Effect of Rapeseed Oil Methyl Ester-Butanol Blend at Various EGR and VCR on Emission Characteristics of Diesel Engine

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Abstract

The main aim of these work is to investigate the effect butanol blending at various EGR and VCR at full load condition, On the emission and performance characteristics the testing results are compared with the pure diesel and rapeseed oil methyl ester (B100). The rapeseed oil methyl ester-butanol blend were 20% butanol by volume basis at EGR rate 0%, 5%, 10%, 15% and VCR 14, 16, 18. The blending result shows that the viscosity and density is decreased and close to the diesel fuel. As compared to biodiesel the butanol blending fuels are showing less nitrogen oxide(NOx) Emission. On the other hand high carbon monoxide(CO) and unburned hydrocarbon emissions. The 20% butanol is a highest concentration of blend in biodiesel causes higher CO and HC emission and lower the NOx emission than biodiesel. The EGR achieves lower NOx as the percentage of EGR is increased. The performance diesel engine increases with the increase in compression ratio.

Keywords: VCR, EGR, Biodiesel, Butanol

ABBREVIATIONS

CR  Compression ratio  
VCR  Variable compression ratio  
EGR  Exhaust gas recirculation  
ROME  rapeseed oil methyl ester  
HC  Hydrocarbons  
NOx  Nitrogen Oxides  
Bu  butanol  
B  Biodiesel  
CO2  carbon dioxide  
CO  carbon monoxide

I. INTRODUCTION

Diesel engines is commonly used as a prime movers in transportation, construction machinery, industrial and agriculture sector because of its reliability, durability and high efficiency. But the emission of the nitrogen oxide is high in diesel engine. It is a big challenge to meet the stringent emission regulations of diesel engines. Therefore, to reduce the NOx emission a number of technologies have been studied and developed[1]. Exhaust gas recirculation (EGR) is an effective technology to reduce NOx emissions [2–3]. There are two types of EGR that is internal EGR and external EGR. Internal EGR uses variable valve timings or other devices to retain a certain fraction of exhaust from a preceding cycle. In external EGR system piping is used to route the exhaust gas to the intake system, where it is inducted into the succeeding cycles and that type is used in this study. While EGR is effective in reducing NOx, it also has adverse effects on the engine efficiency and may cause pollution of lubricating oil and corrosion of inlet manifold and moving parts, as exhaust gas contains a lot of particulate matter[4] the objective of these work was to quantify the efficiency of exhaust gas recirculation when butanol is used as an additive in rapeseed oil methyl ester at various compression ratio for NOX reduction.
A. Exhaust Gas Recirculation (EGR)

An engine recalculates exhaust gas by piping it from the exhaust manifold to the inlet manifold. This design is called external EGR. An EGR Valve within the circuit regulates and times the gas flow. Some engines include a camshaft with relatively large overlap during which both the intake valve and the exhaust valve are open, thus trapping exhaust gas within the cylinder by not fully expelling it during the exhaust stroke.

II. Properties of Fuels

<table>
<thead>
<tr>
<th>Test Description</th>
<th>B100 [8]</th>
<th>B90Bu10</th>
<th>B80Bu20</th>
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<tr>
<td>Density</td>
<td>0.876</td>
<td>0.868</td>
<td>0.861</td>
</tr>
<tr>
<td>calorific value</td>
<td>38.50</td>
<td>38.01</td>
<td>36.50</td>
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<tr>
<td>cetane no</td>
<td>51.10</td>
<td>50.50</td>
<td>50.20</td>
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<tr>
<td>Viscosity</td>
<td>5.40</td>
<td>4.70</td>
<td>4.80</td>
</tr>
<tr>
<td>moisture</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Flash point</td>
<td>163</td>
<td>139</td>
<td>145</td>
</tr>
<tr>
<td>Fire point</td>
<td>171</td>
<td>139</td>
<td>145</td>
</tr>
<tr>
<td>Cloud point</td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Pour point</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ash</td>
<td>0.050</td>
<td>0.050</td>
<td>0.050</td>
</tr>
</tbody>
</table>

III. Experimental Setup and Procedure

The experiment is performed on single cylinder, four stroke variable compression ratio diesel engine diesel engine.

