EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL-PONGAMIA METHYL ESTER DIESEL BLENDS FUELED DI DIESEL ENGINE AT OPTIMUM ENGINE OPERATING PARAMETERS

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ABSTRACT

Experimental investigation have been carried out to examine the performance, combustion analysis and emissions of a direct injection diesel engine coupled with electrical dynamometer fueled with diesel and pungam methyl ester and their blends (PME10, PME20 and PME30). From the investigation it is found that the combined increase of compression ratio, injection timing and injection pressure increases the Brake Thermal Efficiency and reduces Brake Specific Fuel Consumption while decreases emissions for PME20. For small sized direct injection constant speed engines, the optimum operating parameters combination was found as compression ratio of 19:1 with injection pressure of 240 bar and injection timing of 27° bTDC. The heat release rate is reduced for methyl ester of pungam oil blended fuel PME20 compared to diesel. The harmful pollutants such as HC, CO are reduced in pungam oil esters compared to diesel fuel.

Keywords: Alternative fuel, injection timing, injection pressure, pungam oil methyl esters, performance, emission, combustion

INTRODUCTION

Due to rapid depletion of petroleum fuels, researchers throughout the world are looking for alternative fuels to run the engines. Of the various alternate fuels under consideration, biodiesel derived from vegetable oils, is the most promising alternative fuel to diesel due to the following reasons. Biodiesel can be used in the existing engine without any modifications. Biodiesel is made entirely from vegetable sources, it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues. Biodiesel is an oxygenated fuel, emissions of carbon monoxide and soot tend to reduce. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel. Biodiesel is produced from renewable vegetable oils/animal fats and hence improves the fuel or energy security and economy independence. A lot of research work has been carried out to use vegetable oil both in its neat form and modified form. Since India is net importer of vegetable oils, edible oils cannot be used for production of biodiesel. India has the potential to be a leading world producer of biodiesel, as biodiesel can be harvested and sourced from non-edible oils like Jatropha curcus, pongamia pinnata, neem, mahua, castor, linseed, etc. Some of these oils produced even now are not being properly utilized. Out of these plants, India is focusing on jatropha curcas and pongamia pinnata, which can grow in arid and wastelands. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction in dependence on imported crude oil and reduction in air pollution. In the present investigation, biodiesel is prepared from pungam oil and the performance, combustion and emission characteristics were analysed on a four stroke single cylinder direct injection diesel engine have been used. That 20% biodiesel blend could be used as alternative fuel for optimized operating CI engine at optimum operating parameters performs better engine performance and lower emissions. Experimental investigation on low heat rejection engine with raw jatropha oil, methyl ester of jatropha oil, methyl ester of jatropha oil–kerosene blend in the proportion of 70:30 and diesel. The results obtained indicate better performance and emission characteristics of the engine with methyl ester of jatropha oil.

BIODIESEL PRODUCTION

Esterification of pungam oil comprised heating of oil, addition of sodium hydroxide and alcohol, stirring of the mixture, separation of glycerol, and biodiesel. This esterified pungam oil is called biodiesel. Biodiesel properties are similar to diesel fuel as shown in the Table 1. After esterification of the pungam oil, its properties like density, cetane number, viscosity and calorific value are improved. This parameter leads better combustion characteristics and performance of diesel engine. Biodiesel is essentially sulfur free and engines fueled with biodiesel emit significantly fewer particulates, hydrocarbons and less carbon monoxide than those of diesel.

TABLE 1. PROPERTIES OF BIODIESEL COMPARED WITH NEAT DIESEL

<table>
<thead>
<tr>
<th>Properties</th>
<th>Diesel</th>
<th>Pungam Oil</th>
<th>Bio-Diesel (Methyl Ester)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetane No.</td>
<td>48 – 56</td>
<td>47</td>
<td>57</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>821</td>
<td>934</td>
<td>892</td>
</tr>
<tr>
<td>Viscosity (cSt)</td>
<td>3.52</td>
<td>45.62</td>
<td>5402</td>
</tr>
<tr>
<td>Calorific value (MJ/kg)</td>
<td>43</td>
<td>36.64</td>
<td>39.15</td>
</tr>
<tr>
<td>Flash point °C</td>
<td>48</td>
<td>270</td>
<td>156</td>
</tr>
</tbody>
</table>

