EFFECT OF COMPRESSION RATIO ON ENERGY AND EMISSION OF VCR DIESEL ENGINE FUELED WITH DUAL BLENDS OF BIODIESEL

R. D. EKNATH*, J. S. RAMCHANDRA

Department of Mechanical Engineering, S. J. J. T. University, Chudela, Rajasthan, India

*Corresponding Author: erdmech@yahoo.com

Abstract

Abstract: In recent 10 years biodiesel fuel was studied extensively as an alternative fuel. Most of researchers reported performance and emission of biodiesel and their blends with constant compression ratio. Also all the research was conducted with use of single biodiesel and its blend. Few reports are observed with the use of variable compression ratio and blends of more than one biodiesel. Main aim of the present study is to analyse the effect of compression ratio on the performance and emission of dual blends of biodiesel. In the present study blends of Jatropha and Karanja with Diesel fuel was tested on single cylinder VCR DI diesel engine for compression ratio 16 and 18. High density of biodiesel fuel causes longer delay period for Jatropha fuel was observed compare with Karanja fuel. However blending of two biodiesel K20J40D results in to low mean gas temperature which is the main reason for low NOx emission.

Keywords: Biodiesel, Diesel engine, Compression ratio, Energy, Emission.

1. Introduction

Biodiesel fuels are derived from vegetable oils, animal fats and used waste cooking oil. It can be used in its neat form or can be blend with petroleum base fuel diesel. Biodiesel is renewable, environment friendly and can be available as a crop in most of rural area [1-5]. Vegetable oils are produced from the plants and hence their burning gases do not have any sulphur content [6]. Many researchers were reported that engine power is decreased [7-15] due to the fact that blending of biodiesel reduces the heating value compared with petroleum base diesel. Some of authors found that addition of biodiesel increase the power output. It reaches to its maximum value and then decreases [16-21].
Some literature explains that the power of the engine is recovered due to high viscosity of biodiesel. High viscosity improves the air fuel ratio because of fuel spray penetration during injection [22-23]. Most of researches [7, 9-12] reported that fuel consumption of an engine is increased.

This is due to loss of heating value of biodiesel blends. Armas et al. [24] reported that due to lower heating value of B100 biodiesel BSFC is increased by 12%. Also Hasimoglua et al. [25] reported higher BSFC for biodiesel. Godiganur et al. [26] observed that with increasing content of biodiesel engine fuel consumption increases. Raheman and Phadtare [15] reported same observations for use of B100 Karanja biodiesel. Sahoo et al. [27] observed that for B100 Karanja biodiesel BSFC was increased by 13.31%.

PM emission reduced with the use of biodiesel. 40% PM was reduced compare with biodiesel [16, 19, 25]. Sahoo et al. [27] observed that PM reduced by 68.83% for B100 Karanja biodiesel and 64.28% for B100 Jatropha biodiesel. Literatures reported that NOx emission increase with increase in content of biodiesel. Lujan et al. [28] observed that NOx emission increases by 44.8 % for
B100 biodiesel. Sahoo et al. [27] reported comparison of Karanja and Jatropha biodiesel. For Karanja biodiesel NOx emission increases with increase content and for Jatropha biodiesel there is variation in NOx emission. Most of the literatures reported that with the use of pure biodiesel CO emission reduces compared with diesel fuel [7-9, 14, 15, 29-31]. Raheman and Phadtare [15] observed that the CO emission was reduced by 74-94% for B100 Karanja biodiesel. Sahoo et al. [27] reported that the CO emission was increased for Jatropha biodiesel and reduced for Karanja biodiesel. Banapumatha et al. [32] reported that the CO value for Jatropha biodiesel was 0.155% and for diesel fuel it was 0.1125%. Many authors reported that HC emission decreases with increases in content of biodiesel [26, 28, 31-36].

All these literatures findings are based on single fix compression ratio and use of single biodiesel fuel. Compression ratio has a significant effect on combustion and emission of the engine. Few literatures were observed with findings of varied compression ratio and use of dual blends of biodiesel. Hence aim of this work is to identify the performance and emission characteristics of single cylinder diesel engine fuelled with blends of biodiesel (Jatropha and Karanja) with diesel fuel at a compression ratio 16 and 18.

