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Comparative study on biodiesel-methanol-diesel low proportion blends operating with a diesel engine

Mohd Hafizil Mat Yasin[a],Rizalman Mamat[a,*], Ahmad Fitri Yusop[a]

Amir Aziz[a] and Gholamhassan Najafi[b]

[a]Faculty of Mechanical Engineering, University Malaysia Pahang, Malaysia

[b] Department of Mechanics of Biosystem Engineering, TarbiatModares University, Tehran, Iran

Abstract

In this study, biodiesel (20%)-methanol (5%)-diesel (75%), biodiesel (20%)-methanol (10%)-diesel (70%), biodiesel (20%)- diesel (80%), and standard mineral diesel as a baseline fuel are tested in a multi-cylinder diesel engine. Those biodiesel-alcohol low proportion blends are investigated under the same operating conditions at 20%, 40% and 60% of engine loads to determine the engine performance and emission of the diesel engine. Overall, biodiesel-methanol-diesel blends show higher brake specific fuel consumption than mineral diesel. As methanol proportions in blends increase, NO emissions increase, while CO emissions are reduced. Also, biodiesel-diesel blend with 5% of methanol is more effective than biodiesel blend with 20% for reducing CO emissions.

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Keywords: Biodiesel blend; methanol; performance; emission; diesel engine.

1. Introduction

The use of alcohol additives include methanol and ethanol are very practical in the biodiesel blends due to its miscibility with the pure biodiesel[1]. Alcohol additives are very helpful to reduce the viscosity and density of the biodiesel which is higher compared to standard mineral diesel. The alcohol additives improve the combustion efficiency and produce lower exhaust emission when fuelled the diesel engines. Ethanol and methanol has approximately 35% and 30% higher oxygen in basis as compared to mineral diesel that help diesel engine to achieve higher complete combustion[2]. More oxygen in fuels means more complete combustion to be achieved. Qi et al.[3] conducted the study on biodiesel-methanol-diesel

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blends with the volume ratios of 5% and 10% of methanol as an additive in the compression ignition engine. Overall results showed that BDM5 and BDM10 produced a significant decrease of smoke emission and CO emissions. As for combustion results, BDM5 and BDM10 have a combustion delay compared to BD50 at low engine load. However at the high engine load, the engine start for BDM5 and BDM10 were comparable to BD50. Najafi and Yusaf[4]investigated the performance of methanol-diesel blends on a diesel engine. Methanol was added to diesel as additives with volume concentrations of 10%, 20% and 30% (methanol (10%)-diesel (90%), methanol (20%)-diesel (80%) and methanol (30%)–diesel (70%). Overall results show that methanol-diesel blends show a significant increase in effective brake power and torque when compared to mineral diesel. The lowest exhaust temperature produced for the mixing ratio fuels was methanol (10%)-diesel (90%). While mineral diesel produced the highest exhaust temperature as compared to methanol-diesel blends. As for brake specific fuel consumption (bsfc), the mineral diesel produced lower bsfc as compared to other methanol-diesel blends while the bsfc for methanol (30%)-diesel (70%) was the highest. Anandet al.[5]examined the influence of the methanol as an additive on the combustion, performance and exhaust emission when blended with neat karanji biodiesel in a multi-cylinder direct injection. The test fuel was blended according to the volume ratio, 10:90 (90% karanji biodiesel and 10% methanol). Overall results indicated that the peak cylinder pressure and peak energy release rate decreases for biodiesel-methanol blend. However, the unburned hydrocarbon (HC) and CO emissions were slightly higher for the methanol blend compared to neat biodiesel at low load conditions. While at higher engine load conditions, the CO emissions decreased significantly for the biodiesel-methanol blend but as for HC emissions, the results were comparable between the test fuels [6].

In this comparative experimental study, biodiesel-methanol-diesel blends were tested in the same diesel engine under the same operating conditions. Those finding results were compared to B20 and mineral diesel as for the baseline. Biodiesel-methanol-diesel blends were prepared with 20:5:75 and 20:10:70 ratios (B20 M5 and B20 M10). Brake specific fuel consumption (bsfc), exhaust temperatures, CO and NO emissions were compared based on the fuel type and mixing ratio.

