Influence of an additives and nano additives in biodiesel on engine performance, combustion and emission characteristics

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Abstract: In this present work, investigating the affect of additives(diethyl ether) and nano additives(cerium oxide) in the mango seed oil methyl ester (MSME) biodiesel on engine performance, combustion and emission characteristics of four stroke direct injection diesel engine. The B20 blend of MSME is mixed with 10, 15% of diethyl ether and 25, 50 ppm of cerium oxide (CeO$_2$) nano particles added, this nano particles is mixed well with ultrasonicater to form a homogenous mixture. The tests are conducted for above proportions of B20 of MSME with the engine operating at five different loads (0, 25, 50, 75, and 100 %). The brake thermal efficiency (BTHE) is improved with addition of diethyl ether and cerium oxide. The brake specific fuel consumption (BSFC) and exhaust gas temperatures (EGT) are reduced. There are some reductions of hydro carbon (HC), carbon monoxide (CO), carbon dioxide (CO$_2$), nitrogen oxide (NO$_x$) emissions. The cylinder peak pressures and net heat release rate are lower than that of diesel.

Keywords: nanoparticles, mango seed oil methyl ester, performance, combustion, emissions

I. INTRODUCTION

In recent years there is huge change in the prices of conventional petroleum products. So we need to think of alternative for fuel crisis. The biodiesel prepared from the vegetable oils, animal fats, and waste oils are promptly assured alternative for petroleum products. Now a day’s diesel engines are using very efficiently with the biodiesel directly or blending with diesel. There is some disadvantage with diesel emissions that is creating some problems to the environment as well as human kind [1]. These diesel emissions enter the environment in the form of unpleasant smell, gaseous pollutants and particulate matter and these are also cause the formation of acid rain, destruction of the ozone layer and visibility reduction Aluminum oxide nanoparticles adding in rocket’s solid fuel can improve combustion efficiency and speed, these are very active and can be react with water at temperatures from 400-600°C to improve fuel combustion by generating the hydrogen. Hence fuel additives may play an important role to make up the problems and meet up various specified standards. Many researchers have used a lot of additives to improve the quality of biodiesel such as metal based additives (oxides of cerium, aluminum, titanium, zinc, rhodium etc.)[2-4] oxygenated additives(methyl-t-butyl ether, t-amy1-methyl ether, ethyl-t-butyl ether)[6-8] and their metabolites (t-amyl alcohol, t-butyl alcohol and ethanol), cetane improver(nitrates, nitroalkanes (2-ethylhexyl nitrate), nitro carbonates and peroxides), ignition promoter, cold flow improvers(olefin-ester copolymers, ethylene vinyl acetate copolymer and polymethyl acrylate), antioxidants and lubricity improvers etc.[9-13] .Some of them used diesel engines for testing biodiesels without any modifications[14-15] karthikeyan et al.[5,16] did experiments on effect of cobalt oxide (Co$_3$O$_4$) and zinc oxide in the grape seed oil biodiesel with a percentage of 50, 100ppm and found that which improves combustion, brake thermal efficiency and reduces specific fuel consumption. In emissions, maximum reduction in hydrocarbon (HC), carbon monoxide (CO), smoke opacity and oxides of Nitrogen (NO$_x$) at full load operation. Jeryrajkumar et al.[17] also investigated the effect of nano additives like cobalt oxide and titanium oxide on the performance and emission characteristics of Calophyllum innophyllum.
biodiesel (B100) and it is disclose that considerable improvement in combustion, performance and characteristics. The HC emissions 80% reduce by cobalt oxide and 70% reduce by titanium oxide in biofuel. Racopoulos et al. [18] inspect the effect of combustion heat analysis by addition of n-butanol on diesel in proportion of 8%, 16% by volume basis and The key results are showed that with the use of biofuels blends and additives, fuel injection pressure diagrams are very slightly displaced (delayed), ignition delay is increased, maximum cylinder pressures are slightly reduced.

In this research, study the impacts of using additives (alcoholic and metal based nano oxides) in the biodiesel and its blends on performance, combustion, emissions of engine.

