Experimental Analysis of DMM and 2-EEA Diesel Fuel Additives for Use in Direct injection Compression Ignition Engines

M.P. Sudeshkumar¹, G. Devaradjane² & Vineeth John Vincent³

¹Alpha College of Engineering, ²Anna University
Email : mpsk1975@gmail.com¹, v.vineeth29@gmail.com³

Abstract – Due to limited sources of petroleum fuels, stringent emission norms and the growing danger of environmental pollution from these fuels, concerned efforts are underway in exploring alternative fuel for diesel engines. The addition of oxygenated additive to diesel fuel is one of the possible approaches for reducing this problem. The oxygen present in the fuel parts helps for better combustion. In this present work investigations are carried out to study the performance and emission characteristics of a diesel engine with two oxygenated fuel additives namely Dimethoxymethane (DMM) and 2-Ethoxyethyl acetate (2-EEA) to diesel fuel. The additives are added 6% by volume and the readings are observed. Reductions in emissions were realized with the addition of oxygenated blend to diesel fuel.

Keywords – Diesel, Oxygenates, performance and emissions.

I. INTRODUCTION

The diesel engine dominates the field of commercial transportation and agricultural machinery on account of its superior fuel efficiency. However they emit more emissions. The use of oxygenated fuels seems to be a promising solution towards reducing emissions in existing and future diesel engines. Oxygenated fuel is a chemical compound containing oxygen. It is used to help fuel burn more efficiently and cut down on some types of atmospheric pollution. Oxygenated fuels are characterized by the following molecular conditions of the fuels: molecular weights are low and the molecules have high hydrogen to carbon ratios and a low number of carbon to carbon bonds which lower the formation of solid carbon particulates, molecules contain oxygen which suppress the formation of soot, molecular bonds break up to radicals at reasonable activation energy which leads to high cetane numbers. The oxygenated blends usually enhance the combustion efficiency, burn rates and the ability to burn more fuel and these blends offer the reduction of exhaust emissions. Ren et al [1] were investigated combustion and emission characteristics of a DI diesel engine fuelled with diesel diglyme blends. Their results show that the ignition delay and the amount of heat release in the premixed combustion decrease with the increase of the oxygen mass fraction in the blends. The maximum mean gas temperature in the cylinder increases, smoke concentration decreases and NOx concentration shows a slight decrease or remains unchanged with the increase of oxygen mass fraction in the blends. Moghaddam et al [2] studied experimentally the exhaust emission of compression ignition engine for sole diesel and nitrogenated additives. They observed that the addition of nitrogenated additives increased brake thermal efficiency. The smoke emission decreased at the maximum torque speed. Zhu et al [3] studied combustion, performance and emissions for a DI diesel engine fueled with Dimethoxymethane blends. Results showed that Brake specific fuel consumption is higher and thermal efficiency increases a little. Smoke and CO emission decrease and NOx remains almost changed. Srinivasan et al [4] investigated the performance and emission characteristics of two oxygenate 2-Ethoxy ethyl acetate and 2-Butoxy ethanol with three different blends. They observed that a considerable reduction of smoke carbon monoxide and hydrocarbon is obtained and nitrogen oxide emissions are increased when the oxygen content is increased from 5% to 15%. Boot et al [5] studied different blends of low-sulfur diesel fuel with different types of oxygenate. The results confirm the importance of oxygen mass fraction of the fuel blend, but at the same time illustrate the effect of chemical structure. Chen et al [6] investigated the effect of fuel oxygen on diesel emissions and performance. Authors blended ethanol and biodiesel to diesel fuel. They observed that the brake specific fuel consumption, NOx and CO emissions were increased. HC emissions were reduced. Sundarraj et al [7] investigated a stable ethanol-diesel blended fuel with 10% 1,4 dioxane additive to generate the combustion, performance and
emission data for evaluation on a diesel engine. Drastic reduction in smoke density was observed. NOx emissions were found to be higher for coated engines. Oxygen enriched fuel increased the peak pressure and rate of pressure rise with increase in ethanol ratio and is still superior for coated engine. Yanfeng et al [8] conducted experiments with 2-methoxy ethyl acetate blends with diesel fuel. They observed that smoke density reduced by more than 50%. The emissions of CO and HC also decreased with an increase in MEA in the blends. The blends have almost no effects on NOx emissions and the thermal efficiency of the engine increases by 2%. Huang et al [9] investigated the combustion and emission characteristics of diesel-dimethyl carbonate blends in a diesel engine. They obtained satisfactory result for emission reduction. The objective of this study is to compare the performance of two oxygenated fuels and to find out the suitable additive for diesel engines.