2. Materials and Methods

The experimental work was conducted on a four-cylinder, 4-cycle, indirect injection (IDI), water-cooled Mitsubishi 4D68 diesel engine. Table 1 described the details of the engine. Figure 1 shows the schematic diagram of the test engine used in this study. An eddy-current type water-cooled Dynalec dynamometer model ECB-200F SR 617 with capacity of 150 kW was used to load the engine. A Kistler 6041A water-cooled ThermoComp in-cylinder pressure transducer was attached to the first cylinder of four cylinders by replacing the glow plug and wired to a Kistler Model 1929A1 cable to the charge module, DAQP- Charge B.

Table 1. Specification of test engine

Engine Specification	Details
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
Maximum Power	Specific output 43.5 bhp/litre 0.71 bhp/cu in
Fuel system	Mechanically control distributor-type injection

In order to determine the crankshaft position during the combustion process and the continuous movements from top dead centre (TDC) to bottom dead centre (BDC) and so on, with comparable to the differential cylinder pressures, a Kistler CAM crank angle encoder type 2613B1 was mounted in alignment to the pulley of the crank shaft at the side of the engine and connected to the signal conditioner type 2613B2. Both pressure transducer and crank angle encoder were recorded through a Dewetron data acquisition (DAQ) system with Orion 1624 DAQ card installed in a Windows XP based PC, DEW-5000 combustion analyser. The data was recorded for 200 engine cycles so that the average result could be calculated. 19 K-type thermocouples were used to measure the temperatures of the engine include all the exhaust manifolds. Those temperatures were monitored and recorded by a Dewetron DAQ system installed on a DEWE-800, Windows XP based PC.

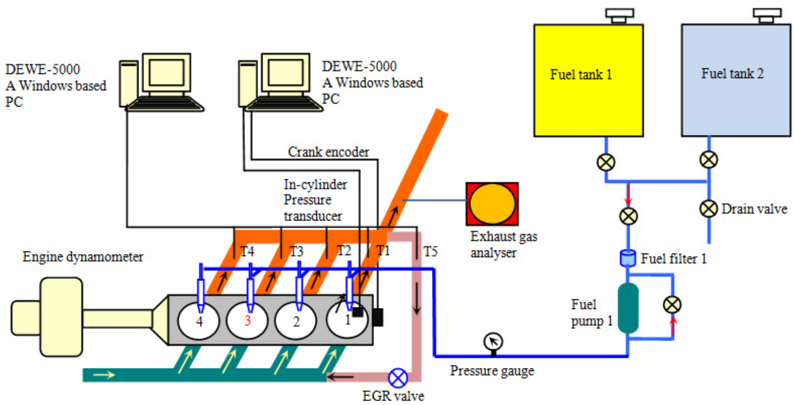


Fig. 1. Schematic diagram of a Mitsubishi 4D68 diesel engine system

A Kane gas analyzer was used to measure the engine exhaust emission and was recorded in Excel file format. The exhaust gas was sampled at 50 cm downstream of the exhaust extractor. The emission parameters measured include carbon dioxide (CO_2), carbon monoxide (CO), nitrogen monoxide (NO) and nitrogen oxides (NOx). In this study, biodiesel blend,B20 biodiesel (20%)-diesel (80%), B20 M5 biodiesel (20%)-methanol (5%)-diesel (75%), B20 M10 biodiesel (20%)-methanol (10%)-diesel (70%) and mineral diesel as a baseline fuel were prepared for the engine testing. Biodiesel was originated from palm oil and been transesterified into palm methyl ester (PME) or palm biodiesel. The process followed ASTM D6751 guidelines and the biodiesel fuel met the standard specification. The biodiesel fuel was purchased from the local biodiesel company while mineral diesel was purchased from the local petrol station. Table 2 summarizes the detail properties of the test fuels.

