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Effect of Low Proportion Palm Biodiesel Blend on Performance, Combustion and Emission Characteristics of a Diesel Engine

Mohd Hafizil Mat Yasin[a], Perowansa Paruka[a],Rizalman Mamat[b,*], Ahmad Fitri Yusop[b] , Gholamhassan Najafi[c] and Azri Alias[b]

[a]*Department of Mechanical Engineering, Politeknik Kota Kinabalu, 88450 Kota Kinabalu, Sabah*
[b]*Faculty of Mechanical Engineering, University Malaysia Pahang, Malaysia*
[b] *Department of Mechanics of Biosystem Engineering, TarbiatModares University, Tehran, Iran*

Abstract

Short-term engine performance tests were carried out on diesel engine fuelled with diesel and B5 (5% palm methyl ester + 95% diesel) blended fuel. Blended fuels was conducted in a Mitsubishi 4D68 4 in-line multi cylinders compression ignition (CI) engine with various engine speeds to determine the torque and power of engine. Brake specific fuel consumption data also has been collected during the experimental tests. NOx, HC, CO_2, CO, and O_2 emissions also have been monitored has been collected. All parameters vary with engine speed. Results showed that at all engine speeds, torque and power outputs for B5 fuel were quite similar to neat petroleum diesel fuel. NO emission reduced significantly for both fuels but the rest emission contents were decreased with engine speed.

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1. Introduction

Instability in world petroleum market occasioned by perpetual rise in petroleum prices, increasing threat to environment from exhaust emissions, global warming and rapidly, dwindling crude oil deposits amongst other factors have been reported to be responsible for the recent attention focused on the search for cheaper, environmentally friendly and renewable source of fuel [1-4]. Studies have been conducted on

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biomass-based fuel such as alcohol, biogas and vegetable oil as possible substitute for petroleum based fuels [5-6]. Reports have shown that vegetable oils are possible alternative fuel for diesel engine. Other oil crop investigated includes palm oil, jatropha curcus, tigernut, rice bran, Palm kernel oil and cottonseed oil [3]. Transesterification is the process of using an alcohol (e.g., methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oil (Biodiesel) with glycerol as a by-product. Korus et al. [7] conducted rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. Peterson and Reece [8] conducted tests on ethyl and methyl esters of rapeseed oil, while Peterson et al. [9] worked on the production and testing of ethyl and methyl esters of canola, rapeseed, soybean oils and beef tallow as well as hydrogenated soy ethyl ester. This work therefore conducts some short-term engine performance tests on diesel engine fuelled with local biodiesel with blend of 5% palm methyl ester and conventional diesel fuel in a steady state condition.

2. Materials and Methods

The experimental program was carried out using a Mitsubishi 4D68 SOHC Direct Injection 2.0L four stroke cylinders engine with EGR (Table 1). This is a naturally aspirated, direct injection diesel engine with a bore of 82.7 mm, stroke 93 mm. It is an air-cooled, low-speed and the maximum power was 64.9 kW at 4500 rpm. An exhaust gas analyzer KANE systems complete with a 3 meter sampling probe was used for emissions measurements. For crank angle measurement and combustion characteristics, the engine was mounted with Kistler CAM crank angle encoder type 2613B connected to Kistler signal conditioner type 2613B2. From the signal conditioner, crank angle encoder being connected to PC DEW-800 with connecting cable type 2613B3. A water cooled piezoelectric pressure transducer (Kistler 6041A) was flush mounted with cylinder head to measure combustion pressure The engine’s glow plugs were removed and the holes modified to accept the pressure transducers. The temperatures of the environment were obtained by RS thermocouples K-type. The engine was directly coupled to an eddy-current brake ECB dynamometer equipped with a Dynalec load controller. The engine, dynamometer and other auxiliary items are mounted on a seismic steel bed (2.49 x 1.34 m) to absorb the engine vibration emitted during the trial (figure 1). The computer based data acquisition system was used in the testing facilities is Orion 1624 E card installed on a DEWE-800 lab instrument with 16 slots for DAQ/PAD modules and 2 PCI slots. This card provides 16 simultaneous sampled differential channels at 200 kS/s each and 24-bit resolution. While Spectrum MI.3111 DAQ card with 12 bit resolution simply provides channel for Kistler crank angle encoder. Data that acquire during experiment was retrieved using software DEWESoft and

DEWECa provided by DEWETRON. In this study, engine was run at different speeds from 1000 rpm to 3000 rpm at steady state condition. Table 2 depicts the fuel properties for neat diesel fuel and B5.

