A Technical Review - Experimental investigation on performance and emissions of Mahua biodiesel in CI engine employing EGR (Exhaust Gas Recirculation)

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Abstract— Trans-esterified Mahua oil, also called Mahua bio-diesel is best replacement for diesel fuel in diesel engine due to several reasons. Mahua Bio-diesel is a renewable, inexhaustible and a clean burning fuel. It can be used in diesel engine without modification. It has no aromatic, no-sulfur and contains 10-12% oxygen by weight. The purpose of this study is to summarise the effect of blend of Mahua oil methyl ester and cooled EGR in order to reduce pollutant from diesel engine emission of NOx, CO, HC. To study various performance parameters such as brake thermal efficiency (BTE), BSFC, Exhaust Gas Temperature (EGT).

Key words: Mahua oil, EGR, NOx emission

I. INTRODUCTION

Due to recent energy crises and dwindling reserves of crude oil the demand for alternate liquid fuels particularly the diesel is increasing. Bio-fuels are being given serious consideration as potential sources of energy in the future, particularly in developing countries like India.

A. Mahua oil

Mahua oil (Madhuca Indica) is one of the forest based tree-borne non-edible oils with large production potential of about 60 million tons per annum in India. The tree, its seed and flowers had been very useful in Indian economy for a long time. It is rich in sugar (73 %) and next to cane molasses; it constitutes the most important raw material for alcohol fermentation. The yield of alcohol is 405 liters from one ton of dried flower. The kernel of the Mahua fruit contains about 50% oil. The expelled cake is relevant to recover the residual oil. Fresh oil is yellow in colour, while commercial oil is generally greenish. As this tree grows mainly in forest area and also in waste and fallow land, its cultivation would not produce any impact on food production.

Fig. 1: Mahua Tree

Fig. 2: Mahua Fruit

Fig. 3: Mahua Seeds

Fig. 4: Mahua Oil

Fig. 5: EGR system schematic [9]

Table 1: Properties of Mahua oil, Mahua biodiesel and Diesel

<table>
<thead>
<tr>
<th>Fuel properties</th>
<th>Mahua Oil</th>
<th>Mahua Biodiesel</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>960</td>
<td>880</td>
<td>850</td>
</tr>
<tr>
<td>Flash point (ºC)</td>
<td>232</td>
<td>208</td>
<td>68</td>
</tr>
<tr>
<td>Calorific value (MJ/kg)</td>
<td>36</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>Viscosity cSt @ 40 ºC</td>
<td>24.58</td>
<td>3.98</td>
<td>2.6</td>
</tr>
<tr>
<td>Auto ignition temperature(ºC)</td>
<td>-</td>
<td>-</td>
<td>316</td>
</tr>
<tr>
<td>Boiling point(ºC)</td>
<td>-</td>
<td>-</td>
<td>188-343</td>
</tr>
<tr>
<td>Carbon residue</td>
<td>3.70</td>
<td>0.20</td>
<td>0.70</td>
</tr>
</tbody>
</table>

B. Exhaust Gas Recirculation (EGR)

Instead of using after treatment systems to comply with exhaust emission legislation, it is also possible to avoid the formation of emissions during the combustion. The raw emissions are reduced and thus no after treatment is needed. It is common practice nowadays, to use EGR to reduce the formation of NOx emissions. A portion of the exhaust gases is recirculated into the combustion chambers. This can be achieved either internally with the proper valve timing, or externally with some kind of piping. [9]
II. EXISTING LITERATURE

A. Literature based on Mahua Biodiesel:

H. Raheman et al. [1] have investigated to achieve the performance of biodiesel obtained from Mahua oil and its blend with high speed diesel in a Ricardo E6 engine. Engine performance (brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature) and emissions (CO, smoke density and NOx) were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel.

Conclusion: The brake specific fuel consumption increased and brake thermal efficiency decreased with increase in the proportion of biodiesel in the blends. The smoke level and CO in exhaust emissions reduced, whereas NOx increased with increase in percentage of Mahua biodiesel in the blends. However, the level of emissions increased with increase in engine load for all fuels tested.