Table 2. Fuel properties

Description	Testing Method (ASTM)	Mineral diesel	B20	B20 M5	B20 M10
Density @ 20 °C g/cm³	D287	0.837	0.845	0.8437	0.8434
Viscosity @40 °C mm²/s	D445	4.237	4.514	3.28233	3.62526
Cetane number	D613	71.6	78.2	92.4	91.2
Flash Point (°C)	D93	70	110	45	49
Acid Number	D3339	0.24	0.02	0.59	0.59
Net heat of combustion (MJ/kg)	D240	49.962	45.714	N/A	N/A
Iodine Number	D1957	N/A	N/A	10.17	
Free fatty acids, %	D664	N/A	N/A	0.2953	0.3892

3. Results and discussions

A series of tests was undertaken to investigate the influence of biodiesel-methanol-diesel blends in a multi-cylinder, water-cooled diesel engine at constant engine speed, 2500 rpm and three engine loads. Also biodiesel-methanol-diesel blends are compared under the same operating condition and results are compared to mineral diesel as a function of load and mixing ratios. Biodiesel-methanol-diesel blends produce higher brake specific fuel consumption (bsfc) as compared to B20 and mineral diesel at three different engine loads as illustrated in Figure 2a. As the methanol concentrations increases, the bsfc for the engine proportionately increases. Overall the mineral diesel has the lowest bsfc compared to other blend fuels. Results indicated that the biodiesel-methanol-diesel blends consume more fuel per energy extracted as load decreases, then resulted more fuel carry-over or unburned fuel. The exhaust gas temperature provides qualitative information about the combustion progress details in the engine [5].

Figure 2b shows the variation of exhaust gas temperature for the test fuels; biodiesel-methanol-diesel blends, B20 and mineral diesel.As expected for all cases, exhaust gas temperature increases regarding to the engine loadsIt can be seen from the figure that there is no a significant difference between the results, however biodiesel-methanol-diesel blends produce a slight increase in exhaust temperatures compared to other test fuels due to the higher oxygen content of the biodiesel-ethanol-diesel blends that could increase the combustion temperature.

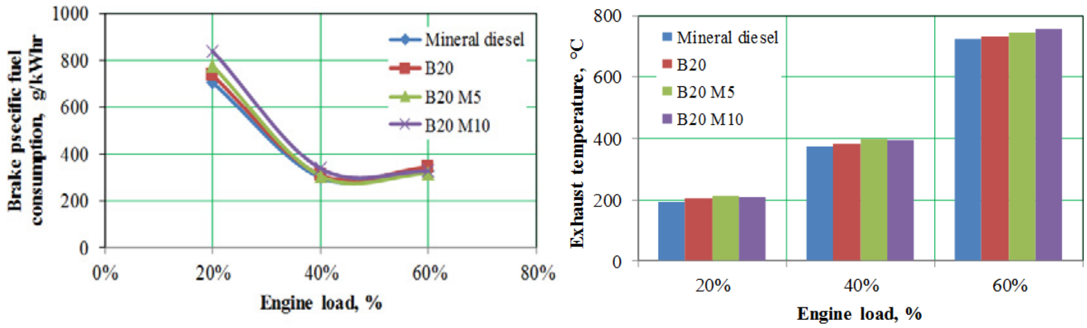


Fig. 2. (a) Brake specific fuel consumption and (b) Exhaust gas temperature for diesel engine running with biodiesel (20%)-methanol (5%)-diesel (75%), biodiesel (20%)-methanol (10%)-diesel (70%), biodiesel (20%)-diesel (80%) and mineral diesel

Figure 3(a) shows the comparison of CO emissions of biodiesel-methanol-diesel blends, biodiesel-diesel blend and mineral diesel at varying load conditions. In general, it is observed that the CO emissions are slightly lower for biodiesel-methanol-diesel blends at low load condition and with increase in load the differences in CO emissions are insignificant between the test fuels. The higher CO emissions for the test fuels were observed at high load condition due to the higher air-fuel equivalence ratio. However, overall results show that biodiesel-methanol-diesel blends achieved the CO emissions reduction at all engine loads due to more complete combustion. The formation of nitric oxide (NO) emissions is primarily governed by the magnitude of maximum cylinder temperature and the crank angle at which it occurs [5]. Figure 3(b) shows the comparison of NO emissions of biodiesel-methanol-diesel blends, biodiesel-diesel blend and mineral diesel at varying load conditions. The NO emissions of biodiesel-methanol-diesel blends are significantly higher compared to mineral diesel at all the tested conditions. The increase in NO emissions with the blend can be explained through the higher magnitude of in-cylinder temperature due to the higher oxygen content of the blends.