2. Materials and Method

Commercial diesel fuel was obtained locally was used as a base line fuel for this study. Test fuel samples are prepared at B. S. Deore College of Engineering and properties are tested from the third party, Horizon Services Chemical Lab at Pune (M.S). Density and Heating value of test fuels is as given in the Table 1. D is referred as pure diesel and K is for Karanja fuel and J is for Jatropha fuel. Engine oil used for the study purpose meets the API CH-4, ACEA A3/B4, SAE 15 W-40 specification.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Fuel Blend</th>
<th>Density (kg/m$^3$)</th>
<th>CV (kJ/kg)</th>
<th>Viscosity (cSt)</th>
<th>Flash Point (°C)</th>
<th>Cloud Point (°C)</th>
<th>Pour Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D</td>
<td>828</td>
<td>42300</td>
<td>2.85</td>
<td>76</td>
<td>6.5</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>J</td>
<td>870</td>
<td>39450</td>
<td>4.56</td>
<td>150</td>
<td>10</td>
<td>4.2</td>
</tr>
<tr>
<td>3</td>
<td>K</td>
<td>880</td>
<td>39890</td>
<td>4.52</td>
<td>166</td>
<td>14.2</td>
<td>5.1</td>
</tr>
<tr>
<td>4</td>
<td>KJD20</td>
<td>824</td>
<td>40367</td>
<td>3.80</td>
<td>94</td>
<td>7.3</td>
<td>3.1</td>
</tr>
<tr>
<td>5</td>
<td>KJD40</td>
<td>834</td>
<td>40778</td>
<td>3.98</td>
<td>130</td>
<td>7.9</td>
<td>3.3</td>
</tr>
<tr>
<td>6</td>
<td>K50</td>
<td>852</td>
<td>39470</td>
<td>3.88</td>
<td>155</td>
<td>9.8</td>
<td>4.5</td>
</tr>
<tr>
<td>7</td>
<td>K20J40D</td>
<td>840</td>
<td>40985</td>
<td>3.76</td>
<td>145</td>
<td>8.8</td>
<td>3.3</td>
</tr>
<tr>
<td>8</td>
<td>K20J60D</td>
<td>852</td>
<td>37710</td>
<td>3.92</td>
<td>150</td>
<td>8.4</td>
<td>3.5</td>
</tr>
<tr>
<td>9</td>
<td>Method</td>
<td>ASTM</td>
<td>ASTM</td>
<td>ASTM</td>
<td>ASTM</td>
<td>ASTM</td>
<td>ASTM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D4052</td>
<td>D240</td>
<td>D445</td>
<td>D93</td>
<td>D2500</td>
<td>D97</td>
</tr>
</tbody>
</table>

Test setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by tilting cylinder block arrangement. During the test fuel injection timing was maintain as a constant and...
it was 23 degree BTDC. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for P0–PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of VCR 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. Labview based Engine Performance Analysis software package “EnginesoftLV” is used for on line performance evaluation. A computerized Diesel injection pressure measurement is optionally provided. Table 2 represents the engine specifications and Fig. 1 shows a photograph of test setup.

**Fig. 1. Photograph of VCR Single Cylinder Diesel Engine.**

Engine used in this experiment was four stroke, naturally aspirated, water cooled engine. Engine was commercial engine and is coupled with dynamometer. Dynamometer was AG series eddy current dynamometer designed for testing of engines upto 400 kW. The dynamometer is bi-directional. The shaft mounted finger type rotor runs in a dry gap. A closed circuit type cooling system permits for a sump. Dynamometer load measurement is from a strain gauge load cell and speed measurement is from a shaft mounted three hundred sixty PPR rotary encoder. During experimentation load on the engine was varied to measure the performance at two different compression ratio 16 and 18. Initially test was conducted for Diesel engine fuel then for Jatropha and Karanja fuel. Every time fuel tank and fuel line was completely drain out and to ensure new fuel supply to the engine was initially run for five to ten minutes. To ensure the steady state readings were taken only when the oil temperature was observed to be constant for a period of at least five minutes.
Table 2. Engine Specifications.

