EXPERIMENTAL INVESTIGATION ON VCR DI DIESEL ENGINE FUELLED WITH DUAL BIODIESEL BLENDS OF PALM AND JATROPHA

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Abstract—As we know from year to year the emission standards are become stringent due to Global Warming Effect. It is difficult for the developing countries like India to meet such stringent emission standards as it involves expensive technologies. In this crisis, there is a need to search for the cost-effective methods to reduce emissions from IC engines. Previous research shows that Biodiesel fueled diesel engines emit less CO₂, HC and Smoke emissions than Diesel fueled Engines. In this study, a dual biodiesel blend, mixture of two different kinds of biodiesel namely palm and jatropha with diesel was considered for evaluation in a single cylinder DI diesel engine after going through physical properties analysis. The objective of present work is to investigate experimentally the effects of Dual Bio-diesel blends on performance and emissions of VCR DI constant speed Diesel Engine under various loads and Compression Ratios. Performance and Emission Tests were conducted on VCR Diesel Engine running at a constant speed of 1500 r.p.m. under various loads and compression ratios. Results showed that Brake power (BP) is increased by 1.5% for the test fuel D90PB5JB5 compared to Diesel. BSFC of D90JB5PB5 Test Fuel is almost same as that of conventional Diesel fuel whereas D80JB10PB10 test fuel showed a slight increase in BSFC at all loads when compared to fossil Diesel fuel. Brake Thermal Efficiency is maximum for D90JB5PB5 Bio-diesel blend and it is minimum for D80JB10PB10 when compared to diesel. It was observed that CO and HC emissions were decreased when Engine is running with dual-biodiesel blends when compared to conventional diesel fuel.

Keywords- Global Warming, Duel Biodiesel blends, palm and Jatropha.

I. INTRODUCTION

Environmental concerns have increased regarding vehicular pollution. Many governments have neglected this issue which has been significantly contributing to climate change. The Research works carried out in this area focus on improving efficiencies and limiting emission levels. Biodiesel reportedly offers a good solution to the above-mentioned problems due to its similar properties to conventional diesel. Biodiesel is produced from trans-esterification reaction of triglycerides of vegetable oils and alcohol in presence of a catalyst. The final product consists of fatty acids of alkyl esters [1]. According to the Ministry of Railways of Govt. of India, Indian Railways reportedly consume more than two billion litres of diesel per year. The Ministry also reports that a small reduction in its diesel consumption through blending of biodiesel can create substantial saving in its fuel bill with benefits of cleaner environment due to low carbon emissions. National Policy on Bio-Fuels by Ministry of New and Renewable Energy, Govt. of India, proposes an indicative target of 20% biodiesel blending by the year 2017. Jatrophacurcas contains fatty acids, which are well suited for biodiesel productions. The plant can grow in arid, semiarid conditions and wastelands of India (except for saline or alkaline wasteland). According to Forbes India, the plant requires small amount of fertilizer and water (about 50 litres per plant). The plant is not browsed by cattle and it is also pest-resistant [2]. It has a high-seed yield that continues to be produced for 30–40 years. Oil content in the jatropha seeds is around 30–40%. Forbes also states
that the crop yield for jatropha is about 2 tonnes per hectare. There is about 65 million hectares of wasteland in India suitable to be deployed for growing jatropha. Palm, on the other hand, can give 4 tonnes of oil per hectare.

In its fourth year it can start yielding fruits and in its sixth year it can attain full maturity thereafter giving fruit for 27 years. Directorate of Oil Palm Research of India reportedly suggests that oil palm can be grown in India on about 2 million hectare land. Implementation of biodiesel will lead to many advantages like providing green cover to barren lands, economical support to agriculture and rural areas, less dependency on imported crude oil and reduction in air pollution. In today’s scenario, the most appropriate method to use the vegetable oils in CI engines is through its conversion into fatty acid methyl ester by the process of transesterification. The engine power output and the fuel consumption of the vegetable oil and its blends are almost the same when the engine is fuelled with diesel. Jatropha oil can also be used as a substitute for diesel in a diesel engine. Due to lower calorific values and higher viscosity as compared to diesel, vegetable oils are converted to biodiesel. Lower blends of palm biodiesel increased the brake thermal efficiency and reduced the fuel consumption with reduction in engine emissions.

