Investigation on Performance Characteristics of a 4 Stroke Diesel Engine Fuelled With Jatropha Biodiesel Blends

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Abstract: Biodiesel has been observed as a potential substitute for current high pollutant fuels obtained by various conventional sources in order to meet the present energy crisis. The use of biodiesel will not only reduce the burden on the foreign exchange by reducing the oil imports, but will also be a less polluting renewable source of energy for the protection of the environment and fulfilling the future energy requirement. Rapid escalation of fuel prices, conventional fuels and depleting petroleum fuel reserves has forced researchers to look for alternative fuels which can meet the ever increasing demand of energy. Implementing and Development of biodiesel as an alternative and renewable source for different sectors has become critical in the national effort towards maximum self-reliance. As a part of the work, complete analysis has been carried out for the effect of biodiesel diesel blend on the performance of diesel engine. Jatropha biodiesel was used as test fuel in different proportion i.e. (5%) B5, (10%) B10, (15%) B15, (20%) B20, (25%) B25 and (30%) B30 on volume basis. The viscosity and density of biodiesel is more than diesel due to which diesel engine cannot run directly on 100% biodiesel without any engine modification. The test result implies that (10%) B10 biodiesel blend can be mixed with diesel as an optimum blend.

Keywords: Biodiesel, Diesel, Performance, Transesterification.

1. Introduction:
Conventional fuels like gasoline, diesel act as primary source of energy for sustainable development of any country and the demand for petroleum based fuels is increasing with accelerating rate [1]. Increase in energy demand is expected to continue unabated owing to increasing industrialization, increasing number of automobiles, increasing standard of living and expanding population. In India the consumption of direct fuel is projected to grow’s from 42.15 Mt in 2010-2011 to 82.33 Mt in 2013-2014 and the demand for diesel fuel has been estimated to be 106.9 Mt in 2015-2016 [2].

Table:-1 shows the production of crude oil and natural gas in India.[3]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Production of crude oil and natural gas (MMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010-11</td>
<td>37.684</td>
</tr>
<tr>
<td>2011-12</td>
<td>38.090</td>
</tr>
<tr>
<td>2012-13</td>
<td>37.862</td>
</tr>
<tr>
<td>2013-14</td>
<td>37.788</td>
</tr>
<tr>
<td>2014-15</td>
<td>37.461</td>
</tr>
<tr>
<td>2015-16</td>
<td>36.950</td>
</tr>
</tbody>
</table>

Rapid escalation of fuel prices, shortages of conventional fuels and depleting petroleum fuel reserves has made everyone to search for an alternative fuels which can meet the ever increasing demand of energy [4]. Out of different non-conventional fuels available today biodiesel is the most possible substitute or extender for conventional diesel and the prospects for biodiesel are very promising in the short term because of their availability and sustainability. Biodiesel is defined as the monoalkyl esters of long chain fatty acid for use in C.I engines [5]. It can be derived from different types of edible as well as non-edible oils like coconut oil, Waste cooking oil, sunflower oil Jatropha oil, Karanja oil, Jajoba oil, Castor oil, Soyabean oil, Kosam oil, Mahua oil, Neem oil, etc. The properties of Biodiesel are very similar to normal diesel. Comparison of properties of diesel with biodiesel derived from Jatropha oil and Karanja oil are presented in Table:-2.

Table:-2 Properties of biodiesel and diesel [1].

