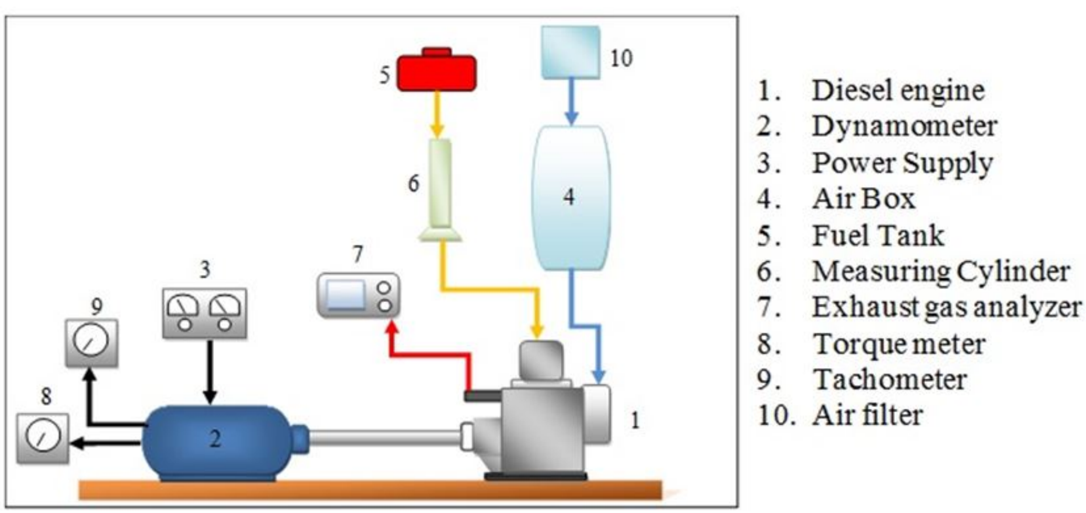


Figure 1 Schematic diagram of experimental setup

2.2 Engine Testing Setup

The B5, B10, B15, B20 and diesel fuel are investigated using direct-injection, single cylinder and air cooled stationary Robin diesel engine. The engine will be coupled to dynamometer to provide load as shown in Figure 1. The electric dynamometer set was tested at different loads by varying electrical load. The engine speed will be measured by tachometer while the load applied was recorded using torque meter for each POME blends. The performance of POME blends and diesel are compared by manipulating the load of the engine while the engine is fixed at rated speed of 1800 rpm. The loads applied were starting from 1 Nm to 5 Nm with increment of 1 Nm. The fuel consumption rate at specific engine load for each blend was obtained from fuel measurement system. The emission analysis for NOx and CO is obtained from gas analyzer devices. The fuel consumption rate, brake specific fuel consumption, and the emission gases such as NOx and CO are recorded.

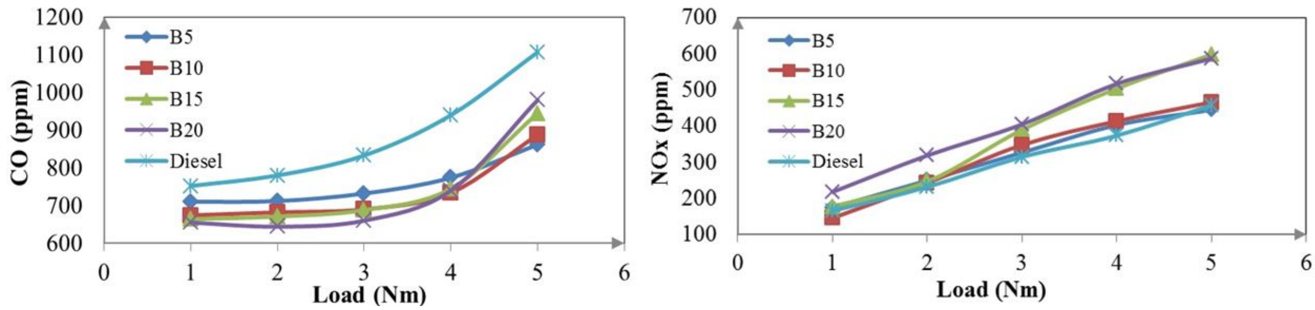


Figure 2 (a) Fuel Consumption vs Load, and (b) Brake Specific Fuel Consumption vs Load