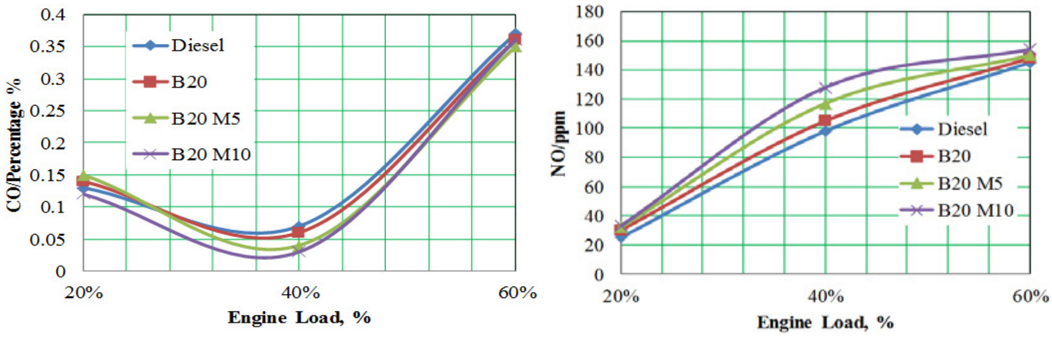


Fig. 3. (a) CO emissions and (b) NO emissions for diesel engine running with biodiesel (20%)-methanol (5%)-diesel (75%), biodiesel (20%)-methanol (10%)-diesel (70%), biodiesel (20%)-diesel (80%) and mineral diesel

5. Conclusions

The following conclusions are drawn from the experimental results of biodiesel-methanol-diesel blends on engine performance and exhaust emission operating with an indirect injection diesel engine:

(i) bsfc of biodiesel-methanol-diesel blends is higher as compared to mineral diesel with higher methanol concentrations (10%) have higher bsfc compared to lower methanol concentrations (5%).

(ii) There were increases in exhaust gas temperatures for biodiesel-methanol-diesel blends varying at all engine loads.

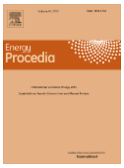
(iii) Higher methanol concentrations decrease NOx emissions while slight increasing in CO emissions. Biodiesel-ethanol-diesel blends substantially reduced the NOx emissions while increasing in CO emissions.

Overall, combustion and emissions strongly depend on methanol blend ratios and engine operating conditions, which may produce favourable and contradict effects overall due to the oxygen content and the cooling effects of methanol.

References

1. Gerdes, K. and G. Suppes, *Miscibility of ethanol in diesel fuels.* Industrial & engineering chemistry research, 2001. **40**: p. 949-956.
2. Hulwan, D. B. and S. V. Joshi, *Performance, emission and combustion characteristic of a multicylinder DI diesel engine running on diesel–ethanol–biodiesel blends of high ethanol content*. Applied Energy, 2011. **88**: p.5042-5055.
3. Qi DH, C. H. Geng L. M., Bian Y.Z.H. and X.C.H. Ren., *Performance and combustion characteristics of biodiesel-diesel-methanol blend fuelled engine*. Applied Energy, 2010. **87**: p.1679-86.
4. Yusaf, T. and G. Najafi, *Experimental investigation of using methanol-diesel blended fuels in diesel engine*, in the 4th International Conference on Thermal Engineering: Theory and Application, Abu Dhabi, UAE, 2009. p. 1-5.
5. Anand, K. Experimental *investigations on combustion, performance and emissions characteristics of neat karanji biodiesel and its methanol blend in a diesel engine*. Biomass and Bioenergy, 2011. **35**: p. 533-541.

6. Ndayishimiye P, Tazerout M. Use of palm oil-based biofuel in the internal combustion engines: Performance and emissions characteristics. Energy 2011. **36**: 1790-1796.



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.