Available online at www.academicpaper.org
Academic @ Paper
ISSN 2146-9067
International Journal of Automotive Engineering and Technologies
Special Issue 1, pp. 38 – 43, 2017

International Journal of Automotive Engineering and Technologies
http://www.academicpaper.org/index.php/IJAET

Original Research Article

An Investigation of Diesel-Biodiesel-Methanol Blends in terms of Performance and Emissions in a Diesel Engine

Ali Keskin[1*], Abdulkadir Yaşar[2]

[1*] Department of Automotive Engineering, Engineering and Architecture Faculty, Cukurova University, Adana, Turkey
[2] Department of Mechanical Engineering, Ceyhan Engineering Faculty, Cukurova University, Adana, Turkey

Abstract

The aim of the study is to determine the effect of small percentage of methanol into diesel-biodiesel fuel blends. In this context, standard diesel fuel (50%)-biodiesel (47%)-methanol (3%) and diesel (50%)-biodiesel (44%)-methanol (6%) blends were tested in a single cylinder, direct injection diesel engine at full load conditions. Performance and exhaust emission characteristics of engine fueled with biodiesel-methanol-diesel were compared to the conventional diesel fuel. Break power of the test fuel blends showed a decreasing trend due to their lower heating value. For all blend fuels, brake specific fuel consumption (BSFC) values increased as compared diesel fuel. Also, the study indicated that methanol percentage of 6% in test fuels is more effective than that of 3% in terms of reducing of the NO_x and CO emissions.

Key Words: Diesel, Biodiesel, Methanol, Engine Performance, Emissions

Note:
This paper was presented at the 1st International Congress of the Mediterranean Science and Engineering (IMSEC'16), which was held in Adana, 26-28 October 2016.
This paper was reviewed by IMSEC'16 scientific committee.

*Corresponding author:
E-mail: akeskin@cu.edu.tr

1. Introduction

Recently, many countries are making effort to substitute their conventional energy sources with renewable and sustainable ones [1]. One of them is biodiesel which has no aromatics, almost no sulfur, and contains10–11% oxygen by weight and provides higher Cetane number leading to ignition quality when blended in the petroleum diesel. Furthermore, these characteristics of biodiesel decrease the emissions of carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM) in the exhaust gas in comparison with diesel fuel [2]. However, biodiesel exhibits some disadvantages in terms of higher cost, lower heating value, higher viscosity and higher NO_x emissions when compared to conventional diesel. Researchers are looking for some additives that can improve the fuel properties and NO_x emissions to overcome the shortcomings of biodiesel use. There are a few alternatives that decrease the density and viscosity of biodiesel. One of them is an alcohol based fuel additives. Methanol is an alcohol based additive having approximately 50% higher oxygen as compared to diesel fuel which contributes complete combustion. However, methanol has lower calorific value and Cetane number in comparison with diesel fuel [3].

Alcohols as additives to biodiesel–diesel blends were investigated in terms of performance and emission characteristics in diesel engines by many authors [4-6]. It was shown that the use of alcohol blends up to 20% does not usually require any important modification [1]. It was also reported alcohol–biodiesel blends with 10% and 15% alcohol concentration increase HC and CO emissions while 5% alcohol addition to biodiesel fuels decrease these emissions [5]. Yilmaz and Vigil [6] demonstrated that biodiesel– ethanol and biodiesel–methanol blends reduce NO_x and PM emissions while methanol is more effective than ethanol to reduce those emissions. Objective of this study is to investigate the effect of small proportion of methanol as a fuel additive in B47 and B44 fuel blends on engine performance and balance the high lubricity of soybean oil methyl ester with the low lubricity of alcohols.

2. Material and Method

Preparing test fuels

The fuel properties of the test fuels were determined at Cukurova University Fuel Analysis Laboratory. Soybean oil is used as a raw material for biodiesel production. Soybean Methyl Ester was produced via the transesterification method [3]. Methanol were supplied by Merch Ltd. Instruments for analyzing of the test fuels were utilized as follows; Tanaka AKV-202 Auto Kinematic Viscosity test for measuring the viscosity; Tanaka AFP-102 for cold filter plugging point device for CFPP; Zeltex ZX 440 NIR petroleum analyzer with an accuracy of ±0.5 device to analyze Cetane number; Kyoto electronics DA-130 for density measurement, IKA Werke C2000 bomb calorimeter for determination of calorific value and Tanaka APM-7 for flash point determination.

