EXHAUST GAS ANALYSIS OF DIESEL - CADOBA FARINOSA FORSKK BIO-ETHANOL BLENDED FUEL SAMPLES RUNNING ON COMPRESSION IGNITION ENGINE

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Abstract

The world is facing declining liquid fuel reserves at a time when energy demand is exploding. As the supply decreases and costs rise, everyone will be forced to adopt the alternative energy resources. In order to achieve a secure and stable energy supply that does not cause environmental damage, renewable energy sources must be explored and promising technologies should be developed. This study investigates the effects of exhaust gases of diesel-Cadoba farinosa forskk bio-ethanol blended fuel samples run on a compression ignition engine. The test fuels were prepared; BDE2 (97% Diesel and 2% bio-ethanol volumetric proportion), BDE4, BDE6, BDE8 and BDE10 with 1% biodiesel (palm oil methyl esters) was maintained throughout to prevent phase separation of the ethanol and diesel respectively. The engine performance and exhaust gas analysis were also conducted to investigate the effect of bio-ethanol as diesel fuel extender, with a TD110-115 single-cylinder, four-stroke and air-cooled, compression ignition engine test rig, under different loading conditions, and incorporated with an SV-5Q automobile exhaust gas analyzer was used to monitor and measure the concentration of gaseous emissions, such as; exhaust gas temperature (EGT), carbon dioxide (CO₂), carbon monoxide (CO), and unburned hydrocarbon (HC) from the engine tail pipe. Results of the test revealed an appreciable increase in exhaust gas temperature of 16.66% due to the rise in cylinder pressure and temperature respectively. An appreciable decrease in HC, CO and CO₂ (15.7%, 37.5% and 15% respectively) emissions was recorded for all blended fuel samples with the exception of diesel. While, the least CO and CO₂ emission levels were observed for BDE10 fuel samples. On the account of its satisfactory engine performance behavior, fuel conservation advantages, and inherent greenhouse gas mitigation potentials, the candidacy of Cadoba Farinosa Forskk bio-ethanol and diesel blends, offers the promise of a prospective fuel for compression ignition engines.

Keywords: Emission, compression ignition engine, unburned hydrocarbon, carbon monoxide, carbon dioxide.