II. EXPERIMENTAL SETUP

Engine tests were performed in a single cylinder, 4-stroke, naturally aspirated water cooled diesel engine with bowl type piston. The engine was operated at a constant speed of 1500 rpm. A complete description of the engine specifications are presented in Table 1. The engine was coupled to an eddy current dynamo meter. A fast data acquisition system was used to record the cylinder pressures obtained by the Kistler piezoelectric transducers.

Crank shaft angle was obtained from a crank angle encoder mounted on the crank shaft. Krypton exhaust gas analyzer was used to measure the emissions of CO, HC and NOx. Smoke meter was used to measure the smoke level. All the engine tests were carried out in the fair ambient conditions.

Table. I Engine Specifications

<table>
<thead>
<tr>
<th>Type of engine</th>
<th>Single cylinder, 4-stroke water cooled DI diesel engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore/stroke</td>
<td>102mm/118mm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17.5</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>200 bar</td>
</tr>
<tr>
<td>Injection timing</td>
<td>26° BTDC</td>
</tr>
<tr>
<td>Maximum power</td>
<td>10 HP</td>
</tr>
</tbody>
</table>

Experiments were carried out using diesel fuel and the corresponding results were obtained. The engine was then operated with 6% oxygenated blend. Fig. 1 Shows the layout of experimental setup. Three trials were recorded at each test point and the average of these was used to arrive various performance and emission characteristics.

III. RESULTS AND DISCUSSION

During the engine tests the following parameters were recorded at each operating conditions considered, in-cylinder pressure, exhaust gas emission, smoke and fuel consumption. The test standards followed for this research work are BIS: 10003-1981.

Table. II Properties of Fuel

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Diesel</th>
<th>DMM</th>
<th>2EEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>$C_mH_n$</td>
<td>$C_3H_8O_2$</td>
<td>$C_6H_{12}O_3$</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>0.826</td>
<td>0.86</td>
<td>0.97</td>
</tr>
<tr>
<td>Oxygen content (wt%)</td>
<td>-</td>
<td>42.1</td>
<td>16.7</td>
</tr>
<tr>
<td>Lower calorific Value (MJ/kg)</td>
<td>42</td>
<td>23.26</td>
<td>23.57</td>
</tr>
<tr>
<td>Cetane number</td>
<td>45</td>
<td>30</td>
<td>61</td>
</tr>
</tbody>
</table>

Fig. 1: Schematic layout of Experimental setup

The engine performance and exhaust emission characteristics of a direct injection diesel engine fuelled with oxygenated blend are investigated experimentally. Fig. 2 shows the comparison of cylinder pressure traces of diesel and oxygenated blend with respect to crank angle at 80% load condition. Cylinder pressure characterizes the ability of fuel to mix well with air and burn. The cylinder pressure changes because of cylinder volume change, combustion rate, heat transfer to the cylinder walls and flow in and out of crevice region. It can be observed that for the same speed and load the peak value of cylinder pressure is higher for both the oxygenates compared to diesel fuel. Peak pressures of 67 bar, 69 bar and 70 bar are recorded for diesel fuel, 6% DMM blend and 6% 2EEA blend respectively. 2-
EEA blend increases the peak value of cylinder pressure due to high cetane number compared to other blend and diesel fuel.