Engine test system

A single cylinder, direct injection diesel engine was used as a test engine. The engine specifications were shown in Table 1. The test fuel was tested at full load conditions ranging from 1200 to 3000 rpm at the intervals of 200 rpm. Before initiating the tests, Sampling data were collected after the engine had been running for at least 30 min. For each combination of parameters, the experiments were performed three times and the results of the three repetitions were averaged. After each fuel test, the engine was operated for at least 30 min to consume the fuel which was left in the fuel system from the previous test. A hydraulic dynamometer was used so as to measure the torque and power values. Specifications of the hydraulic dynamometer are also given in Table 2. Measurement of smoke emission was executed with CAP 3200 determining of opacity of the exhaust gasses. The measurement accuracy and measurement capacity of the CAP 3200 test device is 0.01 m^{-1} and 0–10 m^{-1} for k factor, respectively.

Testo 350-S gas analyzer was used to measure exhaust gas emissions of CO and NO_x. Measurement accuracy of Testo 350-S is 1 ppm for CO and NO_x. Measurement capacity of the device for CO and NO_x is 0–10,000 ppm and 0–3,000 ppm, respectively.

Table 1. Engine specifications

Manufacturer/type	Antor Diesel 4 LD 640
Cylinders number	1
Swept volume	638 cc
Bore	95 mm
Stroke	90 mm
Compression ratio	17:1
Maximum speed	3000 rpm
Maximum power	13 HP
Maximum brake torque	43 Nm at 1800 rpm
Injection type	Direct injection
Cooling system	Air-cooled

Table 2. Technical specifications of hydraulic dynamometer

	Specifications
Maximum torque	1000 Nm
Maximum speed	7500 rpm
Load cell capacity	2500 N
Torque arm length	350 mm
Total weight	110 kgf

3. Results and Discussion

Test fuels

Various diesel-biodiesel-methanol blends were prepared with 50:47:3 and 50:44:6 ratios which are denoted as B47A3 and B44A6, respectively. As can be shown in Table 3, the properties of blend fuels are greatly affected by the concentration of biodiesel and alcohol in the blend fuels. It is clear that the biodiesel and its alcohol blend fuels have similar characteristics as compared to conventional diesel fuel. The viscosity of biodiesel-alcohol blends fuels is higher than that of diesel fuel due to high biodiesel concentration in the blends. However, when alcohol additive reaches 6% by volume diluted into biodiesel fuel. Density values are decreased depending on the alcohol concentration in the blend fuels. The Cetane number is found to increase when the percentage of biodiesel is increased. This is because the Cetane number of biodiesel depends on the distribution of fatty acids in the original oil or fat. The calorific values of B47A3 and B44A6 blend fuels are lower than that of diesel fuel. All fuel properties meet the standards (EN 590). Flash point values of the blend fuels are lower than that of mineral diesel fuel. This situation is more safety for storage and transportation of the fuels.

Table 3. Fuel properties

Fuel property / **Fuels**	**Density (20 ºC), kg/m^3**	**Cetane Number**	**Heating Value, MJ/kg**	**Kinematic Viscosity (40 ºC) mm^2/s**	**Flash Point, °C**
D	830	56.415	44.149	Mar.30	56.5
EN590	820−845	Min 51	-	2.0−4.5	Min 55
B100	884	57.256	39520	04.Haz	160
EN14214	860-900	Min 51	-	3.5-5.0	Min 120
A100	792	5	19.Ağu	0.59	11.Tem
B47A3	859	55.789	42.357	Nis.56	45
B44A6	853	54.231	42.179	Nis.34	42

Torque and power

The torque values of test fuels showed a decreasing trend as compared to diesel fuel as given in Figure 1. This statement is attributed to the lower energy level of the blend fuels. For all the test fuels, the maximum torque values were obtained at 1800 rpm. The maximum decreasing ratio of engine torque were observed to be 4.22% for B47A3 at 2000 rpm. However, torque curves of the engine with blend fuels showed no significant change when compared diesel fuel.

The variation of engine break power with test fuel blends as reference to diesel fuel is shown in Figure 2. As can be seen from the Table 3, biodiesel and methanol have lower heating value compared to diesel fuel. So, break power of the test fuel blends showed a decreasing trend due to their lower heating value as compared diesel fuel. Furthermore, the density of methanol caused a decrease in break power of test fuel blends. The maximum break power values of diesel, B47A3 and B44A6 were observed to be 11.802%, 11.746% and 11.028%, respectively at 3000 rpm. The maximum decreasing ratios were obtained to be 4.28% and 6.55% for B47A3 and B44A6, respectively.