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Properties</th>
<th>Diesel</th>
<th>Jatropha biodiesel</th>
<th>Karanja Biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Density(gm/m³ at 25°C)</td>
<td>0.84</td>
<td>0.88</td>
<td>0.8999</td>
</tr>
<tr>
<td>2.</td>
<td>Calorific value(MJ/Kg)</td>
<td>42.63</td>
<td>38.45</td>
<td>36.72</td>
</tr>
<tr>
<td>3.</td>
<td>Cetane number</td>
<td>45.55</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>4.</td>
<td>Viscosity at</td>
<td>4.5</td>
<td>5.65</td>
<td>5.58</td>
</tr>
</tbody>
</table>
Biodiesel is made from no edible oil which is degradable along with some other properties like clean burning, efficient, natural energy alternative to diesel fuel [6]. Along with many advantages biodiesel also has some disadvantages and the major one being the increase in its NO\textsubscript{x} emissions. Non-flammable and non-toxic, offers almost the same engine durability and performance as petroleum diesel fuel [7]. The use of biodiesel in the engines results in the decrease of the unburnt hydrocarbons, carbon monoxide and particulate matters. Past review says that there are no sulphuric and aromatics while combustion and a high cetane no is required to improve the quality of combustion. As a Non-Conventional (renewable) source of energy biodiesel has a favourable impact on the environment so has the ability to replace fossil fuel for use in engines [8]. Extensive utilization of biodiesel scales back the dependence on petroleum products, which is presently the main source of energy for the world. For countries, having limited petroleum resources, proper utilization of biodiesel can lead in great reduction in imports of petroleum based fuels, thus resulting in significant foreign exchange savings [9]. Use of different edible oils like peanut oil, Soya bean oil, Sunflower oil, coconut oil to produce biodiesel in India is not feasible as these oils are being used for consumption and there is a big gap in demand and supply in the country. So, in Indian conditions only non-edible oils like Jatropha, Karanja, Jojoba, Castor, Kusum etc. can be considered for biodiesel production.

2. Material and Methods:
2.1 Source of Jatropha oil:
Jatropha is a versatile plant with several uses. The oil from the seeds can replace or substitute diesel fuel. Jatropha belongs to the family Euphorbiaceae. It is a large shrub or tree with thick branches and number of large leaves which attains height of 3-4m in 3 years. The percentage of oil in the seed is about 33%-40% [1]. Each seed is about 2cm (\(\frac{3}{4}\) inch) long and the tree can grow upto 5mnts height. After planting the plant starts yielding after two years of its plantation but it reaches to the maximum productivity level after 5-9 years. When the fruit colour becomes yellow at that stage they are harvested. The cleaned seeds are decorticated prior to preuing or expelling. The oils extraction can be done by different methods using engine driven expellers or by crushing. There are simple machines, which can be operated at village level and built within the country. Jatropha plants can be grown on waste barren lands and hilly areas having low rainfall and having low fertility soil [4].

2.2 Sources of Karanja oil:
The tree of karanja reaches a height of 7m which is the average size of the tree. Trees may be planted at density of 1111 plants per hectare with the spacing of 3x3m. It can be generated through shoot cutting, Trans -planting and direct sowing. At the starting stage of the growth of the tree, green pods were carried by the trees which are then changed to the tan colour after 10 months [10]. These pods contain 1 or 2 kidney shaped brownish red kernels, which are 5-7 m long and are horizontally to elliptical in shape. Each karanja tree yields on an average of 8-24 kg of kernels. These kernels are basically white in colour which is covered by with a skin layered in reddish colour. Some typical air – dried kernels are composes of oil varies from 27 to 39%; Protein-17.4% Moisture 19%, in which toxic favourable in oil includes 1.25% Karanjin and 0.85% pongamol [10].
Karanja oil is used as alternative fuel for diesel engines, as lighting oil and for making shop etc. Soaps are also made from this crude oil that are darken in colour due to the presence of isotonchocarpin and in the presence of alkali it gives a colour of wine red colour. In countryside the leaves of these trees are used as a prevention of grains from infestation. After the extraction of the oil, cake which is obtained is used as manure [10].

2.3 Biodiesel production by Trans-esterification of vegetable oil:
Biodiesel is manufactured from vegetable oils by a process called Trans-esterification in which, the triglyceride oils are converted to methyl ester. In the Trans-esterification process the large triglycerides are readily changed into Trans-esterified wine of batch at an atmosphere pressure and at 55-60°C with an excess of methanol in the presence of alkali catalyst. At the end of reaction the mixture is then allowed to settle [1,10]. The upper layer is methyl ester which is washed to remove entrained glycerine that is formed in the lower layer which is drawn off. The condenser is used for recovering the excess amount of methanol and then sent to a rectifying column for purification. Trans-esterification process for biodiesel production is illustrated in figure:-3.