1.0 Introduction

All internal combustion engines depend on the combustion of a chemical fuel typically with oxygen from air. It produces heat steam, carbon-di-oxide and other chemicals at a very high temperature. The most common modern fuels are derived from fossils fuels like gasoline, petroleum gas and the propane. These engines are designed for gasoline use and the diesel engines run with air mixed with gas and a pilot diesel fuel injection. For this, ethanol and a form of diesel fuel produced from crops can also be used. Ethanol is considered to be one of the most promising alternative renewable fuels. Ethanol can be fermented and distilled from sugarcane and
grain, cellulosic materials such as; wood, agricultural solid wastes, coal, sweet sorghum etc. and also it has the potential to reduce CO, HC, NOx, and particulates emissions. Ethanol has some advantages over diesel and gasoline, such as; high octane number and flame speed, high latent heat of vaporization thereby higher volumetric efficiency. It contains 35% oxygen that helps in the complete combustion of fuel, and thus reduces harmful tailpipe emissions. Although having these advantages, due to limitation in technology, economic and regional considerations ethanol as a fuel still is not used extensively. Judging from an environmental standpoint, ethanol diesel blend is better than pure diesel on account of its renewability and lesser toxicity (Sayin, 2018). Several studies on the performance and emission characteristics of compression ignition engines, fueled with pure diesel and blended with ethanol, have been performed and are reported in the literature. De-gang Li, et al. (2005) described that the purpose of this project is to find the optimum percentage of ethanol that gives simultaneously better performance and lower emissions. The experiments were conducted on a water-cooled single-cylinder Direct Injection (DI) diesel engine using 0% (neat diesel fuel), 5% (E5–D), 10% (E10–D), 15% (E15–D), and 20% (E20–D) ethanol–diesel blended fuels. With the same rated power for different blended fuels and pure diesel fuel, the engine performance parameters (including power, torque, fuel consumption, and exhaust temperature) and exhaust emissions [Bosch smoke number, CO, NOx, total hydrocarbon (THC)] were measured. The results indicate that: the brake specific fuel consumption and brake thermal efficiency increased with an increase of ethanol contents in the blended fuel at overall operating conditions; smoke emissions decreased with ethanol–diesel blended fuel, especially with E10–D and E15–D. CO and NOx emissions reduced for ethanol–diesel blends, but THC increased significantly when compared to neat diesel fuel. Arunkumar M., et al. (2014) they described that the use of diesel with ethanol and caster seed oil (biofuels) blends in four stroke diesel engines. For these mixtures brake thermal efficiency, BSFC and combustion characteristic are calculated. The gas emissions of NOx, CO, CO2, and HC are also measured. A single cylinder, 4-stroke, water cooled diesel engine coupled with electrical dynamometer, data acquisition system. At suction side, anti-pulsating drum is attached to measure air inflow quantity. At exhaust side, exhaust gas thermometer, gas analyzer, and combustion analyzer for combustion behavior of engine. Fuel proportions used are 5% caster oil+ 5% ethanol+ 90% diesel (C5E5), 10% caster oil+ 5% ethanol+ 85% diesel (C10E5), 15% caster oil+ 5% ethanol+ 80% diesel (C15E5). AVL smoke meter is filter type smoke meter for measuring the soot content in the exhaust of diesel. From the observation it is conclude that C15E5 have lower value of NO, unburnt hydrocarbon than diesel. The exhaust temperature and brake thermal efficiency for C15E5 is less comparing to C10E5 and pure diesel. Therefore 80% diesel, 15% caster oil and 5% ethanol give us optimum values of performance and emission characteristic. H. B. Parikh, et al. (2013) they described the use of ethanol/diesel mixtures increases the ignition lag time due to low cetane number of ethanol. A single cylinder, 4 stroke, water cooled CI engine manufactured by Rocket Eng. Corporation Ltd. was used in the investigation. The engine was run about 30 min. till to reach steady state. The fuel proportions are 80% diesel+15% biodiesel+5% ethanol D80B15E5, 70% diesel+20% biodiesel+10% ethanol D70B20E10, 70% diesel+25% biodiesel+5% ethanol D70B25E5. The observations recorded were brake load reading, engine
speed, exhaust gas temperature, cooling water inlet and outlet temperature and also CO, HC, emission measured. It is conclude that decrease in BSFC with increase in Brake Power. Due to higher density, lower calorific value of ethanol, brake thermal efficiency of these fuel blends in sequence of D80B15E5, D70B20E10 & D70B25E5 are observed slightly higher for these blends in same sequence.

Hiregoudar Yerrennagoudaru, et al. (2014) they analyze the fuel consumption and emission characteristics of a twin cylinder diesel engine using biofuels and compared with ordinary diesel. They study the brake thermal efficiency, BSFC, and emission at zero load and full load with biofuels. The fuel proportion is 30% ethanol + 70% linseed oil. Engine setup consists of twin cylinder diesel engine, 4 stroke, forced cooling system. Also, multi gas analyzer, monitoring kit for PM for performance and emission analysis. Injection timing is 27 BTDC (static), the opening pressure of nozzle set at 170 bar and speed at 1500 rpm. The observations are, at different loads the SFC of biofuel is more than diesel. Because results lower energy substitute biofuel thus engine respond to load. From the analysis and graph the biofuel shows better performance than diesel. Decrease in emission parameter and increase in performance characteristic. Hence, it is concluded that biofuel can be used as substitute for diesel.