<table>
<thead>
<tr>
<th>Details</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Single cylinder, Four stroke, Variable Compression Ratio Diesel Engine (Computerized)</td>
</tr>
<tr>
<td>Engine</td>
<td>Kirloskar Make, Place of Manufacturer INDIA, Water cooled, 3.5 kW at 1500 rpm, Stroke 110 mm, Bore 87.5 mm, 661 cc, CR range 12 – 18</td>
</tr>
<tr>
<td>Dynamometer</td>
<td>Model ED-I, Manufacturer – Apex Innovations, Eddy current type, Water cooled Max load 7.5 kW.</td>
</tr>
<tr>
<td>Piezo Sensor</td>
<td>Range 5000 PSI with low noise cable</td>
</tr>
<tr>
<td>Crank Angle Sensor</td>
<td>Resolution 1 degree, Speed 5500 rpm, with TDC pulse</td>
</tr>
<tr>
<td>Data Acquisition Device</td>
<td>NI USB-62210, 16 Bit, 250 kS/s</td>
</tr>
<tr>
<td>Piezo Powering Unit</td>
<td>Make – Cuadra, Model – AX 409</td>
</tr>
<tr>
<td>Digital Mili Voltmeter</td>
<td>Range 0-200 mV, Panel Mounted</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>Type RTD, Thermocouple K Type</td>
</tr>
<tr>
<td>Temperature Transmitter</td>
<td>Type two wire, Input RTD PT-100, Range 0 – 100°C, Output 4-20 mA and Type two wire, Input Thermocouple Range 0 – 1200 °C, Output 4-20 mA</td>
</tr>
<tr>
<td>Load Indicator</td>
<td>Digital, Range 0 – 50 kg, Supply 230 VAC</td>
</tr>
<tr>
<td>Load Sensor</td>
<td>Load Cell, Type Strain Gauge, Range 0 – 50 kg</td>
</tr>
<tr>
<td>Fuel Flow Transmitter</td>
<td>DP Transmitter, Range 0 – 500 mm WC</td>
</tr>
<tr>
<td>Air Flow Transmitter</td>
<td>Pressure Transmitter Range (-) 250 mm WC</td>
</tr>
<tr>
<td>Software</td>
<td>EngineosoftLV.</td>
</tr>
<tr>
<td>Rotameter</td>
<td>Engine Cooling 40 – 400 LPH, Calorimeter 25 – 250 LPH</td>
</tr>
</tbody>
</table>

Emission analysis was conducted with portable emission analyser DELTA 1600S. Exhaust gases from the engine was taken directly to the sampling tube. It measures carbon monoxide (CO), carbon dioxide (CO$_2$), hydrocarbons (HC) and nitric oxide (NO). Both heated line and conditioning lines are provide with the instrument. Heated line serves to avoid condensation by ensuring the gas temperature about 200°C and conditioning line maintains the gas temperature below 40°C and the saturation level is correct. The DELTA 1600-L determines the emissions of CO (carbon monoxides), CO$_2$ (carbon dioxide), HC (hydrocarbons) with means of infrared measurement and O$_2$ (oxygen) and NO (nitrogen oxides) with means of electrochemical sensors. The 5-gas analysis is processed by the integrated microprocessor and described in the display. Table 3 represents specification of emission analyser.

Table 3. Specifications of Emission Analysers.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Measuring Range</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>0 – 10000 ppm</td>
<td>1 ppm</td>
</tr>
<tr>
<td>CO</td>
<td>0.000 – 9.999%</td>
<td>0.001%</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0 – 20%</td>
<td>0.01%</td>
</tr>
<tr>
<td>O$_2$</td>
<td>0 – 25%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
3. Results and Discussion

Tests were conducted on single cylinder VCR diesel engine. All experiments were performed after ensuring the full warm-up. A plan was designed for the experimental investigation. Different blends of fuels were tested. The tests were conducted for different blends and were repeated for four times for every kind of fuel, in order to increase the reliability of the test results. For each of the fuel, engine was run on five different loads, 2 kg, 4 kg, 6 kg 8 kg and 10 kg of break load on dynamometer. The engine load was controlled by dynamometer. The dynamometer is eddy current type, water cooled with a maximum load of 7.5 kW.