N. Saravanan et al. [2] studied One of the popularly used biodiesel in India i.e. Mahua oil (Madhuca Indica). In the present investigation Mahua oil was trans-esterified using methanol in the presence of alkali catalyst and was used to study the performance and emission characteristics. The biodiesel was tested on a single cylinder, four stroke compression ignition engine.

Conclusion: The energy consumption is found to be similar to that of diesel at full load, however there is a significant variation at part load. Engine performance tests showed that power loss was around 13% combined with 20% increase in fuel consumption with Mahua oil methyl ester at full load. Emissions such as carbon monoxide, hydrocarbon were lesser for Mahua ester compared to diesel by 26% and 20% respectively. Oxides of nitrogen were lesser by 4% for the ester compared to diesel.

Avinasha P. et al. [3] studied the blends of Mahua methyl ester and Diesel in the proportion B10, B25, B50, B75 and B100 were prepared analyzed and their performance and emissions characteristics compared with performance and emission characteristics of diesel. In engine performance and Emission test obtained the thermal efficiency, Mechanical efficiency, fuel consumption and indicated thermal efficiency for different blends and also obtain the emissions like CO, HC, NOx and CO2.

Conclusion: Smooth running of engine is observed with esterified Mahua oil compared with that of diesel. Brake thermal efficiency of B25 is nearer to diesel. Specific fuel consumption of B10, B25 is close with the diesel. Minimum emission of CO compare with diesel. Highest HC emissions for diesel, B10 at no load, B100 has minimum HC emission at all loads.it is conclude that the B10, B25 gives optimum performance where B100 gives the lower emission of HC and CO. Mahua methyl ester give the good engine performance and less emission.

M.Harinathareddy et al. [4] presents the results of investigation of performance and emissions characteristics of diesel engine using Mahua biodiesel. The blends of varying proportions of Mahua biodiesel and diesel were prepared, analyzed and compared with the performance of diesel fuel, studied using a single cylinder diesel engine. The brake thermal efficiency, brake-specific fuel consumption, exhaust gas temperatures, CO, HC, NO, and smoke emissions was analyzed.

Conclusion: The tests showed decrease in the brake thermal efficiencies (BTE) of the engine as the amount of Mahua biodiesel in the blend increased. The maximum percentage of reduction in BTE is 14.3% was observed for B-100 at full load. The exhaust gas temperature with the blends decreased as the proportion of Mahua increases in the blend. The smoke, CO, and NO emissions of the engine were increased with the blends at all loads. However, HC emissions of Mahua biodiesels were less than that of diesel.

B. Literature based on EGR (Exhaust Gas Recirculation)

A. Paykani, et al. [6] presents the study performance and emission characteristics of a diesel engine fueled with biodiesel and diesel fuel using EGR. All the experiments were conducted on a single-cylinder, four-stroke, water cooled, indirect injection (Lister 8-1) diesel engine at the engine full load operation and constant engine speed of 730 rpm. The results obtained with biodiesel (canola oil ethyl ester) were compared with the diesel fuel as reference fuel.

Conclusion: The engine performance and efficiency obtained in biodiesel case were less, which could be attributed to lower calorific value of biodiesel. CO and HC emissions for biodiesel were lower than that of diesel fuel. Exhaust gas recirculation (EGR) is a very effective technique to reduce NOx emissions from a diesel engine. In this study the venturi type EGR system was used. When similar percentages (% by volume) of exhaust gas recirculation (EGR) were used in the cases of diesel and canola oil ethyl ester, NOx emissions were considerably reduced to lower values.

S. Ghosh et al. [7] studied on a single cylinder four stroke direct injection water cooled diesel engine is operated with soybean oil methyl ester (SOME) and neat diesel and EGR which replaces a fraction of incoming air during suction. Three observations are made for performance and exhaust gas emission analysis using 0% EGR, 5% EGR and 10% EGR. The rotational speed of the engine is kept as constant at 1500 rpm. The performance of the engine in terms of specific fuel consumption, and brake thermal efficiency and emission characteristics such as oxides of nitrogen, hydrocarbon and smoke density is compared.
Conclusion: When the engine was operated with SOME, the brake thermal efficiency decreases due to the lower calorific value of biodiesel compared to net diesel fuel. The brake thermal efficiency increases at low EGR rates for both the fuels. However, increasing EGR flow rates to high levels resulted in decrease in brake thermal efficiency for both net diesel fuel and SOME. It is observed from the figure that the bio-diesel emits higher NOx than diesel fuel at all loading conditions. The NOx emissions were decreased with increase in EGR flow rate for both net diesel fuel and SOME. The emissions of smoke and HC were found to be lower with SOME. However, with the increase of EGR flow rates resulted in considerable rise in smoke and HC emissions for both net diesel fuel and SOME.