II. MATERIALS AND METHODS

A) Biodiesel

For this investigation, business diesel was brought from neighborhood oil station, mango seed oil was brought from oil plant and biodiesel was formed by transesterification process, the different processes of mango seed to biodiesel are shown in Fig.1 At first, mango seed oil was responded with a monohydric alcohol (methanol (CH$_3$OH)) within the presence of catalyst (potassium hydroxide (KOH)). The procedure of transesterification was influenced by the method of response condition, molar proportion of alcohol to oil, sort of alcohol, sort and measure of catalysts, response time, temperature and virtue of reactants. After transesterification, water wash was done by refined water took after by warming for virtue. The diverse advances associated with transesterification process are given underneath

\[
\begin{align*}
\text{CH}_2\text{OOCR}_1 & \quad \text{R}_1\text{COOH}_3 \quad \text{CH}_2\text{OH} \\
\text{CHOOCR}_2 + 3\text{CH}_3\text{OH} \quad \text{KOH} & \quad \text{R}_2\text{COOH}_3 + \text{CHOH} \\
\text{CH}_2\text{OOCR}_3 & \quad \text{Methanol} \\
\text{Triglyceride} & \quad \text{Methyl Ester} \\
\text{R}_3\text{COOH}_3 & \quad \text{Ch}2\text{OH} \\
& \quad \text{Glycerol}
\end{align*}
\]

The physical and thermal properties of the Diesel fuel and biodiesel blend B20% are summarized in Table 1. The representative values like fire point, density, flash point, viscosity, cetane index and gross calorific value are measured for biodiesel and its blends

![Fig.1 Different stages of mango seed oil methyl ester](http://dynamicpublisher.org/)
a) Mango fruit wastage from juice factory, b) dry mango seed, c) oil extracting machine, d) mango seed oil, e) transesterification, f) settling after transesterification, g) water wash after separating the biodiesel, h) glycerol, i) pure mango seed oil methyl ester.

B) Diethyl ether (C\textsubscript{2}H\textsubscript{5}O\textsubscript{2})

Diethyl ether (DEE) is also called as Ether, Ethyl ether, Ethyl oxide, and sulfuric ether, it is a byproduct of the vapor-phase hydration of ethylene to make ethanol. However it has different properties like colourless, clear, very mobile liquid, with a characteristic odour, very volatile and flammable. Because of its high Cetane index, it is used as ignition improver in CI engines. The different properties of DEE are tabulated in table 1.

C) Cerium Oxide (CeO\textsubscript{2})

Cerium oxide with various valence states and different crystalline structures has been investigated for different applications for example, electrical, electronic, synergist, adsorption, optical, electrochemical, batteries, functional materials, vitality capacity, attractive information stockpiling and detecting properties. Be that as it may, to upgrade different properties of nanomaterials to meet the expanding requirements for various applications, it is expected to decrease the molecule size and increment the dynamic surface zone of nanomaterials. Ceria (CeO\textsubscript{2}) is a cubic fluorite-type organized earthenware material that does not appear any known crystallographic change from room temperature up to its melting point (2700°C). The size of nanoparticles is less than 100 nm.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Diesel (D\textsubscript{100})</th>
<th>B20</th>
<th>Biodiesel (B\textsubscript{100})</th>
<th>Diethyl ether (C\textsubscript{2}H\textsubscript{5}O\textsubscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash point in °C</td>
<td>60</td>
<td>78</td>
<td>160</td>
<td>- 40</td>
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<tr>
<td>Fire point in °C</td>
<td>63</td>
<td>82</td>
<td>170</td>
<td>34</td>
</tr>
<tr>
<td>Density kg/m\textsuperscript{3}</td>
<td>830</td>
<td>849</td>
<td>929</td>
<td>713</td>
</tr>
<tr>
<td>Kinematic viscosity in cst</td>
<td>3.26</td>
<td>3.51</td>
<td>4.66</td>
<td>0.23</td>
</tr>
<tr>
<td>at 40°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calorific value in kJ/kg</td>
<td>42500</td>
<td>41888</td>
<td>39442</td>
<td>36830</td>
</tr>
<tr>
<td>Cetane number</td>
<td>51</td>
<td>----</td>
<td>48</td>
<td>125</td>
</tr>
</tbody>
</table>

