Environmental Impact of Butanol and Algae Oil addition in Gasoline at different Compression Ratio

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The utilization of biofuels in IC engines have been increased and trending area of research due to the sustainability of butanol and algae fuels. As these fuels are readily available and the route of production of these fuels is also not limited. Because of the technological advancements and demand of alternative fuels, the operating conditions of IC Engines are becoming stringent, precise and more demanding. Further, it is very well established fact that the emissions of engine depends on the performance of fuel, type of fuel blends and ratio of blending. Therefore, it is more important that the type of fuel or fuel blends may be selected in such a way that it may provide the optimal performance. The review of the available experimental studies shows that the performance and emission characteristics of butanol and algae oil fuel blends with gasoline are limited in SI Engines. Thus, there is need to carry out the experimental studies related to the emissions of butanol and algae oil fuel blends in SI Engines. Further, the use of butanol and algae oil may be good alternative fuel or may be added to gasoline.

**Keywords:** Microalgae, Emissions, Carbon monoxides, Hydrocarbons, Variable compression ratio, Bio-fuel

**Introduction**

Butanol can be produced from a number of production sources; it has a higher heat of evaporation and higher oxygen content which makes it suitable for its use in IC engines\(^1\)\(^-\)\(^5\). Butanol can be generated from a number of renewable sources like corn-fiber, wheat straw, dry grains, barley straw and other plant materials\(^6\)\(^-\)\(^9\). The theoretical and experimental available studies of biofuels i.e. butanol blends; algae oil blends with the gasoline have been comprehensively analyzed and reviewed in this paper. The experiments were conducted on variable compression ratio single cylinder engine at open ECU mode. The setup comprises of eddy current dynamometer for loading variations and separate setup of engine testing software IC Enginesoft along with emission analyzer was coupled with the set up for the data collection and analysis purpose. The important technical information of setup was listed in Table 1. The properties of fuel and characteristics of blends have been determined for 5.2 KW variable compression ratios, multi-fuel engine. Several researchers have presented their research work on bio-fuels performance and emission analysis in IC Engines.

**Experimental procedure**

The testing was performed on variable compression ratio engine by changing the compression ratio, loading condition as well as blending percentage. Seven different blends are used during the testing which includes three test blends (Butanol5, Butanol10 and Butanol15) namely B5, B10 and B15, three test

<table>
<thead>
<tr>
<th>S.No</th>
<th>Characteristics of Engine</th>
<th>Technical Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of cylinders</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Number of strokes</td>
<td>4</td>
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<td>3</td>
<td>Diameter of cylinder</td>
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<tr>
<td>4</td>
<td>Length of stroke</td>
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<td>5</td>
<td>Length of connecting rod</td>
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<td>6</td>
<td>Diameter of orifice</td>
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<td>7</td>
<td>Length of dynamometer arm</td>
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<tr>
<td>8</td>
<td>Power</td>
<td>3.5 kW</td>
</tr>
<tr>
<td>9</td>
<td>Speed range</td>
<td>1200 to 1800 RPM</td>
</tr>
<tr>
<td>10</td>
<td>CR range</td>
<td>6:1 to 10:1</td>
</tr>
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</table>

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blends namely (Algae 5, Algae10 and Algae15) namely A5, A10 and A15 and finally gasoline as baseline fuel are analyzed separately in comparison to gasoline in order to search for their potential. Butanol AA and Algae AA represent AA percentage content of butanol and algae oil (v/v) content in test blend fuel. The data is noted for 100 continuous cycles for the analysis by considering the effect of continuous cycle variations in the outcomes of performance and emissions. All the experiments and data collection process is performed at a fixed speed of 1500 rpm.

**Results and Discussions**

Every emission data were recorded at the constant speed of 1500 rpm and at varying load condition.

The analysis of emissions generated by the blends of butanol and algae were presented in three different sections of carbon monoxides, Hydrocarbon and NOx respectively on different loading conditions and at fixed speed.

**Carbon monoxides emissions**

Figure 1 shows values of CO with increasing BMEP. The emissions of CO is higher at lower compression ratio and low at higher compression ratio but in both the cases of algae and butanol at all variable parameters such as blending ratio and variable compression ratio, the emission of CO is noted lesser than gasoline by both fuels. The least CO emissions have been delivered by algae oil. This trend is due to the reason that on increasing engine load, the larger rate of combustion is required and at that moment butanol or algae supplied which contains ample amount of oxygen which helps incomplete combustion. But as the load on the engine is increased; the emission of CO is also increased as the time for combustion is also reduced. Variation in CO emission for lower loading condition is in case of B15 butanol blend with 49.13% (maximum reduction) at CR 10. On the other hand, maximum reduction by using algae oil is 87% for A15 Algae oil blend with CR 10. At higher loading condition, this maximum reduction in case of butanol is found 26.32% at B15 butanol blend with CR 10 and in algae oil, it is 32% at A15 Algae oil blend with CR 10.