Increased brake thermal efficiency of palm blends is attributed to increase in oxygen content of the fuel, resulting in improved combustion. Efficient fuel combustion of low viscosity and low density fuel leads to lower fuel consumption. Previous research works also found out that high kinematic viscosity and density fuels with lower calorific value tend to increase the brake specific fuel consumption and lower the brake power as it results in poor atomization of fuel during spraying of fuels inside the combustion cylinder. The presence of high amount of oxygen molecules in biodiesel results in complete combustion of fuel. This condition leads to lower hydrocarbons and carbon monoxide emissions. The in-cylinder temperature is an important factor for nitrogen oxides (NOx) formations. The NOx emissions substantially increase with temperatures. In many experiments, there has been decrease in nitrogen oxides emissions with biodiesel perhaps because in-cylinder temperature is lower which can be due to lower calorific value of the fuel. In single cylinder engine running with palm and jatropha biodiesel, the reported results indicate lower brake powers and higher brake specific fuel consumptions (BSFC).

In six cylinder engine fuelled with palm biodiesel, the brake power decreased about 2.5% and BSFC increased by 7.5%. The literature shows lower smoke, hydrocarbons and CO emissions. The NOx emissions, on the other hand, increases compared to those fuelled with conventional diesel. There have been studies on oxidation stability of biodiesel from tree borne oil seeds like jatropha, pongamia, etc. Oxidation stability of jatropha biodiesel is poor when compared to palm biodiesel. For market acceptability and for longer storage of jatropha biodiesel, antioxidant doping is required. To cut the doping cost, studies of palm biodiesel with jatropha has been carried out. The blend of palm and jatropha biodiesel leads to a composition with improved and efficient low temperature property and good oxidation stability. Research works published regarding palm, jatropha and other biodiesels are mainly based on single biodiesel blending i.e. mixing only one kind of biodiesel with diesel. Very few works have been done with the combination of two different biodiesel blends with diesel.

The brake thermal efficiency of the blend with 90% diesel, 5% Pongamia pinnata ethyl ester and 5% mustard ethyl ester composition was found to be greater than those from diesel. The emissions of hydrocarbons, nitrogen oxides and smoke were higher than diesel but the exhaust gas temperature was lower for the Pongamia pinnata and mustard ethyl ester blends. The objective of present work is to investigate the performance and emissions of a Single Cylinder VCR DI Diesel Engine when fuelled with dual biodiesel blends, a mixture of two different kinds of biodiesels namely palm and jatropha. The final product will have the beneficial attributes of both biodiesels. Furthermore fuel property tests have to be conducted in order to understand the properties of newly formed biodiesel mixture and the changes in properties when mixed with diesel in different proportions.
II. MATERIALS AND METHODS

2.1 Production of biodiesel

Crude jatropha oil has been procured from market and processed to produce jatropha biodiesel (JB). For Transesterification of crude Jatropha oil, 1 litter of Jatropha oil is taken in a beaker and heated up to 60 ºC. The mixture of 250 ml of methyl alcohol and 5 g of NaOH (Methoxy solution) is poured into the heated jatropha oil and vigorously stirred for half an hour and kept in separating funnel for 15–20 h. This leads glycerol to settle down and jatropha biodiesel to come up. For separating the methanol from biodiesel if any quantity of methanol is still remaining in biodiesel, distillation has been conducted to remove the traces of methanol. Palm biodiesel was procured from Universal Biofuels private limited, Vakalapudi, Kakinada.

2.2 Preparation of Duel-biodiesel blends

A. Preparation of D90JB5PB5 Blend: It is prepared by taking out 100 ml diesel from 1 litre of diesel and replaced with 50 ml of jatropha and 50 ml of palm biodiesel.

\[ D90JB5PB5 = 90\% \text{ of Diesel} + 5\% \text{ of Jatropha Biodiesel} +5\% \text{ of Palm Biodiesel} \]

B. Preparation of D80JB10PB10 Blend: It is prepared by taking out 200 ml diesel from 1 litre of diesel and replaced with 100 ml of jatropha and 100 ml of palm biodiesel.