III. EXPERIMENTAL SETUP

A 5HP (3.5 kW) 4-Stroke direct injection research diesel engine was chosen to investigate the performance and combustion characteristics (shown in Fig.2). The air flow rate into the engine was measured by mass flow sensor and the fuel consumption was measured by burette method. Loading was applied on the engine with the help of eddy current dynamometer. The experiment was carried at different loads (0, 25, 50, 75% and full load). Various sensors were utilized during the experiment to collect, store and analyze the data by computerized data acquisition system (IC enginesoft). An exhaust gas analyzer (AIRREX HG-540, 4Gas analyzer) was employed to measure HC, CO, CO\textsubscript{2} and NO\textsubscript{X} emissions. The performance, combustion and emission results obtained were tabulated. The specifications of Research engine are shown in Table 2.
TABLE 2
Specifications of the Research engine

<table>
<thead>
<tr>
<th>Engine parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>Kirloskar</td>
</tr>
<tr>
<td>Model/Type</td>
<td>TV1/Four stroke</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>Single</td>
</tr>
<tr>
<td>Bore/Stroke</td>
<td>87.5 mm/110 mm</td>
</tr>
<tr>
<td>Rated power</td>
<td>5 HP (3.5 kW) @ 1500 rpm</td>
</tr>
<tr>
<td>Capacity(cc)</td>
<td>661</td>
</tr>
<tr>
<td>Type of cooling</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Compression Ratio range</td>
<td>12–18</td>
</tr>
<tr>
<td>Injection timing range</td>
<td>0–25° BTDC</td>
</tr>
<tr>
<td>Loading</td>
<td>Eddy current dynamometer</td>
</tr>
<tr>
<td>Data acquisition device</td>
<td>NI USB-6210, 16-bit, 250kS/s.</td>
</tr>
<tr>
<td>Temperature sensors</td>
<td>Type RTD, PT100 and Thermocouple, K-Type</td>
</tr>
<tr>
<td>Load sensor</td>
<td>Load cell, type strain gauge, range 0-50 Kg</td>
</tr>
<tr>
<td>Fuel flow transmitter</td>
<td>DP transmitter, Range 0-500 mm WC</td>
</tr>
<tr>
<td>Air flow transmitter</td>
<td>Pressure transmitter, Range (-) 250 mm WC</td>
</tr>
<tr>
<td>Software</td>
<td>“Engine soft” Engine performance analysis software</td>
</tr>
<tr>
<td>Rotameter</td>
<td>Engine cooling 40-400 LPH; Calorimeter 25-250 LPH</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSIONS

A. Performance Characteristics
The major performance parameters such as Brake power (BP), Brake thermal efficiency (BTHE), BSFC, exhaust gas temperature are evaluated for B20 of MSME and different combinations of diethyl ether and cerium oxide nano particles.

1) Brake power and Brake thermal efficiency: Fig.3a shows the variation of BTHE with BP for MSME at various combinations of additives and nano additives comparing with diesel. The BTHE is gradually increasing with BP. BTHE of the engine is improved by adding the diethyl ether and cerium oxide nano particles (CONP) compare with B20 of MSME. B20+ 50ppm cerium oxide (31.62%) shows higher BTHE than neat diesel (31.43%) at full load. The oxides of metal nano particles present in the biodiesel blend promote the complete combustion, while compared to the individual biodiesel blend.
Cerium oxide nano particles do something as an oxygen barrier and thus improve the BTHE. It is also observed that the development in the BTHE increases with the dosage level of nano particles. A maximum increase of 3.5% in the BTHE was attaining while dosage level of nano particles is 50ppm. Whereas adding of diethyl ether in the blend improves BTHE but dosage level increases it is decreases [19].

2) Brake power and Brake specific fuel consumption: Fig.3b shows the variation of BSFC with BP for B20 of MSME and modified biodiesel with different dosage level of additives and nano additives comparing with diesel. Corresponding to BP, BSFC is decreasing while increasing the BP. At full load, BSFC is higher for B20 (0.3 kg/kWh) than adding additives and nano particles but it attains 10% lower value for B20+50ppm CONP and diesel (0.27kg/kWh). CONP, oxidize the carbon deposits in the engine cylinder to reduced fuel consumption.