Fig. 2: Comparison of Cylinder pressure traces

Fig. 3 shows the comparison of Brake specific energy consumption between diesel and two oxygenated blend for different load conditions. The results revealed that initially with increasing brake mean effective pressure the brake specific energy consumption of oxygenates and diesel fuel was decreased and the minimum brake specific energy consumption is observed at 80% load and then tend to increase with further increase in brake mean effective pressure. Addition of Di methoxy methane and 2-ethoxy ethyl acetate blend to diesel fuel increases Brake specific energy consumption compared to diesel fuel at all loads. The increase in brake specific energy consumption for the oxygenates is due to lower calorific value of the blended fuels. 6% Di methoxy methane increases the specific fuel consumption by 15% at 80% load. The specific energy consumption of 2EEA blend is increased by about 20% at 80% load.

Fig. 3: Comparison of BSEC with BMEP

Fig. 4 shows the comparison of carbon monoxide emissions with respect to brake mean effective pressure. It is inferred from the results that carbon monoxide emission decreases as the specific energy consumption. 6% Di methoxy methane emits lower CO emissions compared to other oxygenate and diesel fuel. This is due to the oxygen content of blended fuel which makes better combustion resulting in reduced CO emission. 6% DMM decreases the CO emission by 16.6% and 6% 2EEA decreases the CO emission by 10% respectively.

Fig. 4: Comparison of CO emissions with BMEP

Figure 5 shows the comparison of hydrocarbon emissions with respect to brake mean effective pressure. Unburnt HC emissions consist of fuel that is incompletely burnt. The hydrocarbon emissions are reduced with the addition of DMM and 2EEA blend to diesel fuel. Due to higher oxygen content proper mixing of air and fuel takes place inside the combustion chamber. Therefore HC emission of oxygenate was reduced. The emission of HC was lowered by 14.3% and it was reduced by 9.3% with 6% 2EEA blend. The presence of oxygen in the blend may be responsible for the reduction in HC emissions.

Fig. 5: Comparison of HC emissions with BMEP
Fig. 6 shows the comparison of NO\textsubscript{X} emission with brake mean effective pressure. The formation of oxides of nitrogen is highly dependent on in-cylinder temperatures, the oxygen concentration and residence time for the reaction to take place. It is observed that addition of 2-EEA blend to diesel fuel exhibits higher NO\textsubscript{X} compared to dimethoxy methane and diesel fuel for all the loads. The Higher NO\textsubscript{X} emission of oxygenated blend can be attributed to improved fuel spray characteristics, better combustion of the blend due to its oxygen content. 6% DMM blend has comparable NO\textsubscript{X} emissions than that of diesel fuel for all the loads.

Fig. 6: Comparison of NO\textsubscript{X} emissions with BMEP

IV. CONCLUSION

Experiments were conducted in a diesel engine to study the effects of diesel and two oxygenated blend on performance and emissions. Based on the experimental results the following conclusions were drawn.

- 2-EEA blend to diesel fuel has higher Peak value of cylinder pressure compared to DMM and diesel fuel due to higher cetane number.
- Both the oxygenates increases the specific energy consumption. 6% DMM increases the BSEC by 15%.
- Both the oxygenates reduces the CO emissions compared to diesel fuel. 6% DMM reduces the CO emissions considerably compared to 2EEA and diesel fuel.
- Reduction in HC emissions were observed with the addition of oxygenates. 6% DMM reduces the HC emissions considerably compared to 2EEA and diesel fuel.
- The formation of NO\textsubscript{X} emission is increased for both the oxygenates.
- Oxygenates are showing better result in reduction of smoke. 6% DMM reduces the smoke intensity by 12.6%.

From the above studies it is concluded that 6% DMM is a good oxygenated additive for diesel engines in terms of performance and emission characteristics which may be used for advanced engine testing.

V. ACKNOWLEDGEMENT

The authors gratefully acknowledge the management of Hindustan University for providing the experimental facilities for the completion of this work.

VI. REFERENCES