\[ D80JB10PB10 = 80\% \text{ of Diesel} + 10\% \text{ of Jatropha Biodiesel} +10\% \text{ of Palm Biodiesel} \]

2.3 Measurement of fuel properties

The following fuel properties were measured for physical examination

1. Density
2. Viscosity
3. Lower Calorific Value (LCV)

Density of the test fuels was determined with the aid of digital balance which is available in fuels and lubricants laboratory. Similarly viscosity is measured by using Red-wood viscometer-1 and Calorific value of test fuels was determined by using Bomb-calorimeter which is available in the...
same laboratory. The various properties are tabulated below which are very close to the properties of Diesel.

Table 1. Physical properties of Test fuels

<table>
<thead>
<tr>
<th>Sample</th>
<th>Specific Gravity</th>
<th>Calorific Value KJ/Kg</th>
<th>Kinematic Viscosity (mm²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Diesel</td>
<td>0.82</td>
<td>46049</td>
<td>2.10</td>
</tr>
<tr>
<td>D90JB5PB5</td>
<td>0.83</td>
<td>45233</td>
<td>2.35</td>
</tr>
<tr>
<td>D80JB10PB10</td>
<td>0.84</td>
<td>44123</td>
<td>2.49</td>
</tr>
<tr>
<td>Pure JB</td>
<td>0.87</td>
<td>39847</td>
<td>5.48</td>
</tr>
<tr>
<td>Pure PB</td>
<td>0.85</td>
<td>36494</td>
<td>4.03</td>
</tr>
</tbody>
</table>

III. EXPERIMENTAL SETUP AND EXPERIMENTAL PROCEDURE

3.1 Experimental Set-Up

The setup consists of single cylinder, four stroke diesel engine connected to Eddy current dynamometer for loading. It is provided with necessary equipment and instruments for the measurement of combustion pressure, and crank-angle. These signals are interfaced to computer for P-0& P-V diagrams. The set-up also consists of air intake measurement set-up, fuel measuring unit, temperature measuring unit and exhaust gas calorimeter with temperature measurement system. An arrangement is provided for changing the compression ratio of the engine by increasing the clearance volume of the engine. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. It provides a comprehensive educational software environment within which the investigations can be performed. Interfacing the set up with computer using software can do the real time data acquisition. Data can be transferred in Excel Files for further calculations, plotting graphs, printing etc. Sample readings can be tabulated according to requirement of experiment under study and results obtained can be compared.

Figure 2 Layout of Experimental Set-up
Figure 3 Experimental Set-up

Table 2. Specifications of VCR DI Diesel Engine

<table>
<thead>
<tr>
<th>Make</th>
<th>Kirloskar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Injection</td>
<td>Direct Injection (DI)</td>
</tr>
<tr>
<td>No. of cylinders</td>
<td>Single</td>
</tr>
<tr>
<td>Type of cooling</td>
<td>Water cooling</td>
</tr>
<tr>
<td>Rated Power</td>
<td>6KW</td>
</tr>
<tr>
<td>Rated Speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Cubic Capacity (cc)</td>
<td>990 cc</td>
</tr>
<tr>
<td>Cylinder Bore</td>
<td>102mm</td>
</tr>
<tr>
<td>Stroke Length</td>
<td>116 mm</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>17.5:1 std</td>
</tr>
<tr>
<td></td>
<td>Range 13.2:1 to 21.5:1</td>
</tr>
</tbody>
</table>

3.2 Experimental Procedure

Performance and Emission tests were conducted on VCR CI Engine for the test fuels pure diesel, D90JB5PB5, D80JB10PB10 by changing compression ratio. The Experimental procedure can be well understood with the aid of table which is given below.