Table 1. Specification for a Mitsubishi 4D68 Diesel Engine Model 1995

Description	Specification
Number of cylinders	4 in-line
Combustion chamber	Swirl chamber
Total displacement cm	1.998 cc (121.925 cu in)
Cylinder bore mm x Piston stroke mm	82.7 x 93
Bore/stroke ratio	0.89
Compression ratio	22.4:1

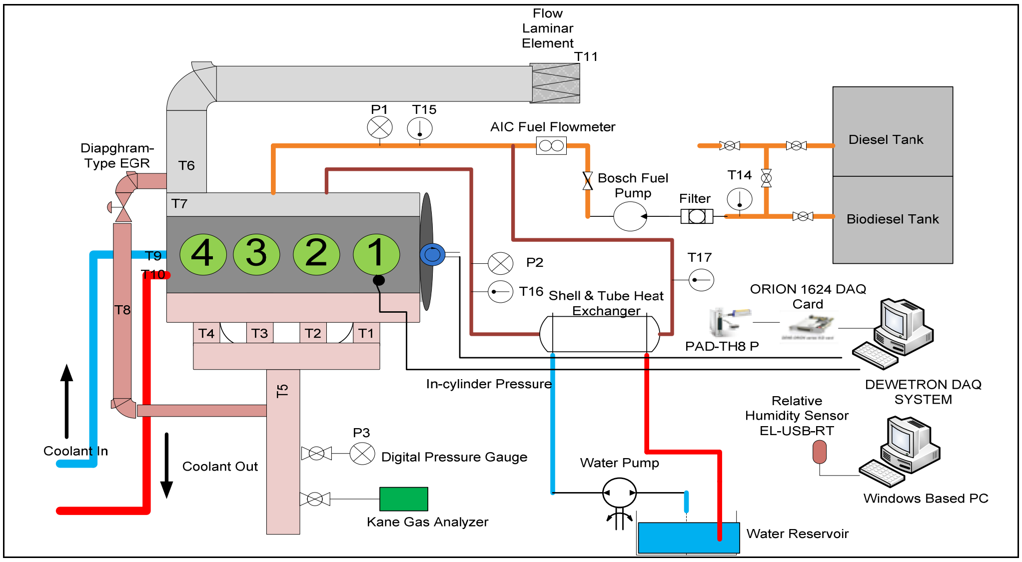

Fig. 1. Engine Instrumentation system set up

Table 2. Properties of fuel for Diesel and B5

Property	Diesel	B5
Heat value (MJ kg-1)	45.28	45.135
Cloud point (°C)	18	13.7
Density @ 15°C (kg/m3)	853.8	827
Flash point (°C)	93	81.1
Pour point (°C)	12	9.0
Cetane Number	54.6	-