1) F1 and F2- Flow sensor for fuel and air, 2) F3 and F4- Engine and Calorimeter Rotameters, 3) PT- Cylinder Pressure, 4) W- Load Sensor, 5) T1-T8-Temperature Sensors, 6) N- Engine speed sensor, 7) V- EGR valve.
1) Ensure that all the nut bolts of engine, dynamometer, propeller shaft and base frame are properly tightened.
2) Ensure the sufficient lubrication oil is present in the engine sump tank this can be checked by marking on the level stick
3) Ensure sufficient fuel in fuel tank. Remove air in fuel line, if any
4) Switch on electric supply and ensure that DLU (Dynamometer loading unit), Load indicator and Voltmeter are switched on.
5) Start water pump. Adjust the flow rate of "Rotameter (Engine)" to 250-350LPH and "Rotameter (Calorimeter)" to 75-100 LPH by manipulating respective globe valves provided at the rotameter inlet. Ensure that water is flowing through dynamometer at a pressure of @ 0.5 to 1 Kg/cm².
6) Adjust the required compression ratio.
7) Start the set up and run the engine at no load for 4-5 minutes.
8) Note down the observations for no load condition.
9) Note down the fuel consumption per 50cc of fuel.
10) Gradually increase the load to 12 kg on the engine by rotating dynamometer loading unit.
11) Wait for steady state (for @ 3 minutes) and collect the reading at full loads.
12) According to flow rate calculate the required air flow for 5 and 10% of EGR and adjust the valve by manual operation.
13) Now insert the probe of gas analyzer in the exhaust line and wait for the steady reading shown on the analyzer screen.
14) Gradually decrease the load to zero.

IV. RESULT AND DISCUSSION

Effect of EGR and VCR using different fuels on emissions

A. NOx Emission:

![Fig. 4.1: NOx Emission at 0% EGR](image1)
![Fig. 4.2: NOx Emission at 5% EGR](image2)
![Fig. 4.3: NOx Emission at 10% EGR](image3)
![Fig. 4.4: NOx Emission at 15% EGR](image4)

From the results it is shown that rapeseed oil methyl ester shows maximum NOX emission than the other fuels as the n-butanol is added in ROME the NOX emission is less as compared to the ROME. As EGR and CR increases the NOX emission decreases.
B. CO Emission

![Graphs showing CO emission at different EGR levels](image)

It is observed that CO emission are higher at low compression ratio and lesser at high compression ratio for various fuels except diesel, at CR 18 the CO emission is high than the other fuels at various EGR. Also it is seen that as the EGR is increased then the CO emission is increased.

C. HC Emission

![Graphs showing HC emission at different EGR levels](image)
It can be observed from the fig. 9-12 that hydrocarbon emission decreases as the CR is increases for all tested fuels it is because of the complete combustion of fuel at higher CR. It is also observed that the butanol blend is increases in ROME then the HC emission is increases, also the HC Emission increases as the percentage of EGR increases.

**D. CO$_2$ Emission**

It is observed from fig. 13-16 that the CO$_2$ emission is increases for diesel fuel as the CR is increases while it decreases for other tested fuels, also for increase in EGR the CO$_2$ emission is increased.
V. Conclusion

This study shows that rapeseed oil methyl ester blended with butanol as alternative diesel fuel can be used successfully to operate a variable compression ratio diesel engine with EGR without any modification to engine. According to the results obtained from the present investigation using diesel, biodiesel and biodiesel blend with EGR following conclusion may be drawn:

1) NO\textsubscript{X} emission are reduced by 27% at 15% EGR compared to that of neat diesel due to lower flame temperature and reduced oxygen availability. Also 20% butanol addition causes 14% less NO\textsubscript{X} emission compared to the ROME. CR14 showing the less NO\textsubscript{X} emission the other CR.

2) CO emission is increases by 30% when EGR is increased up to 15%. Also butanol addition shows a small decrease in CO emission. At CR 18 all tested fuels shows minimum CO emission.

3) HC emission is increased by 25% as the EGR is increased up to 15%. Also the result shows butanol percentage is increases the HC emission is also increases. CR 18 shows the optimum result of HC emission.

4) CO\textsubscript{2} emission is increased by 12% as the EGR is increased up 15% for diesel fuel CR 14 shows the optimum result while for ROME and its blend the CR 18 having minimum CO\textsubscript{2} emission.

References