Kavati Venkateswarlu et al. [8] performed the experimental investigations were carried out on a single cylinder four stroke naturally aspirated direct injection air cooled diesel engine with exhaust gas recirculation and cetane improver Di Tertiary Butyl Peroxide (DTBP) as an additive to diesel-biodiesel blends. The combined effect of EGR and DTBP on Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC), cylinder pressure and exhaust emissions is studied.

Conclusion: With increase in percentage of the EGR, BTE increases initially and then decreases while BSFC decreases initially and then increases. The optimum EGR for maximum BTE and minimum BSFC is found to be around 15%. The peak pressure decreases slightly with the increase in percentage of EGR, further, it is found that the presence of EGR advances the ignition with increase in percentage of biodiesel. NOx and exhaust gas temperature decrease with increase in percentage of EGR and furthermore at a fixed EGR, they decrease with the increase in percentage of the biodiesel. CO and HC emissions are found increasing with increase in the percentage of EGR. However, at a fixed EGR, they are found decreasing with the increase in percentage of biodiesel. The increase in smoke is insignificant initially, which however increases slightly with further increase in EGR which also increase with the increase in percentage of biodiesel.

K Srinivasa Rao et al. [9] performed an experimental investigation to study the effect of Exhaust Gas Recirculation on diesel engine Performance and Emission characteristics fueled with Waste Cooking Oil Methyl Ester and its blends with diesel. The EGR setup required for this work was developed on a single cylinder, direct injection, water cooled compression ignition engine. Waste Cooking Oil Methyl Ester produced by Trans-esterification process was used to operate the engine. The different EGR rates ranging from 0% to 20% in steps of 5% for waste cooking oil methyl ester blends with diesel fuel were considered for the study of various Performance and Emission characteristics.

Conclusion: Increase of EGR rate up to 15% increases the BTE slightly. Further increase in EGR rate above 15% decreases BTE. At lower EGR rates the unburnt HC present in exhaust gets burned completely leads reduction in fuel consumption thereby increased BTE. EGR rates above 15% cause less availability of fresh oxygen for combustion results in decrease of BTE. The highest BTE was obtained at 15% EGR for all blends of fuel. The lowest BSFC was obtained for all blends at 15% EGR. BSFC increases with increase of EGR rate above 15% because of formation of rich mixture due to insufficient oxygen supply. The temperature of exhaust gas continuously decreases with increase of EGR rate. The higher specific heat of intake air and exhaust gas mixture and lower oxygen availability are main reasons for lower EGT with EGR. Decrease of combustion temperature due to lower oxygen availability results lower NOx emission with EGR. HC and CO emission show same trend of increase with increase of EGR rate, however the rate of increase was observed more above 15% EGR rate. All blends at 15% EGR exhibited better characteristics compared to diesel at 0% EGR. Hence the problem of higher NOx emission with biodiesel blends can be reduced with suitable EGR rates.

III. CONCLUSION

- From the above literature review I conclude the emission from the vehicle can be reduce by two ways.
- By modification in conventional IC engine.
- With the use of the alternative fuel.
- CI engine with EGR fueled with biofuel can greatly reduce the exhaust emission from the engine.
- CI engine with EGR can reduce the nitrogen oxides (NOx) and particulate matter (PM) because of lower temperature inside the cylinder.
- Oxides of carbon (CO and CO2) may increase slightly because of lower temperature inside the cylinder.
- CI engine with EGR can delays the ignition timing because of mixing of exhaust gas with intake fresh charge.
- Specific fuel consumption may increase and combustion efficiency may decrease slightly.

REFERENCES

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