

Comparison of Performance and Emission Characteristics of Biofuel and Diesel Fired Engine

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ABSTRACT

Biodiesel is playing an important role in transport sector as a substitute for petroleum fuels. The present study diagnoses the use of phenolic biofuel blends namely, cardanol at higher fuel injection pressure on the performance and exhaust emissions of a direct injection, 4-stroke, single cylinder compression ignition engine. In this study, biofuel blends used with three different percentage composition of cardanol such as B10M10, B20M10 and B30M10. The results are compared with base line diesel operation at 180 bar standard injection pressure. The experimental results show better engine performance and exhaust emission characteristics for the biofuel blends at 220 bar injection pressure. Biofuel blend B20M10 gives better performance and emission results when compared to B30M10, and there is not much difference in the results when compared to B10M10. B20M10 blend gives slightly lower brake thermal efficiency (BTE), sharp reduction in carbon monoxide (CO), unburnt hydrocarbon (HC) and smoke emissions and drastic increase in oxides of nitrogen emissions (NO_x), when compared to baseline diesel operation.

Keywords: Biofuel, Cardanol, emission, injection pressure, nitrogen oxide, performance.

INTRODUCTION

Diesel engines are widely used in transport and industrial sector because of their higher efficiency and performance (higher torque at lower RPM). However, an increased use of diesel engines in vehicle applications causes a degradation of the environment due to exhaust gas emissions. There is an extensive research work being carried out all over the world

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to replace petro diesel with biofuels. Biofuels are renewable, environmental friendly and now replacing the petroleum based fuels. The research reports of various investigations have shown that the biofuel fuelled engines work with minimum exhaust emissions. Pure or neat biofuels are not suitable because of their higher density and viscosity.

Such higher properties will cause atomization and mixing with air when they are injected into the combustion chamber. The viscosity and density can be reduced by blending biofuels with diesel fuel at different compositions. It is found that the biofuel-diesel blends result in improved efficiency and reduced emissions over neat biofuel.

Nomenclature

B10M10	10% cardanol + 80% diesel + 10% methanol
B20M10	20% cardanol + 70% diesel + 10% methanol
B30M10	30% cardanol + 60% diesel + 10% methanol
bTDC	before top dead centre
BTE	brake thermal efficiency (%)
CO	carbon monoxide (%)
CNSL	cashew nut shell liquid
DI	direct injection
HC	hydrocarbon (ppm)
NOx	oxides of nitrogen (ppm)
ppm	parts per million
RPM	revolution per minute
HC	hydrocarbon (ppm)

The combustion property of biodiesel can be improved by adding additives. The exhaust emissions can be minimized by using pre combustion treatment and post combustion treatment. Many research papers have reported that increased NOx is obtained with the use of biofuel [1, 2]. Some researchers found less NOx emission for biofuel over diesel fuel [3]. The exhaust emissions can be decreased to a tolerable level by various methods such as changing the engine operating parameters, fuel compositions, pre-combustion and post combustion treatments. Changing the engine operating parameters are most economical method and widely used in compression ignition engines. Injecting the fuel at higher pressure into the combustion chamber will helps to reduce the emissions without compromising with the efficiency. Effect of injection pressure has been studied in all over the world and reported for various biofuel

blends with favourable results. Jindal et al. [4] have reported lower HC, NO_x and smoke emissions and higher CO emission at higher injection pressure. They also observed higher exhaust gas temperature at that injection pressure. Sayin and Gumus [5] conducted engine experiments and reported better results for engine performance at higher fuel injection conditions. The only one important drawback of increasing the fuel injection pressure is higher NO_x emission due to increased combustion temperature.

Cardanol as an alternative fuel

Cardanol is derived from Cashew Nut Shell Liquid (CNSL). CNSL is one of the sources of naturally occurring phenols. It is obtained from the shell of a cashew nut. Research findings of various investigators have been focused a positive direction to use the CNSL based biodiesel blends as an alternative fuel for compression ignition (CI) engines [6-8]. In the present study, B10M10, B20M10 and B30M10 blends are used to investigate the performance and emissions of a diesel engine at 220 bar injection pressure and 29.5 degree bTDC advanced injection timing. The results are discussed with baseline diesel at standard injection conditions of 180 bar injection pressure and 27.5 degree bTDC injection timing.

EXPERIMENTAL SETUP

The experiments are carried out on a computerized Kirloskar diesel engine test rig as shown in Figure 1. The detailed specification of the test setup used for the experimentation is given in Table 1. The engine is loaded by using an eddy current dynamometer loading unit. A control panel is used to interface the engine and the loading unit, which is linked to a computer. A speed sensor is used to measure the crank angle and speed of the engine. An analog to digital converter (ADC) card PCI-1050 is equipped on the motherboard of the computer to obtain the engine performance results.