3.1. Combustion analysis

3.1.1. Pressure crank angle

Figures 2 and 3 represent pressure vs. crank angle diagram for compression ratio of 18 and 16 respectively. Figures 4 and 5 represents summary of the combustion data. For a compression ratio of 18 it is observed that the peak pressure for Jatropha fuel was maximum by 6% compared with pure diesel, whereas for Karanja it is 4%, for KJD20 and KJD40 it was more by 1% compared with pure biodiesel. However for the blends of K20J40D peak pressure was low by about 12% compared with pure diesel fuel. For K20J60D fuel peak pressure was low by 2% compared with pure diesel. For a compression ratio of 16, peak pressure for all fuel was also decreased and it was observed that the peak pressure was low for each blends compare with diesel fuel. This is mainly because of increase in ignition delay.

Higher pressure rise was observed for fuel due to longer delay. Pressure reached during the second stage of combustion depends on the duration of delay period. Long delay period results in high pressure rise, since more fuel is present in the cylinder before the rate of burning comes under control. Same trend was observed compared with Jatropha fuel since; Jatropha has 6% more pressure rise compared with diesel fuel. For the same proportion of Karanja and Jatropha pressure rise observed to be same. However, with increase in Jatropha content for the fix value of Karanja content pressure was low compare with diesel fuel. This is due to higher density of biodiesel fuel. It is observed that for all blends peak pressure was observed to be after TDC only this ensures the smooth running of engine.

![Fig. 2. Pressure vs. Crank Angle (CR-18).](image-url)
Fig. 3. Pressure vs. Crank Angle (CR-16).

Fig. 4. Ignition Delay, Peak Pressure and Peak Heat Release Rate for Compression Ratio 18.

Fig. 5. Ignition Delay, Peak Pressure and Peak Heat Release Rate for Compression Ratio 16.
Figure 6 represents net heat release rate for the different blends for the two compression ratios 16 and 18. It is observed that ignition delay was short for biodiesel and its blends compare with biodiesel. Also the maximum heat release rate for biodiesel was less compared with pure biodiesel. Long delay results in accumulation of fuel in the cylinder and hence higher heat release rate was observed for the diesel fuel. Due to shorter delay higher heat release rate for biodiesel occur earlier compare with diesel. Because of higher oxygen content of biodiesel combustion in biodiesel is complete in the after main combustion phase.

3.1.2. Mass fraction burn
Figures 7 and 8 represent crank angle for the same mass fraction burn. The data regarding mass fraction burn was the part of LABVIEW software which was used in this analysis. At compression ratio of 18 it is observed that start of combustion occurs at earlier stage for K20J40D fuel, 21 degree BTDC, i.e., 33.33% earlier than diesel, 38.1% earlier than Jatropha and 47.62% earlier than Karanja. It is observed that 90% of the mass was burn at about 14.44 degree ATDC where as for other fuel same mass was burn at 18 degree ATDC and more. This indicates early burning property of this blend. However as compression ratio decreases to 16 for the fuel K20J40D fuel combustion starts at 18 degree BTDC. This is mainly due to decrease in temperature of the charge.
3.1.3. Mean gas temperature

Figures 9 and 10 represent mean gas temperature vs. crank angle diagram. It is observed that at a compression ratio 18, mean gas temperature was low for K20J40D. This temperature is 6.01% less than diesel, 0.8% less than Jatropha, 41.82% less than Karanja and 47.83% less than KJD20 and 6.37% less than K20J60D. This low temperature results in to low NOx emission and even combustion efficiency is improved due to complete combustion. However as the compression ratio decreases to 16 Jatropha is having lower mean gas temperature compare with other fuels. K20J40D fuel temperature is 766.46°C which is 48-49% less than any other fuel except Jatropha. It is observed that for both compression ratios for fixed content of Karanja (20%) with increase in content of Jatropha mean gas temperature was decreasing first and again increases, it is observed to be minimum when Jatropha content is 40% by volume. This indicates that the fuel K20J40D can be low emission environmental friendly fuel for Indian rural requirements where Karanja and Jatropha can easily available.
3.2. Energy analysis