TESTING PROCEDURE

Fig.1 shows the schematic diagram of the engine test rig and its specification are given in Table 2. Testing was
carried out at various loads starting from no load to the full load condition. An Electrical dynamometer was used to apply the load on the engine. A water rheostat with an adjustable depth of immersion electrode was provided to dissipate the power generated. At each load, the fuel flow rate is measured using burette and stop watch. Various constituents of exhaust gases such as hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxides (NOx), were measured with a 5-gas MRU delta exhaust gas analyzer. The analyzer uses the principle of non-dispersive infrared (NDIR) for the measurement of CO and HC emissions while NOx measurement was by means of electrochemical sensors. Combustion analysis was carried out by means of an AVL pressure pick-up fitted on the cylinder head and a TDC encoder fixed on the output shaft of the engine. The pressure and the crank angle signals were fed to a pentium personal computer.

![FIG.1. EXPERIMENTAL SET UP](image)

Various combustion parameters like heat release rate, cumulative heat release rate and peak pressure and its accuracy were obtained using data acquisition system. The engine was first operated with diesel oil to generate the baseline data followed by methyl esters pungam oil and their blends PME10, PME20 and PME30 blends and the test were carried out in the same manner. The results of PME20 blends are comparable with diesel results.

### TABLE.2. RANGE OF OPERATING PARAMETERS CONSIDERED IN THE PRESENT TESTING

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Load</td>
<td>0.25, 50, 75 and 100</td>
</tr>
<tr>
<td>Speed (rev/min)</td>
<td>1500</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>16:1, 17.5:1 and 19:1</td>
</tr>
<tr>
<td>Injection Timing° bTDC</td>
<td>21, 24 and 27</td>
</tr>
<tr>
<td>Injection Pressure (bar)</td>
<td>200, 220 and 240</td>
</tr>
</tbody>
</table>

### RESULTS AND DISCUSSIONS

Experimental investigation has been carried to examine the performance and emission at different compression ratio, injection timing and injection pressure and the details have been mentioned in Table.3. From the experimental analysis it was found that the engine is run well and produced maximum performance at compression ratio of 19:1, advanced injection timing of 27° bTDC and injector pressure of 240 bar. Also the engine were set to run at injector opening pressure of 200 bar and 220 bar and injection timing of 21° bTDC and 24° bTDC and compression ratio of 17.5:1 and 16:1 for diesel and pungam methyl esters, but the engine performance and emission was found to be very poor.

![Fig.2. shows the comparison of brake thermal efficiency with brake power for different fuel blends. The maximum brake thermal efficiency obtained is about 30.5 % for PME20 and 30.1% for diesel. Brake thermal efficiency increases due to percentage of oxygen present in the biodiesel and a rapid change in combustion behavior of the blend. The addition of PME20 with diesel reduces ignition delay and also reduces the burn duration. Hence the injected fuel completes its combustion closer to the TDC and shorter than diesel baseline. The increase in air entrainment and rapid release of heat from the first stage of combustion could be the additional reason for the higher brake thermal efficiency of PME20.](image)

![Fig.3. shows the comparison of brake specific fuel consumption with brake power for different biodiesel blends. It can be observed that the Brake Specific Fuel Consumption of 0.273 kg/kW-hr was obtained for diesel and 0.272 kg/kW-hr for PME20. This is due to complete combustion of PME20 because of presence of high cetane of PME, as a result lower BSFC of](image)
From the fig.4. it is found that PME20 blend offers comparatively lower Brake Specific Energy Consumption than the other fuels. This is due to better combustion of PME20 due to presence of high cetane of PME. PME30 fuels are containing higher proportions of PME and this reduces the heat content of fuel. This may be the main reason for higher Brake Specific Energy Consumption of this fuel. The presence of lower fraction of PME enhances the combustion behaviour of diesel and releases its heat within a shorter duration than the diesel operation. This is the main reason for lower Brake Specific Energy Consumption of PME20 blend.