3. Results and discussions

Power curves in the figure 2(a) shows that engine running with diesel have a slight higher brake power with the increasing engine speeds as compared to B5 correspondingly. B5 and Diesel recorded highest brake power at 2500 rpm with 24.61 kW. For torque curves, the patterns definitely decreased from the beginning of the engine speed to the maximum speed. For diesel fuel the graph started at 102 Nm at 1000 rpm and slowly decreased to 75 Nm of torque at the speed of 3000 rpm. While for B5 the trend quite different which is started at 104 Nm at 1000 rpm and increased to 115 Nm at the speed of 1500 rpm, and keep reducing to 69 Nm at 3000 rpm or 39.1% of maximum torque. Diesel had the lowest BSFC as compared to B5 with increasing BSFC from 0.326 kg/kW.hr at 1000 rpm to 0.3906 kg/kW.hr at 3000 rpm. While BSFC for B5 fuel has increased with respect to the engine speed, from 0.3384 kg/kW.hr to 0.4071 kg/kW.hr with percentage of 13.8% (figure 2b).The increase in BSFC was understandable as the biodiesels have approximately 0.32% less energy than the diesel. The higher the palm oil contents in the biodiesel, the lower its heating value, resulting in higher BSFC. This is due to the bio-diesel has lower heat value than diesel fuel. The energy per unit mass of B5 was 45.135 MJ/kg, respectively, while for diesel the energy per unit mass was 45.28 MJ/kg. As the amount of palm methyl ester in the blends increases, heat value of the blends decreases. In order to maintain the same mean effective pressure in the cylinder, more fuels are consumed.

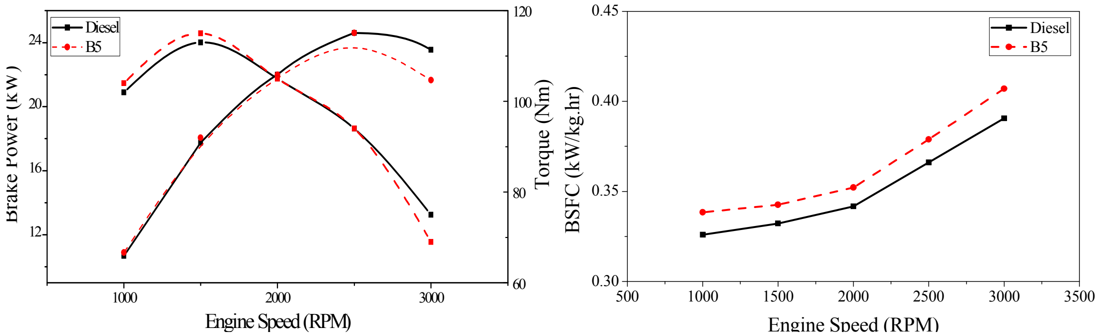

Fig. 2. (a) Power and torque curves vary with various engine speeds for diesel and B5 fuels, (b) Variations of BSFC with engine speed for diesel and B5

The formation of NOx is highly dependent on in-cylinder temperature, the oxygen concentration and residence time for the reactions to take place. Comparing the graphs for diesel fuel in figure 3(a), it shows that the content of NOx was decreased due to the engine speed and nearly achieved to range 80 – 90 ppm for NOx for both fuels. These gases absorb energy released by combustion, which reduces the peak combustion temperature in the combustion chamber, and also it replaces the oxygen in the combustion chamber. As a result of reduction in temperature and oxygen, the NOx reduces within emission. In the testing, the data has been collected to seek the oxygen content in the exhaust emission when fuelled with neat diesel and B5 fuels. The highest point for UHC that can be determined in figure 3(b) was 104 ppm operated with B5 fuel while for diesel was 105 ppm at 1000 rpm. The lack of oxygen is responsible for reduced oxidation rate, which leads to incomplete combustion, hence higher unburned hydrocarbon emissions. Carbon dioxide is a principal constituent of exhaust gas recirculation.

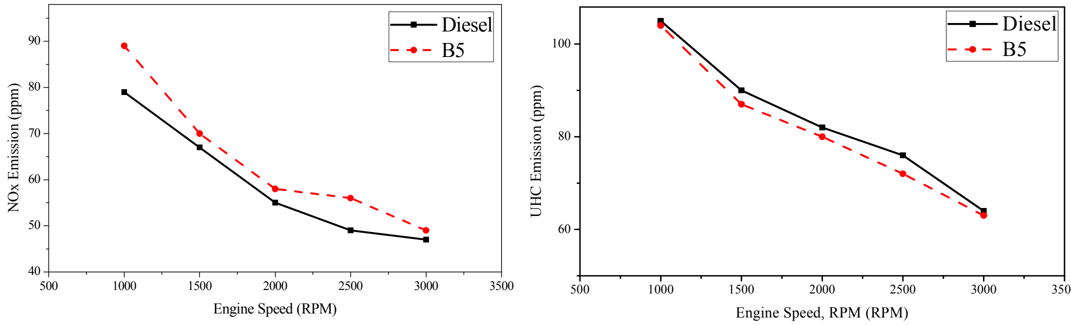

Fig. 3. (a) Variation of NOx emissions with engine speed for B5 and diesel fuel, (b) Variations of unburned HC (Hydrocarbon) content with engine speed for diesel and B5