Alireza Shirneshan (2013) they described that a test was applied in which an engine fueled with diesel and four different blends of diesel and biodiesel made from waste frying oil. The experiments were conducted on 4 cylinder, 4 strokes, and turbocharged direct injection diesel engine. The test engine was coupled to a hydraulic dynamometer providing a maximum engine power of 110 kW with +0.1 kW of uncertainty to control speed and load. Inductive pickup speed sensor used to measure the speed of the engine. Waste frying oil methyl ester was blended with diesel fuel in 0%, 20%, 40%, 60%, 80% proportions by volume. All fuels were tested at 1800 rpm and four engine partial loads (25%, 40%, 65%, and 80%). From the observation they conclude that biodiesel blends emit very low amount of CO2 compared to diesel. After addition of biodiesel in blends HC & CO emission decreases due to enrichment of the fuel. But NOx emission increases due to higher combustion temperature

Xiaoyan Shi, et al. (2006) have described an oxygenated diesel fuel blends have a potential to reduce the emission of particulate matter (PM) and to be an alternative to diesel fuel. This paper describes the emission characteristics of three compounds oxygenated diesel fuel blend (BE-diesel), on a Cummins-4B diesel engine. BE-diesel is a new form of oxygenated diesel fuel blends consisted of ethanol, methyl soyate and petroleum diesel fuel. The blend ratio used in this study was 5:20:75 (ethanol: methyl soyate: diesel fuel) by volume. The results from the operation of diesel engine with BE-diesel showed a significant reduction in PM emissions and 2%–14% increase of NOx emissions. The change of CO emission was not conclusive and depended on operating conditions. Total hydrocarbon (THC) from BE-diesel was lower than that from diesel fuel under most tested conditions. Formaldehyde, acetaldehyde, propionaldehyde and acetone in the exhaust were measured, and the results indicated that use of BE-diesel led to a slight increase of acetaldehyde, propionaldehyde and acetone emissions. A small amount of ethanol was also detected in the exhaust from burning BE-diesel. Due to stringent emission norms through different international protocols, environmental impacts of any alternative fuel to be used in Internal Combustion (I.C) engines should be evaluated first. Most of the emissions from the engines are carcinogens,
and are harmful to the environment as well as human health, and hence, the evaluation of exhaust gases analyses (CO2, CO and HC) arising from the combustion of Diesel-
*Cadoba Farinosa Forsk* bio-ethanol blended fuel samples run on a compression ignition engine, forms the core objectives of this research.

### 2.0 Materials and Methods

#### 2.1 Experimental Set-Up

The engine employed in the study is a TD110-TD115 test rig Diesel engine. The engine technical characteristics are shown in Table 1.

<table>
<thead>
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<th>Type</th>
<th>Single cylinder, four-stroke, air-cooled</th>
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<tr>
<td>Bore * Stroke</td>
<td>65 mm x 70 mm</td>
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<tr>
<td>Brake power</td>
<td>2.43Kw</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500rpm</td>
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<td>Manual cranking</td>
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<tr>
<td>Compression ratio</td>
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<tr>
<td>Net weight</td>
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<td>TQ Educational Training Ltd</td>
</tr>
<tr>
<td>Model</td>
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</table>

**Table 1. Technical specifications of engine test rig**

At the test rig (Figure 1), A hydraulic dynamometer was coupled to the engine for torque measurement. Experiments were conducted with blended fuel samples; BDE2 (97% Diesel and 2% bio-ethanol volumetric proportion), BDE4, BDE6, BDE8 and BDE10, and with 1% biodiesel (palm oil methyl esters) was maintained throughout to prevent phase separation of the ethanol and diesel respectively. The volumetric fuel consumption of the engine at each operating point was measured by means of a simple but accurate device, specifically designed and built in-house (a graduated burette with check valves). The time taken by the engine to consume 8 ml of each fuel sample was recorded.

AVL Di-Gas 4000 gas analyzer (Figure 2) was used to measure exhaust gas temperature (EGT), concentration of gaseous emissions for unburned hydrocarbon (UHC), carbon monoxide (CO), carbon dioxide (CO2) to evaluate the behavior of the Compression ignition (C.I.) engine. The results obtained from the emission analyses were tabulated and necessary graphs were plotted.

