Combustion Characteristics of Methanol Blended Diesel Fuel in CI Engine

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ABSTRACT
The consumption of diesel fuel is increasing day by day due to its wide application in agriculture and transportation sectors which is also responsible for deteriorating condition of environment due to emissions i.e., smoke, CO, HC, NOx, etc. These emissions may be reduced by adding methanol in diesel fuel. As compared to diesel, lower value of viscosity and density of methanol-diesel blends helps in easy pumping. The lower boiling point of methanol helps in reducing the ignition delay and thereby avoiding knocking. Methanol with higher oxygen content also helps in easy availability of more oxygen in the vicinity of the diesel for its quick and better combustion. To improve the working of diesel engine and control its emission level, blend diesel version definitely plays a very important role.

Keywords: Methanol, Diesel, Combustion properties.

INTRODUCTION

For the improvement in engine efficiency and reduction of environment exhaust emissions, considerable research has been carried out to improve the combustion characteristics of fuels in recent years1. The use of additives with diesel fuel is a potential method for improving the combustion characteristic of the diesel-additives blend. It may improve engine performance and reduce the emissions simultaneously without any structural changes2-4.

Among all available additives, oxygenated additives have strained more attention due to better combustion properties and rich oxygen content in their molecular structure5-6. Oxygenated additives are renewable in character and their oxygen content support in reaction for better combustion7-10. Alcohols are bio-oxygenated compounds with low viscosity and high volatile characteristics which make them appropriate fuel additives for CI engines11-12. Alcohol compound additives (i.e., methanol, ethanol, n-butanol etc.) are fuels infused with rich oxygen content and used to improve the combustion characteristic when blended with diesel13-14. The advantages of alcohols as an additives include15:

- It can be easily injected, atomized and mixed with air due to its low viscosity as compared to diesel fuel.
- It improves the volumetric efficiency of the engine due to its high latent heat of evaporation which results in cooler intake process.
- It may improve the thermal efficiency of engine due to its high laminar flame propagation speed which helps in completing the combustion process earlier.
- It may reduce the emissions due to its high oxygen and low sulfur content.

Among alcohols, methanol is an alternative, renewable, economic, environment friendly and one of the most promising additives for conventional fossil base fuels. The main raw material available for the production of methanol is coal. In recent years, several researchers have been used the methanol as an alternative to conventional fuels for CI engine16-18. Though there are so many methods to solve the difficulty of direct application of methanol in diesel engine, the fumigation of methanol seems to be a promising method that could flexibly switch from pure diesel mode to relatively high methanol substitution mode19.

The aim of current study is to investigate the effect of methanol blended diesel fuel on combustion characteristics of diesel engine.

Preparation of Methanol-Diesel Blends

Different methanol-diesel blends on volume basis were prepared using a magnetic stirrer and glassware for blending and storage as shown in Figure 1. The methanol used was of 99.0% purity.

Figure 1: Diesel-methanol blend preparation
Several blends of varying concentrations were prepared by varying the methanol concentration (2.5, 5, 7.5 and 10% methanol) in diesel denoted by D-M2.5, D-M5, D-M7.5 and D-M10. The comparison of properties of diesel and methanol is given in Table 1 and Figure 2.

### Table 1: Properties of diesel and methanol

<table>
<thead>
<tr>
<th>Property</th>
<th>Diesel</th>
<th>Methanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value (kJ/kg)</td>
<td>44800</td>
<td>20000</td>
</tr>
<tr>
<td>Cetane number</td>
<td>55</td>
<td>05</td>
</tr>
<tr>
<td>Density (kg/m³) at 20 °C</td>
<td>829</td>
<td>729</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>190</td>
<td>64</td>
</tr>
<tr>
<td>Latent heat (kJ/kg)</td>
<td>250</td>
<td>1178</td>
</tr>
<tr>
<td>Oxygen content (%)</td>
<td>00</td>
<td>50</td>
</tr>
<tr>
<td>Auto ignition temp. (°C)</td>
<td>315</td>
<td>470</td>
</tr>
<tr>
<td>Viscosity (cSt) at 40 °C</td>
<td>2.45</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Calculation of Properties of Diesel-Methanol Blends