Fig.5. shows the comparison of hydrocarbon for different biodiesel blends with respect to brake power. It was observed that diesel emits the maximum rate of hydrocarbon is 36ppm among the tested fuels. Other fuels are offering relatively lower HC emissions due to the presence of higher cetane number of PME. The addition of PME with diesel fuel enhances the combustion of fuels and improves better reaction with the air present inside the cylinder. The higher compression ratio, injection pressure and more advanced injection timing helps to provide clean combustion. Hence PME blended fuels performs better at these settings and completes its combustion and liberates its heat in shorter duration. This may be the additional reason for lower HC emission of PME blended fuels.

Fig.6. shows the variation of carbon monoxide emissions of various PME biodiesel blends with brake power. From the figure it is observed that CO emissions of PME are lower than the standard diesel fuel. The reason for the lower CO emission of PME blends are due to the high cetane number of fuel, better combustion and shorter duration of combustion and better spray. Also due to higher compression ratio, injection pressure and injection timing the combustion of the charge occurs in a shorter duration. Hence more heat is released and subsequently increases the cylinder temperature. As a result the whole mixture is combusted fully without leaving the carbon monoxide. In addition the presence of molecular oxygen helps in the combustion of fuels with less emission.

From the fig.7. it is observer that PME20 blend offers comparatively higher NOx emission than the standard diesel. This is mainly due to the presence of high cetane fuel in a blend, higher compression ratio and higher injection pressure. Generally bio-fuel are possessing fewer unsaturation in the molecules. This causes rapid generation of intermediate compounds and consequently the mixture liberates heat in a shorter duration of combustion and hence it offers higher combustion temperatures and promotes higher NOx formation.

Fig.8. shows the variation of pressure with crank angle for different pungam methyl ester biodiesel blends and diesel at full load. The peak pressure of PME20 is slightly higher than that of neat diesel operation. The presence of high cetane biofuel in a diesel causes better combustion and liberates more heat in a shorter duration. This is the main reason for high peak pressure of this blend PME20 blend.

Fig.9. shows the variation of heat release rate with crank angle for different pungam methyl ester biodiesel blends and diesel at full load. It is seen that the height of premixed phase of combustion decreases with addition of PME proportions in the blend. More PME blends offers comparatively lower premixed phase and higher diffusive combustion phase. This is due to rapid production of intermediate compounds in high PMEblends.
Fig. 10. shows the variation of cumulative heat release rate with crank angle for different pungam methyl ester biodiesel blends and diesel at full load. It is noticed that the cumulative heat release rate is decreased for PME20(1310J) compared to diesel(1458J). This is due to high exhaust gas temperature and NOx emission.

CONCLUSION
Following are the conclusions based on the experimental results obtained while operating single cylinder diesel engine fuelled with biodiesel from pungam oil and their blends.

- Pungam methyl esters (biodiesel) can be directly used in diesel engine without any modifications.
- Properties of different blends of biodiesel are very close to the diesel and PME20 is giving good results.
- The combined increase of compression ratio of 19:1, injection timing of 27ºbTDC and injection pressure of 240bar increases the Brake Thermal Efficiency and reduces Brake Specific Fuel Consumption with lower emissions for PME20.

Good mixture formation and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from pungam oil can provide a useful substitute for diesel thereby promoting our economy. Finally it can be concluded that PME20 could be used as alternative fuel for operating CI engine at compression ratio of 19:1, higher injector opening pressure of 240bar and advanced injection timing of 27ºbTDC with less emission of CO and HC and better engine performance.

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REFERENCES


H.Raheman and A.G.Phadate “Emissions and performance of Diesel Engine from Blends of Karanja Methyl Ester(Biodiesel) and Diesel”Indian Institute of Technology Kharagpur-India.

J.Nandagopal and P.Vijayakumar “kinetic study of the esterification of free fatty acids in non edible Pongamia pinnata oil using acid catalyst” Indian Journal of Science and Technology (2009).