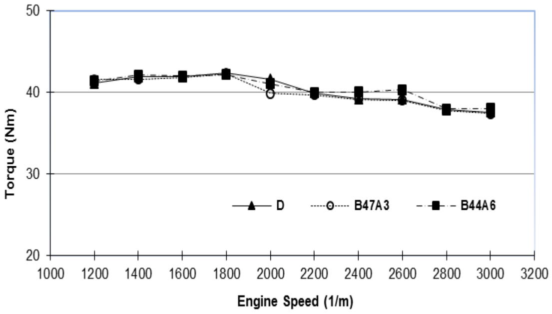

Figure 1. Variation of torque values versus engine speed

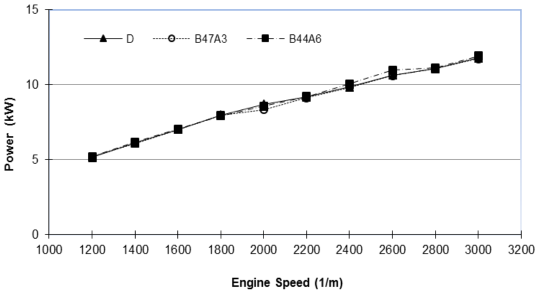

Figure 2. Variation of power values versus engine speed

Brake Specific Fuel Consumption

Variation of BSFC values are shown in Figure 3. Specific fuel consumption is one of the important parameters of an engine and is defined as the consumption per unit of power in a unit of time. According to diesel fuel, there is usually an increasing trend in BSFC values of the engine with the fuel blends because of the increasing biodiesel and methanol content. The maximum increasing ratio were found to be 5.23% for B47A3 and 5.911% of B47A6 at 1400 RPM. The average increases in BSFC are 2.38% and 3.19%, respectively. This results are good agreement with the studies done by the authors [7-9].

CO emissions

Influence of fuel blends on CO emissions as reference to conventional diesel fuel is shown in Figure 4. It was observed that addition of biodiesel and methanol into diesel fuel improved CO emission. This could be attributed to higher oxygen content and thus, enhanced the fuel air mixing process. Especially, CO emissions increased slightly at low engine speeds, while they decreased at high engine speeds. The maximum decreasing ratio is 56.46 for B44A6 fuel at 2200 rpm. Average decreasing ratios for B47A3 and B44A6 fuels were obtained to be 23.78% and 21.04%, respectively. CO emission values of the test fuels didn't change significantly between 2400 and 3000 rpm.

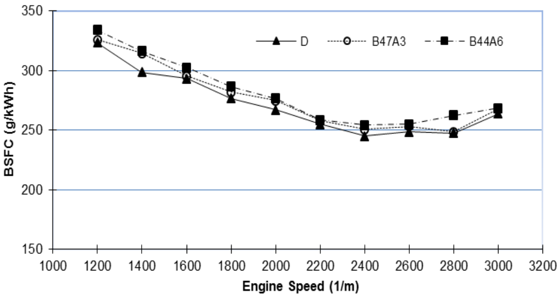

Figure 3. Variation of specific fuel consumption values at full load

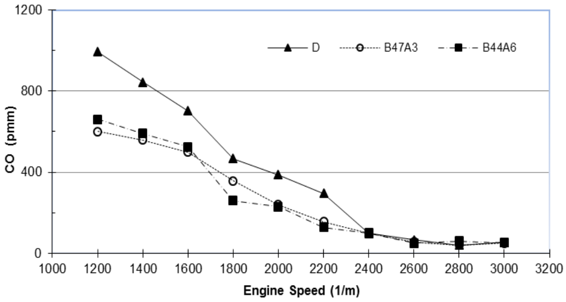

Figure 4. Variation of CO emissions at full load

NO_x emission

The NO_x forms by oxidation of atmospheric nitrogen at sufficiently high temperatures. Nitrogen formation is highly dependent on temperature and availability of oxygen. NO_x emission variation for test fuels were indicated in Figure 5. On average, NO_x emissions were increased for B47A3 and B44A6 test fuels as compared to diesel fuel. The average increasing ratios is 10.27% and 4.73% for B47A3 and B44A6, respectively. It was observed that the average increasing ratio of B44A6 was lower than that of B47A3 fuel. This is due to the fact that a low concentration of methanol in fuel blends (3%) increases the oxygen content of the fuel mixture leading to better combustion and thus, higher combustion temperature. When the methanol concentration increases (6%) the cooling effect of methanol becomes more effective which leads to a lower combustion temperature and a reduction of NO_x emission. This statement is in parallel with the studies performed by the authors [5, 6].