Table 3. Experimental procedure

<table>
<thead>
<tr>
<th>Test No</th>
<th>Test fuel</th>
<th>Compression Ratio</th>
<th>Load (%) in %</th>
<th>Performance data</th>
<th>Emission data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test-1</td>
<td>Pure Diesel</td>
<td>16.5: 1 &amp; 19:1</td>
<td>0, ¼, ½, ¾ &amp; full load</td>
<td>BP,BTE,BSFC &amp; VE</td>
<td>CO, CO₂ &amp; HC</td>
</tr>
<tr>
<td>Test-2</td>
<td>D90 PB5 JB5</td>
<td>16.5: 1 &amp; 19:1</td>
<td>0, ¼, ½, ¾ &amp; full load</td>
<td>BP,BTE,BSFC &amp; VE</td>
<td>CO, CO₂ &amp; HC</td>
</tr>
<tr>
<td>Test-3</td>
<td>D80 PB10 JB10</td>
<td>16.5: 1 &amp; 19:1</td>
<td>0, ¼, ½, ¾ &amp; full load</td>
<td>BP,BTE,BSFC &amp; VE</td>
<td>CO, CO₂ &amp; HC</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION

4.1 Performance analysis

A) Brake thermal Efficiency

Fig 4 shows the variation of BTHE with Load. Thermal efficiency indicates how well an energy conversion or transfer process is accomplished. From the graph it was found that, Brake Thermal Efficiency is maximum for D90JB5PB5 bio diesel blend and it is minimum for
D80JB10PB10. The increase in thermal efficiency D90JB5PB5 is due to a complete combustion of fuel. The decrease in thermal efficiency D80JB10PB10 is due to lower calorific value and higher viscosity. At full load Brake thermal efficiency for the test fuels pure diesel, D90JB5PB5 and D80JB10PB10 are 18.24%, 19.18% and 17.23%. Fig 5 shows the effect of Compression ratio on Brake Thermal Efficiency of engine. From the graph it is evident that BTE is increased up on increase in compression ratio.

![Figure 4 Variation of Thermal Efficiency with Load for different Test Fuels](image1)

**Figure 4** Variation of Thermal Efficiency with Load for different Test Fuels

![Figure 5 Effect of CR on Thermal Efficiency of Engine](image2)

**Figure 5** Effect of CR on Thermal Efficiency of Engine

B) Brake specific Fuel Consumption (BSFC)

Fig 6 shows the variation of BSFC with load. BSFC is the measurement of fuel mass consumption in kilogram per unit of work done by the engine. In other words the amount of fuel consumed by the engine in order to produce a unit brake power. From the graph it is found that, BSFC is lowest for pure diesel at all loads when compared to other two test fuels (D90JB5PB5 & D80JB10PB10). The possible reason for increase in BSFC with increase in Biodiesel proportion is may be due to the higher viscosity resulting in poor mixing (weak atomization) of biodiesel blend with air. Not only that, BSFC is increases for higher biodiesel blends due to its lower calorific value when compared to conventional Diesel fuel.

![Figure 6 Variation of BSFC with Load for different Test Fuels](image3)

**Figure 6** Variation of BSFC with Load for different Test Fuels
C) Brake power (BP)

The output power of an engine is known as brake power. Fig 7 shows the variation in brake power of the tested biodiesel samples with varying loads. D90JB5PB5 sample showed slight increase in brake power of an average 1.5% than diesel. The reason behind increase in BP for the test fuel D90JB5PB5 is may be higher thermal stability and higher concentration of oxygen in biodiesel. Lower BP was observed for the test fuel D80JB10PB10. The possible reason for decrease in BP is viscosity and density plays major roles in atomization process of fuels and can slow down the fuel–air mixing rate, which can result in poor combustion of fuels leading to a lower brake power [13]. Figure 8 shows the Effect of Compression Ratio on BP, From the graph it is clear that BP increased up on increase in compression ratio.

![Figure 7 Variation of BP for different Test fuels](image)

![Figure 8 Effect of Compression Ratio on BP developed by the Engine](image)

D) Volumetric Efficiency

Fig 9 shows the variation of volumetric efficiency with load. Volumetric efficiency is defined as the ratio of actual volume of air entering into the engine at atmosphere conditions to swept volume (Vₚ) of cylinder. The graph shows that variation of volumetric efficiency for different test fuels with variation of loads. From the graph it was observed that sample D90JB5PB5 has lowest volumetric efficiency when compared to pure diesel and D80JB10PB10.
4.2 Emission Analysis

A) CO Emissions

Incomplete combustion of fuels results in formation of carbon monoxide. Petroleum fuels do not contain any oxygen molecule in their chain and readily produces carbon monoxide. Since, biodiesel have oxygen in their structure, the combustion of biodiesel is more complete resulting in considerably lower carbon monoxide emissions than fossil diesel. Figure 8 shows variation of CO emissions for different test fuels. From the graph, it is evident that CO emissions gradually decreased for the samples D90JB5PB5 and D80JB10PB10 when compared to pure diesel. Average reduction of 7.1% and 17.7% was observed for D90JB5PB5 and D80JB10PB10 samples respectively, when compared with diesel.