The properties parameters for diesel–methanol blends were obtained analytically by using Eqs. (1-3). The formula presented in Eq. (1) was used to calculate the calorific value of blend. Formulae presented in Eqs. (2) and (3) were used to calculate cetane no. of blend and density of blend respectively. Table 2 shows the calculated calorific value, cetane number and density of different diesel-methanol blends.

\[
\text{Calorific value of blends (CV) (kJ/kg)} = \left(\frac{V_m \times CV_m + V_d \times CV_d}{V_m + V_d}\right)
\]

\[
\text{Cetane No. of blends (CN)} = \left(\frac{V_m \times CN_m + V_d \times CN_d}{V_m + V_d}\right)
\]

\[
\text{Density of blends } (\rho_b) = (X_m \times \rho_m) + (X_d \times \rho_d)
\]

where

- CV= Calorific value of blend (kJ/kg), CV<sub>m</sub> and CV<sub>d</sub>=Calorific value of methanol and diesel,
- V<sub>m</sub> and V<sub>d</sub>= Volume percentage of methanol and diesel,
- \(\rho_m\) and \(\rho_d\)= Density of methanol and diesel,
- T = Brake torque (i.e. load) (Nm), N= r.p.m., m<sub>f</sub>= mass of fuel consumption (kg/h),
- CN<sub>m</sub> and CN<sub>d</sub>= Cetane number of methanol and diesel,
- X<sub>m</sub> and X<sub>d</sub>=Mass fraction of methanol and diesel.

**RESULTS AND DISCUSSION**

The experiments were performed on single cylinder, water cooled, four stroke CI engine at standard parameters (i.e. CR= 17.5, Injection timing=23° btdc and Injection pressure= 210bar) with different blend ratio of diesel-methanol (D-M). The engine performance in term of brake thermal efficiency (BTE) for different blends and diesel are shown in Figure 3.
Table 2: Composition of diesel-methanol blends and its properties

<table>
<thead>
<tr>
<th>Blend</th>
<th>Pure diesel</th>
<th>D-M2.5</th>
<th>D-M5</th>
<th>D-M7.5</th>
<th>D-M10</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Diesel</td>
<td>100</td>
<td>97.5</td>
<td>95</td>
<td>92.5</td>
<td>90</td>
</tr>
<tr>
<td>% of Methanol</td>
<td>0</td>
<td>2.5</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
</tr>
<tr>
<td>Calorific value (kJ/kg)</td>
<td>44800</td>
<td>44180</td>
<td>43560</td>
<td>42940</td>
<td>42320</td>
</tr>
<tr>
<td>Cetane number</td>
<td>55</td>
<td>53.75</td>
<td>52.50</td>
<td>51.25</td>
<td>50</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>829</td>
<td>826.5</td>
<td>824</td>
<td>821.5</td>
<td>819</td>
</tr>
</tbody>
</table>

Figure 3: Variation in BTE with BP for pure diesel and D–M blends

The best engine performance (BTE) and reduced emission (Smoke NOx, CO, HC) results were found with D-M5 blend among all blends and diesel.

With D-M5 blend, increment in BTE (17.39%) and reduction in emissions (Smoke= 25.54%, NOx= 8.22%, CO= 12.24%, HC=10.34%) was observed as compared to pure diesel at full load condition.

Better physico-chemical properties of D-M blends may be responsible for these obtained results. With respect to diesel, the lower value of boiling point of methanol helps in reducing the ignition delay and thereby avoiding knocking. Higher auto-ignition temperature of methanol also helps in avoiding knocking in diesel engine.

Methanol with higher oxygen content helps in easy availability of more oxygen in the vicinity of the diesel for its quick and better combustion. As compared to diesel, lower value of viscosity and density of methanol-diesel blends helps in pumping.

CONCLUSIONS

To improve the working of diesel engine and control its emission level, methanol-diesel blend version definitely plays a very important role. Although blending diesel with methanol results in comparatively low calorific value of the blend but oxygen content in methanol helps in completing combustion of diesel thereby compensating for low calorific value. However high specific fuel consumption may lead to higher input cost, but due to better combustion of fuel blend, this cost may be negligible.

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