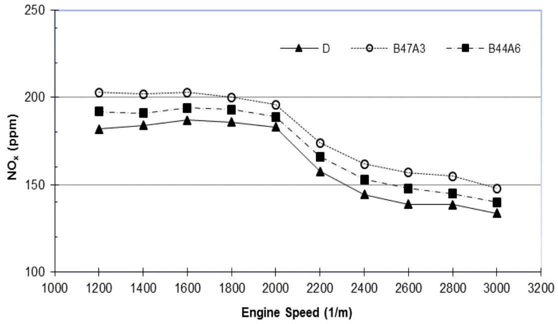

Figure 5. Variation of NO_x emissions at full load

Smoke emissions

Variation of smoke opacity values is shown in Figure 6. As can be seen from Figure 6, smoke emission values with B47A3 and B44A6 fuel decreased considerably as compared to mineral diesel fuel due to the higher oxygen content of test fuels. For all test fuels, the minimum smoke opacity values were obtained at 2400 rpm. The average reduction rates of B47A3 and B44A6 fuels were 25.46% at 2400 rpm and 20.87% at 2200 rpm, respectively.

4. Conclusions

In this experimental study, the influence of small proportion of methanol as a fuel additive in B47 and B44 fuel blends on performance and emissions in a diesel engine were investigated. Fuel properties of the fuel blends were also determined. The following conclusions can be summarized as follows;

- Break power of the test fuel blends showed a decreasing trend owing to their lower heating value when compared diesel fuel. Moreover, the low density of methanol resulted in a decrease in break power of test fuel blends.
- SFC values of the engine with fuel blends showed a decreasing trend due to the increase in methanol content as reference diesel fuel.
- Addition of biodiesel and methanol into diesel fuel improved CO emission because of the higher oxygen content of them.
- When the methanol concentration increased in the fuel blend, the cooling effect of methanol became more dominant leading to a lower combustion temperature and a reduction of NO_x emissions. Accordingly, alcohol additives improved the NO_x emission characteristics.
- Smoke emission values with B47A3 and B44A6 fuels decreased remarkably as compared to conventional diesel fuel.

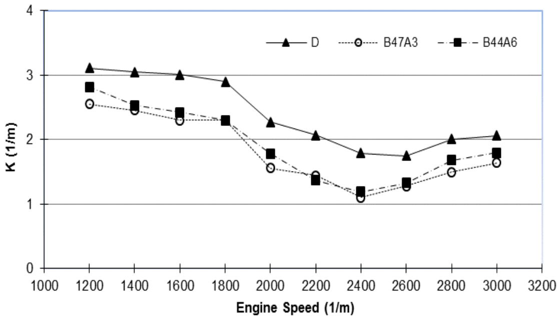

Figure 6. Variation of smoke opacity values at full load condition

5. References

[1] Karabektas, M., Hosoz, M., Performance and emission characteristics of a diesel engine using isobutanol–diesel fuel blends, Renewable Energy 34 (2009) 1554-1559.

[2] Tsai, J.H., Chen, S.J., Huang, K.L., Lin, W.Y., Lee, W.J., Lin, C.C., Hsieh, L.T., Chiu, J.Y., Kuo, W.C., Emissions from a generator fueled by blends of diesel, biodiesel, acetone, and isopropyl alcohol: Analyses of emitted PM, particulate carbon, and PAHs", Science of the Total Environment 466–467 (2014) 195–202.

[3] Keskin, A., Yasar, A., Resitoglu, I., Akar, M.A., Sugozu, I., The influence of diesel fuel-biodiesel-butanol blends on the performance and emission characteristics of a diesel engine,

Energy Source Part A, 35:1873-1881, 2013.

[4] Lapuerta, M., Contreras, R.G., Fernandez, J.C., and Dorado, M.P., Stability, Lubricity, Viscosity, and Cold-Flow Properties of Alcohol-Diesel Blends, Energy Fuels 2010, 24, 4497–4502.

[5] Yilmaz, N., “Performance and emission characteristics of a diesel engine fuelled with biodiesel–ethanol and biodiesel–methanol blends at elevated air temperatures”, Fuel 94 (2012) 440–443.

[6] Yilmaz, N., and Vigil, F.M., “Potential use of a blend of diesel, biodiesel, alcohols and vegetable oil in compression ignition engines”, Fuel 124 (2014) 168–172.

[7] Yasin, M.H.M., Yusaf, T., Mamat, R., Yusop, A.F., “Characterization of a diesel engine operating with a small proportion of methanol as a fuel additive in biodiesel blend”, Applied Energy 114 (2014) 865–873.

[8] Yasin, M.H.M., Mamat, R., Yusop, A.F., Rahim, R., Aziz, A., and Shah, L.A., Fuel Physical Characteristics of Biodiesel Blend Fuels with Alcohol as Additives, Procedia Engineering 53 (2013) 701 – 706.

[9] Zhu, L., Cheung, C., Zhang, W., Huang, Z., Combustion, performance and emission characteristics of a DI diesel engine fueled with ethanol–biodiesel blends. Fuel2011; 90:1743–50.