**Hydrocarbon emissions**

Incomplete combustion inside the engine results in the emissions of hydrocarbons. This emission may also be due to the reason of engine misfiring and poor vaporization of the fuel. Figure 2 presents the emission trend of HC. At lower loading condition, emissions of hydrocarbons are higher as at lower BMEP the amount of fuel burnt is quiet less and leads to lower vaporization of fuel and due to the mixing of fuel with air. Due to this phenomenon, the engine leads to poor combustion of fuel. On the other hand, at higher loading, the engine delivers higher output in terms of power and comparatively better combustion which improves the degree of emission of hydrocarbons. The emission of hydrocarbons in case of both the fuels is noted and concluded that the algae blend produces higher HC in comparison to butanol and gasoline. The HC emission in both the fuels is

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**Fig. 1 — Variation in CO Emission of Butanol and Algae Blends at (a) 5%, (b) 10% and (c) 15%**
reduced by adding the butanol and algae content respectively in the fuels but increases as the compression ratio gets increased. These emissions are also increased as the loading on the engine is also increased. But in all the variable testing parameters, the emission of HC is highest in case of algae and butanol has shown nearly fair emissions in comparison to gasoline. The minimum enhancement in HC emissions with respect to butanol was 1.13% at B10 butanol blend with CR 10. In case of algae oil, it is 81% with 15% blending ratio at CR 10. In the case of higher loading, it is 5.33% at B10 butanol blend with CR 10 in case of butanol and 68.33% with 15% blending ratio and at CR 10 while using algae oil in comparison to gasoline.

Nitrogen oxides emissions

The emission of NO\textsubscript{x} from engine is directly proportional to the rise in the temperature of the engine as well as due to the result of the use of lean mixture in the combustion process. Figure 3 shows that at lower BMEP, there is a low temperature inside the cylinder. Hence, the emission of NO\textsubscript{x} is also lower. But at the higher loading condition, there is a rise in the cylinder temperature, hence the NO\textsubscript{x} emission is also increased. The NO\textsubscript{x} emission of algae oil is higher than butanol and gasoline. Butanol also has higher emissions in comparison to gasoline. These emissions were increased as the loading on the engine and compression ratio is increased. The minimum percentage enhancement in the NO emission at lower loading condition in case of butanol is 9.48% at B15 butanol blend with CR 10 while in case of algae oil it is 1.23% at 15% Algae oil blend with CR 10. At higher loading, in case of butanol it is 6.82% at B15 butanol blend with CR 10 and in algae, it is 8.62% at 15% Algae oil blend with CR 10 in comparison to gasoline.

![Fig. 2 — Variation in HC Emission of Butanol and Algae Blends at (a) 5%, (b) 10% and (c) 15%](image1)

![Fig. 3 — Variation in NO Emission of Butanol and Algae Blends at (a) 5%, (b) 10% and (c) 15%](image2)
Conclusions

The characteristics of the fuel blends with a blending ratio of 5%, 10% and 15% have been analyzed and presented in terms of carbon monoxide, hydrocarbons and NOx. The conclusion of the tested fuel blends are listed below:

Carbon monoxide emission

The retardation in CO emission at lower loading condition is noted for B15 butanol blend with a maximum reduction of 49.13% at CR 10. But for higher loading condition, this maximum reduction for the butanol blend MSB 15 is observed as 26.32% for the same compression ratio. From the experimental results in case of algae blends at different blending ratio, and low loading condition, a reduction of 87% in CO emission is found for A15 algae oil blend operating at CR 10 while for the high load condition, this percentage reduction in CO emissions is 32% for A15 algae oil blend corresponding to CR 10.

Hydro carbon emissions

When the engine is operating at low load for butanol blends, an enhancement in HC emissions is observed 1.13% for low load and 5.33% for higher load of 4 bar for B10 butanol blend with CR 10. But in case of algae blends at different blending ratio and lower load of 2 bar, the maximum reduction in HC emissions for algae blended fuel is found as 81% with 15% blending ratio and CR 10. While, at higher load of 3.5 bar, the maximum reduction is noted as 78.33% with same blending ratio and compression ratio.

NOx emissions

The minimum percentage enhancement in NO emissions at low loading conditions is recorded as 9.48% for B15 butanol blend with CR 10 and for same compression ratio, the enhancement in NO emissions is observed as 6.82% in case of B15 butanol blends. In case of algae oil blends, enhancement in NO emissions is seen at 15% Algae oil blending ratio operating at CR 10. But for the high load of 3.5 bar, the minimum percentage enhancement in NO emissions is 8.62% at 15% algae oil blend with CR 10.

References