2.4 Experimental setup and experimentation:
Experimental work was carried out in a four-stroke air cooled single cylinder diesel engine develops a 5.5kW at 1500 rpm. Engine details along with alternative are given in table:-3 and table:-4. For loading the engine, an electrical dynamometer was used along with a manometer that uses manometric fluid like water that is attached to a large tank of 0.2 m³ which is 275 times of the engine’s swept volume [1]. This arrangement is then connected to the engine to make air flow measurement. In round sharp edge orifice of 32mm diameter a pressure difference is produced in which air flow was measure. And on a basis of volumetric the flow of fuel was measured by using stop watch and some capacity burette. By using 100 watts and 200 watts capacity the electric load bank is prepared. Electrical connection were framed in such a way that 20% load interval can be achieved for entire load range [4].
Figure 5 presents the variation of brake specific fuel consumption (BSFC) for the diesel and diesel-blends at different engine loads. In general, at all loads the BSFC values of the base fuel are somewhat higher to the blends [11]. So, to produce the same amount of energy the more fuel is needed for the blending of biodiesel with diesel, because of its lower heating value in comparison to base fuel. However, for B10 the BSFC was nearly equal to the value of diesel. For B5 at part load condition, the BSFC decreased as compared to diesel by 1.51%. For B20, BSFC increased by 5% due to decrease in Calorific value of the fuel.

3.2 Brake specific energy consumption:

![Fig 6. BSEC vs load](image)

Figure 6 presents the variation of brake specific energy consumption (BSEC) for the diesel and diesel-biodiesel blends at different engine loads. In normal conditions, the BSEC values of the blend were somewhat lower than those of the base fuel. For B10, the specific energy consumption was nearly equal to the values for pure diesel. For B5 at part load condition the BSEC decreased as compared to diesel. For B25, BSEC increased due to decrease in calorific value of the fuel [12].

3.3 Brake thermal efficiency:

![Fig 7. BTE vs Load](image)

Figure 7 presents the variation of thermal efficiency distribution for diesel and diesel blends. On account of oxygen enrichment in the direct biodiesel blends, the BTE shows an increment with biodiesel addition at greater loads due to enhancement of diffusive combustion stage. Depending on these causes, the rate of energy consumption of blends decreases. With 10% biodiesel addition to diesel, around 2.4% rise in thermal efficiency can be achieved as compared to diesel for almost entire range of load [13]. Although at partial loads the Brake specific fuel consumption values of the blends were somewhat higher than those with the diesel due to higher O₂ content in the chemical composition of the fuel.

3.4 Exhaust gas temperature:

![Fig 8. EGT vs Load](image)

Figure 8 presents the EGT values which are varied with respect to different load that are applied at different fuels tested is shown in figure 5. The biodiesel contains some amount (11% by weight) of O₂ molecule; it also takes part in the combustion. When biodiesel concentration was increased, the EGT slightly decreased [1]. The NOx emission is directly related to the engine combustion temperature. Hence with decrease in temperature, NOx emission should decrease but higher ability of O₂ at the time of combustion leads to higher formation of NOx. For diesel, the exhaust gas temperature is very high for entire range of load. As the biodiesel contain increased in the fuel, the temperature decreased.

4. Conclusion:

The entire work is concentrated around the blending of biodiesel-diesel fuels. Biodiesel is more viscous (4.34 mm²/sec) as compared to diesel (3.2 mm²/sec). For 10% diesel-biodiesel beyond (on volume basis) the density becomes 3.14 mm²/sec. In order to decrease the viscosity nature in the higher blends of biodiesel, some modifications are required in the injection system.

Biodiesel is having less calorific value (40160 KJ/Kgsec) as compared to diesel (42500 KJ/KgK). Because of this lower calorific value of the
biodiesel blends, consumption of fuel is more as compared to diesel.

For performance test analysis, it is evident that when 10% biodiesel-diesel blend is used, the BSFC is decreased by around 1%, BSEC is increased by 1.15%, engine efficiency is increased by 1.53% and exhaust gas temperature is reduced by 7.21% at part load condition. By considering all these performance parameters, it was concluded that the 10% biodiesel blend B10 (On volume basis) can be mixed with diesel as an optimum blend without any engine modification.

5. References