3) Brake power and exhaust gas temperature: The exhaust gas temperature (EGT) for all blends of MSME with respect to BP as shown in Fig.3c It is observed that the EGT for B20 blend having diethyl ether and CONP is lower than that of B20 of MSME and neat diesel. The maximum EGT obtained for diesel and B20 of MSME are 367°C, 361°C where as adding diethyl ether and CONP, the maximum values are ranging from 283-286°C approximately 20% reduction in the EGT. This may happen due to the complete combustion of the fuel and reduced the heat loss during the combustion by adding diethyl ether and CONP.

4) Brake power and mechanical efficiency: Fig.3d shows the variation of mechanical efficiency with BP for B20 of MSME and modified biodiesel with different dosage level of additives and nano additives comparing with diesel. Mechanical efficiency is greatly improved by adding diethyl ether and CONP in blend B20 of MSME. This may be reducing the loss of energy in transmission.
**B. Combustion Characteristics:** The major parameters that influence the combustion inside the cylinder are ignition delay, cylinder pressure, and heat release rate.

1) **Cylinder pressure (CP):** Fig.4a demonstrate the variation of cylinder pressure with crank angle for B20 blend and modified biodiesel blend with different dosing levels of the diethyl ether and CONP at different engine load conditions. Peak pressures attain for diesel (80.82 bar) and B20 blend (76.4 bar) when compare to B20 adding additives. This may be addition of CONP tends to reduce the ignition delay and enhances the combustion.

2) **Net heat release rate (NHRR):** Fig.4b shows the variation of net heat release rate with crank angle for B20 blend and modified blends at different engine operating conditions. NHRR is increased the addition of nanoparticles because of increases higher carbon combustion activation and hence promotes the complete combustion.
3) **Cumulative heat release (CHR):** Fig.4c reveal that the variation of cumulative heat release rate with crank angle. It is clearly shows the CHR is higher values for diesel (1.4kJ) and blend B20 (1.2kJ) than other blends having additives (0.95kJ).

**B. Emission Characteristics:** The major emissions of engine are unburned hydro carbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxides (NOₓ) and particulate matter from internal combustion engines. The effects of additives and nano additives on emissions of B20 blend of MSME are discussed here.

1) **Hydro carbons (HC):** The Fig.5a shows the variation of HC with BP for B20 blend and modified blends of B20. The HC increases with BP for all the blends. However, HC emissions are found to be considerably reduced with the addition of diethyl ether and nano particles than the neat diesel and biodiesel blend [20]. Fundamentally, the oxygen content of fuel is the main reason for hydro carbon emissions reduction. May be addition of CONP improves the combustion by excess oxygen.

2) **Carbon monoxide (CO):** Fig.5b shows the influence of additives to biodiesel on carbon monoxide emissions. CO emissions are decreasing while increasing the BP for all the blends. Hence CO emissions shows lower values for B20 blend adding diethyl ether than CONP additives .This may be combustion improvement due to adding diethyl ether. Because of incomplete combustion causes CO emissions.

3) **Carbon dioxide (CO₂):** Fig.5c shows the variation of carbon dioxide with BP for different combinations of B20 blend and diesel. It is clearly disclose that conventional diesel having higher CO₂ emissions than biodiesel blends. Hence the addition of nano particles decreases CO₂ emissions.

4) **Nitrogen oxides (NOx):** Fig.5d illustrates the variation of nitrogen oxides with brake power for different blends of biodiesel and diesel. Nitrogen oxides are mainly formed due to high temperatures. NOₓ is increasing with brake power however diesel values are higher than B20 blend having nano particles. B20 with dosage of 25ppm cerium oxide shows lower values.
Fig. 4 Variation of CP, NHRR, CHR with Crank angle
V. CONCLUSION

The effect of diethyl ether and cerium oxide nano particles on performance, combustion and emission characteristics of a four stroke direct injection research diesel engine is investigated for mango seed oil methyl ester (MSME) biodiesel blend B20 at different proportions of additives. It is concluded that BTHE and ME is improved, BSFC and EGT is reduced by adding diethyl ether and cerium oxide nano particles. There is considerable reduction in the HC, CO, CO₂, and NOₓ emissions.

REFERENCES