RESULTS AND DISCUSSION

Experiments are conducted on the engine at four load conditions (25, 50, 75 and 100%) to study the effect of higher injection pressure on

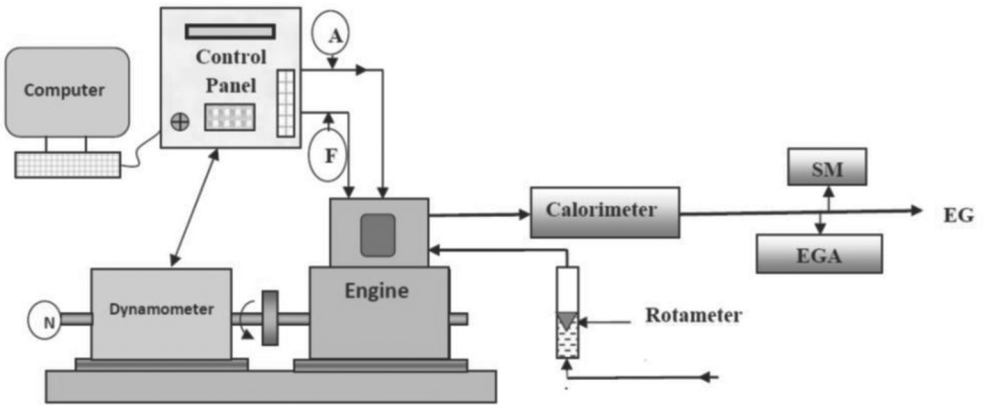


Figure 1. Schematic diagram of the experimental test rig
*(N- RPM sensor; EG- Exhaust gas; EGA-Exhaust gas analyzer;
 SM-Smoke meter; F-Fuel; A-Air flow)*

Table 1: Test Engine Specifications

Engine Type	Kirloskar, TV 1, four-stroke, single cylinder, water cooled, CI engine
Rated power output (kW)	5.2
Speed	1500 RPM
Compression ratio	17.5 :1
Stroke length (mm)	110
Bore diameter (mm)	87.5
Dynamometer Type	Eddy Current, with loading unit

the engine performance and emissions of the test engine setup. The results are discussed with the base line diesel at the same loading operation conditions at standard fuel injection conditions. B10M10, B20M10, and B30M10 are used as the fuel blend to analyze the performance like brake thermal efficiency and emissions such as NO_x, CO, HC and smoke.

Brake Thermal Efficiency (BTE)

Figure 2 shows the variation of BTE verses engine loads for all fuel variants. The BTE increases with increasing engine load for all fuels, and maximum BTE obtained for 75% load. From the figure it is observed that the BTE of the cardanol blended fuels decreases as the percentage volume of cardanol is increased. The BTE of diesel is 30.25%, whereas it is 30.3%, 30%, and 28.6% for B10M10, B20M10, and B30M10 blends, respectively. As the injection pressure increased, the BTE increases due to improved atomization and mixing of the fuel particles which intern reduces the ignition delay period.

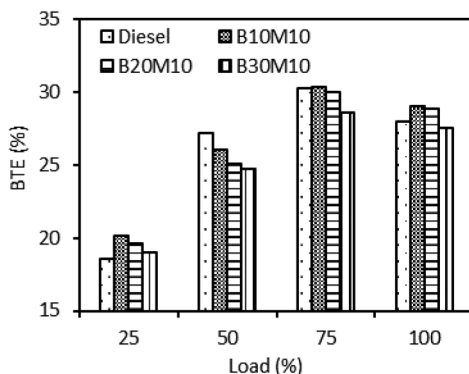


Figure 2. Variation of BTE for different fuel blends

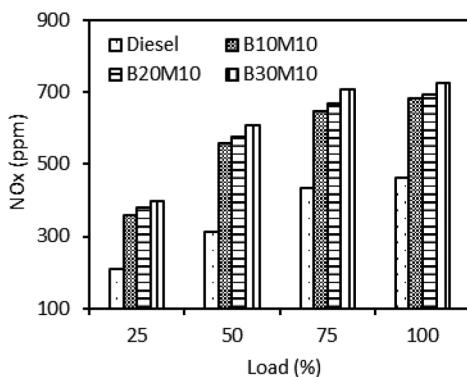


Figure 3. Variation of NOx emission for different fuel blends

NOx Emission

Figure 3 depicts the variation of NOx emission verses load for fuel variants. As the load increased, the NOx emission increases, and maximum NOx is obtained at 100% load. The NOx of diesel is 464 ppm at 100% load, whereas it is 684, 693, and 727 ppm for B10M10, B20M10, and B30M10 blends, respectively, at the same load. The NOx level increases as the cardanol bio-fuel percentage is increased from B10M10 to B30M10. It is observed that 47%, 49%, and 56.8% higher NOx is obtained respectively for B10M10, B20M10, and B30M10 blends compared to diesel. At 29.5 degree bTDC advanced injection timing, the NOx level increases as the cardanol volume percentage is increased from 10% to 30%. Higher NOx emission may be due various reasons such as improved fuel jet penetration, improved combustion of biofuel due to oxygen content in its chemical structure, and higher combustion temperature.