#### 3.0 Results and Discussion

#### 3.1 Exhaust temperature for all the fuel samples

Figure 3 shows the variation of exhaust gas temperature with load for various blends and diesel. The results show that the exhaust gas temperature increases with increase in load for all blends.
Figure 3: Variation of exhaust temperature for the Diesel and the blends with increase in load.

At all loads, diesel was found to exhibit the lowest temperature, and the temperatures for various blends show an upward trend with increasing concentration of bioethanol in the blends. This could be due to increased heat loss of the higher blends, which are also evident from their lower brake thermal efficiencies as compared to diesel. The mean temperature increased linearly from 282 °C at 500 g load to 326 °C under 3000 g load condition for diesel with an average increase of 16.66% for every 100% increase in load. This increase in exhaust gas temperature with load is obvious because more amount of fuel was required in the engine to generate that extra power needed to take up additional loading. Biodiesel contains oxygen which enables the combustion process, and hence the exhaust gas temperatures are higher. Moreover, the engine being air-cooled runs hotter, and this resulted in higher exhaust gas temperatures. The higher amount of heat release may occur in the latter part of the power stroke, and this may result in lower time for heat dissipation and higher exhaust gas temperatures (Agarwal, 2017).

3.2 Carbon dioxide emission for all the samples

Figure 4 depicts the emission concentration of CO\textsubscript{2} with respect to load for various fuel blends. The CO\textsubscript{2} emission decreases with increase in load for all blends, and BDE10 fuel sample has lower emission than other fuel samples under varying loading conditions. Also, CO\textsubscript{2} emission levels are lower than that of all tested fuel samples than diesel. In general, biodiesel has a low carbon and lower elemental carbon to hydrogen ratio than diesel fuel (Raheman and Phadatare, 2014).

3.3 Carbon monoxide (CO) emission for fuel samples.

The variation of CO emission with load is shown in Figure 5. It was observed that the engine emits more CO for diesel under all load conditions for the blended samples under study. The percentage variation of carbon monoxide for the various blends is much less when compared with the baseline diesel fuel sample. These lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to diesel fuel sample (Karabektas, Ergen and Hosoz, 2018).
Some of the CO produced during the combustion of biodiesel might have converted to CO$_2$ by taking up the extra oxygen molecule present in the biodiesel chain - biodiesel has up to 11% oxygen content (Alireza, 2013), and thus reduces CO formation during combustion. This trend was observed for all the fuel blends under study. CO emission increases as fuel–air ratio becomes more than stoichiometric value. It was observed that with the BDE10 blend, engine CO emission reduced by 37.5% at 500 g load compared to the CO emission with neat diesel fuel (He and Wang Jian, 2003).

### 3.4 Hydrocarbon (HC) Emission for all the Samples

Figure 6 shows the variation of HC emission with increasing load for all fuels blends, it is observed that HC emissions of the various blends were lower for engine loads ranging from 500 g to 2500 g, when compared with the diesel fuel. This could be attributed to longer ignition delay, the accumulation of fuel in THE combustion chamber could be responsible for lower HC emission (Agarwal, 2017).

**Conclusion**

The following conclusion could be drawn from the study;

(i) The exhaust temperature increased linearly from 282°C at 500 g load to 326°C at 3000 g load condition for diesel with an average increase of 16.66% with every 100% increase in load.

(ii) The CO$_2$ emission increases with increase in load for all blends. The BDE10 fuel samples have lower emission than other fuels at all load levels which amount to 15% decrease by volume for every 1000 g.

(iii) CO emission was lower in blended fuel samples than diesel fuel samples, and decreases with increase in load. The lowest value obtained for CO emission was with BDE10 fuel samples decreases of almost 37.5% by volume.

(iv) Hydrocarbon emission decreased with increase in percentage bioethanol in the blend and decreased with increase load until 2500 g load where it showed an increase value. HC emission in all blends are lower than that of diesel and the least value was obtained BDE10 blends with decrease of about 15.7% by volume.
REFERENCES