B) CO₂Emissions

Carbon dioxide is formed when there is sufficient amount of oxygen present during formation of CO as combustion product. The CO₂ emissions are the result of complete combustion of fuel. In Figure 11 D90JB5PB5 and D80JB10PB10 showed average 2.6% increase and 4.1% decrease in CO₂ Emissions respectively when compared to pure diesel.
C) HC Emissions

The presence of high amount of oxygen molecules in biodiesel results in complete combustion of fuel. This condition leads to lower hydrocarbons. Figure 12 shows variation of HC emissions for different test fuels. HC Emissions for the blends D90JB5PB5 and D80JB10PB10 showed an average of 5% and 15% decrease in HC Emissions respectively when compared to diesel.

V. CONCLUSION

Biodiesel samples made from mixing palm and jatropha biodiesel with conventional diesel at different proportions were examined for viscosity, density and calorific value. Samples D90JB5PB5 and D80JB10PB10 possess viscosity, density and thermal characteristics which are much more comparable to those of diesel fuel.

- The tests were conducted on single cylinder, four strokes, air cooled, direct injection VCR diesel engine using different proportions of palm and jatropha biodiesel with conventional diesel fuel. The sample D90JB5PB5 showed 1.5% average increase in brake power than those operated with conventional diesel. The result shows that lower viscosity and greater calorific values of fuel leads to higher brake power and vice versa.
• BSFC of D90JB5PB5 Test Fuel is almost same as that of conventional Diesel fuel whereas D80JB10PB10 test fuel showed a slight increase in BSFC at all loads when compared to conventional Diesel fuel. Higher viscosity resulting in poor mixing of biodiesel blend with air, increases BSFC due to weak atomization of fuel. Lower calorific value of higher % biodiesel blends also plays its part in increased value of BSFC. BSFC seems to be affected by the density of the fuels as higher density samples showed slightly higher BSFC and vice versa.

• Brake Thermal Efficiency is maximum for D90JB5PB5 Bio-diesel blend and it is minimum for D80JB10PB10. At full load Brake Thermal efficiency for the test fuels pure diesel, D90JB5PB5 and D80JB10PB10 are 18.24%, 19.18% and 17.23%. The increase in Thermal Efficiency of D90JB5PB5 Test Fuel is due to the complete combustion of fuel and decrease in Thermal efficiency of D80JB10PB10 Test fuel is due to lower calorific value and higher viscosity.

• For CO emissions, reductions were estimated at 7.1% and 17.7% for D90JB5PB5 and D80JB10PB10 samples respectively when compared to conventional diesel.

• At the measurement of CO2 emissions, D90JB5PB5 and D80JB10PB10 Test Fuels showed average 2.6% increase and 4.1% decrease respectively than diesel.

Based on the findings of this research it can be concluded that lower blends of dual biodiesel blends such as D90JB5PB5 and D80JB10PB10 can be used as alternative fuels in diesel engine without any engine modification. Furthermore drawbacks associated with palm biodiesel blend and jatropha biodiesel blend can be eliminated by running the engine with Dual-Biodiesel blends of palm and jatropha. The resultant combinations possess good oxidation stability than either of biodiesel blends (Palm or Jatropha) operated individually. And it is also emphasized that, the average BP developed by Dual-Biodiesel blends is higher than either of palm and jatropha operated individually. The reason for the improvement of Engine performance is may be due to the good oxidation stability of the duel biodiesel blends as it leads to complete combustion of the fuel.

In future works, combustion parameters can also be determined for better understanding of fuel mixture. In addition, for the same fuel mixture, exhaust emissions analysis for smoke can be done for a broader perspective. The present work can also be extended by implementing exhaust gas recirculation (EGR) in order to reduce the emissions further.

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