CO emission

Figure 4 depicts the variation of CO verses load for all fuel variants. Carbon monoxide emission increases as the engine load is increased due to fuel rich mixture requirement during full load conditions. The CO of diesel is 0.53% at full load, whereas it is 0.45%, 0.47%, and 0.7% for B10M10, B20M10, and B30M10 blends, respectively, at the same load. When compared to diesel, B30M10 blend has higher CO emission, B10M10 and B20M10 blends have lower CO emission. It can be seen from the figure that 15% and 11% less CO emission respectively obtained for B10M10 and B20M10 fuels, respectively, compared to diesel. But 32% more CO emission obtained for B30M10 blend due to higher viscosity of the cardanol biofuel. Lower blends of cardanol give lower CO emissions as it undergoes complete combustion at higher fuel injection pressure.

HC emissions

The variation of HC emission verses loads for different fuel variants is depicted in Figure 5. As the load is increased the unburnt hydrocarbon emission increases and maximum HC emission is obtained for 100% load condition. Moreover, the HC emission increases as the biofuel volume percentage composition is increased in the fuel blend and maximum HC emission obtained for B30M10. It is observed from the figure that 23%, 6.6% less HC emission obtained for B10M10 and B20M10 fuels, respectively, compared to diesel at 100% load. A drastic increase in HC emissions observed for B30M10 blend when compared to the baseline

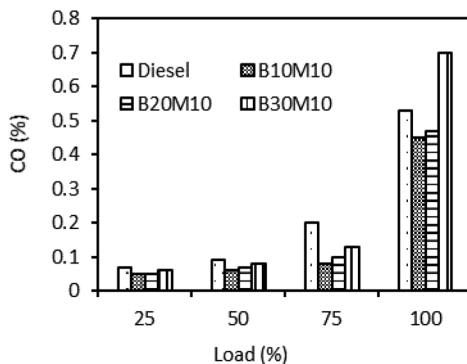


Figure 4. Variation of CO emission for different fuel blends

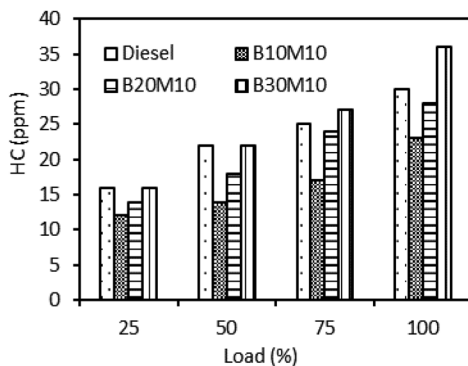


Figure 5. Variation of HC emission for different fuel blends

operation. As the fuel injection timing advanced to 29.5 degree, B10M10 and B20M10 give lower HC emission, since more time is available for the combustion. A marginal variation in HC emission is observed for B10M10 and B20M10 at all load conditions. In addition, the higher cetane number of biofuel reduces the delay period, which helps to reduce emission.

Smoke emissions

Figure 6 shows the smoke emission variation verses load. It is clear from the figure that the smoke emission tend to increase for biofuel

blends compared to diesel for all loading conditions. It is also observed from the figure, that 5.5%, 0% less smoke is obtained for B10M10 and B20M10 fuels, respectively, compared to diesel at full load condition. When the percentage composition of cardanol is increased to 30%, the smoke emissions increases to 14% when compared to the baseline diesel operation. The smoke emission is mainly due to the higher viscosity of the biofuel blend and this results incomplete combustion causing the formation of smoke.

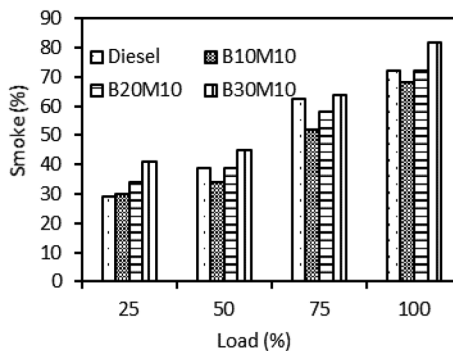


Figure 6. Variation of smoke emission for different fuel blends

CONCLUSIONS

From the above findings the following conclusions can be made:

1. B10M10 and B20M10 blends gives higher brake thermal efficiency compared to base line diesel operation.
2. Due to advanced injection timing and increased injection pressure, higher NO_x emissions are obtained for biofuel blends.
3. CO and HC emissions are lower for B10M10 and B20M10 compared to diesel but B30M10 has higher CO and HC emissions.
4. The smoke emission is minimum for B10M10 and B20M10 compared to diesel operation.

From these research investigations, it can be concluded that the fuel blends B10M10 and B20M10 have comparatively similar performance and emission values when compared to diesel. B20M10 fuel blend shows comparatively similar result trend as that of standard diesel operations.

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