3.0 RESULTS AND DISCUSSION

3.1 Fuel Consumption.

The comparison of fuel consumption of POME blended diesel and conventional diesel fuel is shown in Figure 2(a). The pattern shows that as the load increases, the fuel consumption rate also increases for all blends as well as diesel fuel. However, the fuel consumption of POME blends relatively higher than diesel fuel and increased as mixture increase. B20 recorded highest fuel consumption compared to other blends for all loads. In comparison with diesel fuel, the increment of fuel consumption for B20 is about 17.0% and 27.0% at low load and high load respectively. At low load condition, the fuel consumption of B5, B10 and B15 are comparable to the diesel fuel. At high load condition, diesel fuel recorded the lowest fuel consumption compared to the POME blends with difference about 3.6% and 14.1% for B5 and B10 respectively. The difference in fuel consumption rate is mainly due to the calorific value of POME that is lower than diesel fuel [3]. With increase in POME percentage in the blends, the calorific value of fuel will also decrease thus more fuel was consumed in order to achieve the same power as diesel fuel. Other than that, the relationship of higher fuel density and viscosity which promote poor atomization and mixing process lead to significant increase in fuel consumption.

3.2 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with load for different fuels is presented in Figure 2(b). The brake specific fuel consumption decrease with increase in load for all fuel tested. This inverse relation is due to higher percentage increase in brake power with load as compared to the increase in fuel consumption. B20 shows the highest brake specific fuel consumption compared to the other blends as well as diesel fuel at all loads. B20 shows percentage difference of 18.8% and 30.0% at low load and high load respectively as compared to the diesel fuel. Brake specific fuel consumption increase with increase in POME in biodiesel blends at high load condition. B10 shows significant difference in BSFC about 15.0% at high load condition in comparison with diesel fuel. At intermediate range of load, the brake specific fuel consumption of B5, B10 and diesel fuel shows comparable values. Diesel fuel recorded lowest brake specific fuel consumption for low and high load condition. Increase in the BSFC is due to the lower energy content of the biodiesel which is 14% lower than that of diesel [7]. Any increase in biodiesel percentage in the blends will reduce the calorific value of the fuel thus higher amount of fuel is consumed in order to achieve the similar maximum brake torque causing an increase in the BSFC. Therefore, the higher percentage of biodiesel in blends will promote higher BSFC compared to the diesel. Furthermore, the combined effect of higher viscosity also contributes to the increment in BSFC due to poor combustion and atomization..

3.3 Carbon Monoxide

Figure 3(a) illustrates the emission of carbon monoxide which is one of the major concerns towards the environmental effect. For all load tested, the emission of carbon monoxide increases as the load increase for all types of fuels. All type of fuels emits lower amount of carbon monoxide at low load and higher amount of carbon monoxide at higher load [3]. This is normal due to air-fuel ratio decreases with increase in load. From the graph obtained, it clearly shows that increases in POME percentage in the blends caused the reduction in carbon monoxide emission. Diesel fuel recorded highest emission of carbon monoxide compare to the POME blends. At low load condition, B20 produce lowest amount of carbon monoxide followed by B15, B10, and B5. B20 emits 11.6% and 11.5% lower amount of CO as compared to diesel fuel at low load and high load condition respectively. At high load condition, the emission of B5 is the lowest among the blends followed by B10, B15 and B20. This lower CO emission of POME blends as compared to diesel fuel is mainly attributed by the presence of oxygen content in the biodiesel. This higher amount of oxygen as compared to the diesel fuel will enhance the combustion of POME blends thus promote complete combustion of the fuel. However, in the case of high load condition, the emission of CO for B20 is the highest among the POME blends due to the increment of fuel viscosity and poor atomization causing to poor combustion which promote higher CO emission.