CO emission is toxic and must be controlled. It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air fuel ratio relative to the stoichiometric proportions. Rich combustion invariably produces CO, and emissions increase linearly with the deviation from the stoichiometry. CO is predominantly formed due to the lack of oxygen. Since B5 is an oxygenated fuel, it leds to better combustion of fuel resulting in the decrease in CO emission. Percentage of CO emissions had linearly decreased due to the speed with both fuels and at the speed of 1500 rpm, the situation was completely changed with the content has been dropped to nearly 2.5 % at the speed of 3000 rpm. Percentage of CO was higher at the beginning of the speed and slowly decreased due to the increasing of the engine speed for both fuels. The percentage of CO Diesel emission was higher than B5 fuel (figure 4(a)).

The nature of CO_2 is higher heat capacity and it serves as a heat absorbing agent during the combustion, which reduces the peak temperature in the combustion chamber. The scenario explains that there were higher peak temperatures in the combustion chamber during the testing with adding the exhaust gas which has higher temperature without cooling it first before entered the intake manifold with ambient air. The percentage of carbon dioxide also vary with engine speed which the higher combustion chamber works, less carbon dioxide has been produced (figure 4(b)).

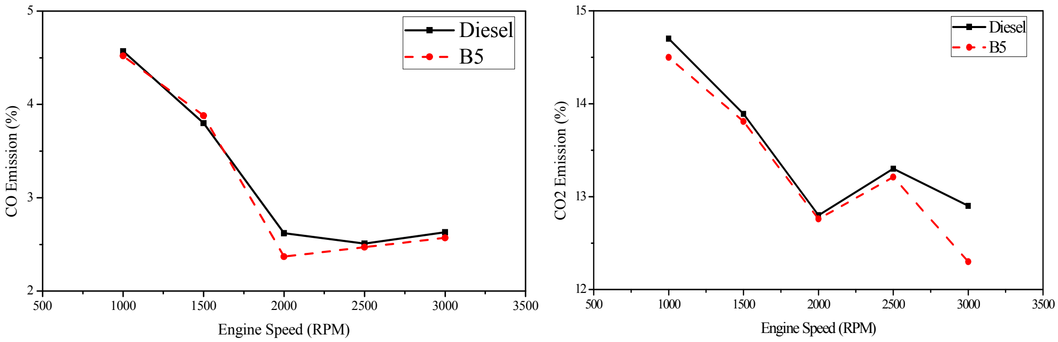

Fig. 4. (a) Variations of carbon monoxide (CO) content with engine speed for diesel and B5 Fuel, (b) Variations of carbon dioxide (CO_2) content with engine speed for diesel and B5

5. Conclusions

In this paper, an experimental investigation of the engine performance and exhaust emissions in a diesel engine operating with diesel and B5 (5% palm methyl ester + 95% diesel) respect to engine speed was carried out. Results showed that there is slight difference in brake power output and torque between B5 and diesel due to small effect of biodiesel properties in B5. BSFC increased with the reduction in NOx emissions is obtained when the engine fueled with B5. CO, CO_2, and UHC reduced in the exhaust emission for B5 compared to neat diesel fuel.

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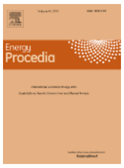

Biography

Dr. Rizalman Mamat is associate professor in Mechanical engineering department, University Malaysia Pahang, Pahang, Malaysia. He is expert in the fields of internal combustion engines and renewable energies.