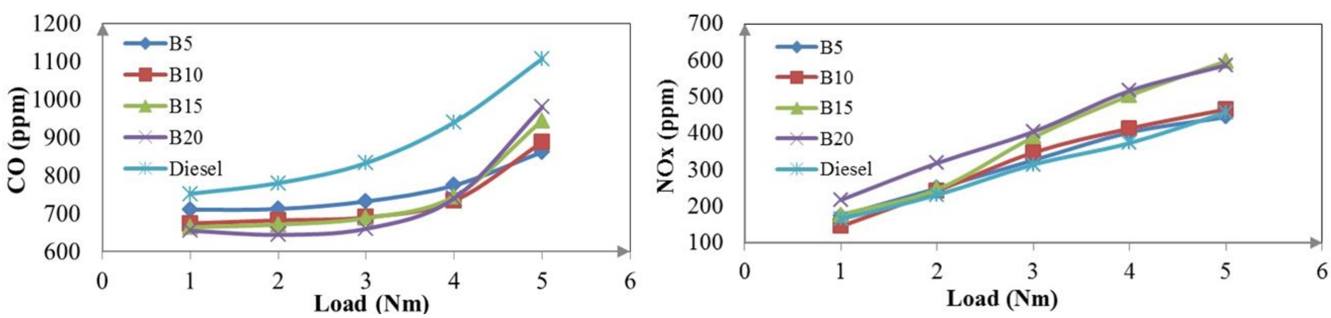


Figure 3 (a) CO emission vs Load, and (b) NOx emission vs Load

3.4 Nitrogen Oxide

Figure 3(b) shows the trend of nitrogen oxide emission for each fuel. For all fuel tested NOx emission increases with increase in load. The graph also shows that any increase in POME percentage in the blends will increase the NOx emission. The emission of diesel, B5 and B10 shows comparable value for all load tested. B20 emits highest amount of NOx compared to other fuels. NOx emission for B20 increased about 31.3% and 28.2% as compared to diesel fuel for low load and high load condition. At high load condition, the emission of NOx from B15 and B20 roughly shows comparable values. NOx emission is mainly depends on the temperature of combustion temperature [5]. The higher exhaust temperatures of B20, B15, B10 and B5 as compared to the diesel are the main contributor to the higher emission of NOx. Air contains higher amount of nitrogen in free form but it will not react with oxygen unless a particular temperature is reached. Nitrogen oxide may generate when the exhaust temperature achieves extremely high values and at this point it is very sensitive to oxygen content of the fuel. Higher cetane number of POME promoted the fuel begin to ignite shortly after injection into the cylinder and therefore it will have sufficient time for complete combustion of fuel during the power stroke which leads to significant increases in combustion temperature as well as thermal NOx formation.

4.0 CONCLUSION

Based on the results and observation from this experiment, it can be concluded that this research has led to a deeper understanding and beneficial information about performance and emissions associated to POME blends taking the petroleum diesel fuel as reference fuel. The study on performance and emissions using Four Stroke single cylinder Diesel engine can be conclude that the fuel consumption rate increases as the POME percentage in the blends is increased, the brake specific fuel consumption (BSFC) marginally increase as the percentage of POME in the blends increases, the carbon monoxide (CO) emissions significantly reduce as the blend ratio increase, and the nitrogen oxide (NOx) emission shows an increment with respect to increase in blends ratio. From the results obtained, it clearly shows that POME blends have the advantages over the petroleum diesel in terms of lower CO emissions which is one of the major concerns towards the environmental pollution issues. However, higher amount of NOx emitted from its uses associated with higher combustion temperature has reduced further research interest to increase the percentage of POME in the blends. Although other disadvantage of the POME blends in terms of performance which is higher in fuel consumption rate due to the reduction in generated power, it does not show much difference with diesel fuels. As an alternative fuel, POME has potential to become fuel additives in diesel engine as well as alternative fuel to replace diesel fuel. Moreover, further research need to be carried out towards the potential of POME and ways to overcome its disadvantages.

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