3.2.1. Break power

Figures 11 and 12 indicate break power variation vs. engine load. It was observed that there were no significant differences in break power of the engine between for biodiesel, its blends and diesel fuel for both compression ratios 18 and 16. At maximum load for any compression ratio difference between petroleum diesel and pure biodiesel is less than 1.5% only. This is mainly due to higher SFC at higher load at any compression ratio, lower heating value and higher oxygen content of biodiesel. Since density of the biodiesel fuel is more than petro diesel, biodiesel supplied to the engine is more than diesel fuel, which compensate for the loss of heating value.
3.2.2. Specific fuel consumption

Figures 13 and 14 represent effect on fuel consumption with increase in load on engine. It is observed that with increase in load on engine SFC decreases for all the fuels. At maximum load of 10 kg and compression ratio 18, Karanja fuel has 10% more fuel consumption than Diesel and 6.6% more than Jatropha. For KJD20 fuel consumption is 10% higher compare with diesel, 6.66% compare with Jatropha and same compare with Karanja. For KJD40 fuel consumption is higher by 6.89% compare with diesel, 3.45% higher compare with Jatropha and 3.4% lower compare with Karanja. For K20J40D fuel consumption was higher by 12.9% compare with diesel, 9.67% higher compare with Jatropha and 3.23% higher compare with Karanja. This indicates that for fixed content of Karanja, increase in content of Jatropha results in higher fuel consumption. It is observed that density of blends of the fuel is 2 to 5% more than petro-diesel. Since density is higher than diesel fuel specific fuel consumption is higher for blends compare with diesel.
3.2.3. Break thermal efficiency

Figures 15 and 16 represent effect of engine load on break thermal efficiency. It is observed that for Jatropha fuel break thermal efficiency is higher at any load compare with any other fuel. It is observed that for a compression ratio of 18, compare with diesel, Jatropha fuel has 37.75% higher efficiency at low load of 2 kg and about 9.29% higher at maximum load of 10 kg. Similarly for Karanja fuel it is observed that compare with diesel efficiency is higher by 15.94% at low load of 2 kg and 6.71% higher at maximum load of 10 kg. For the blend KJD20 it is observed that for a maximum load of 10 kg thermal efficiency is 4.89% less than diesel fuel and 15.6% less than Karanja and Jatropha fuel.
For KJD40 it is observed that for a maximum load of 10 kg thermal efficiency is 1.18% less than diesel, 11.54% less than Jatropha and 8.5% less than Karanja. For K20J40D it is observed that at a maximum load of 10 kg thermal efficiency is 7.08% less than diesel, 18.05% less than Jatropha and 14.8% less than Karanja. Similarly for K20J60D thermal efficiency is 2.73% less than diesel, 13.26% less than Jatropha and 10.1% less than Karanja. This shows that with increase in content of Jatropha for fix content of Karanja thermal efficiency decrease first and then again increases this is because of change in heating value and SFC. Also it is observed that decrease in compression ratio has a significant change (decrease) in thermal efficiency for all fuel blends. However, it is observed that for fuel blend K20J40D change is less than 1%.

3.2.4. Mechanical efficiency
Figures 17 and 18 represent effect on mechanical efficiency with increase in load on engine. It is observed that at compression ratio 18, for Jatropha and Karanja biodiesel at part load operation mechanical efficiency is close to diesel fuel however, with increase in load on engine for both these fuels efficiency decrease by about 15 to 17%. For other blends similar effects are observed. At a load range of 6 to 10 kg loss in mechanical efficiency is about 20 to 22% compare with diesel fuel. However, decrease in compression ratio to 16 it is observed that all the fuel blends are having the efficiency is more or less same compare with diesel fuel.

3.2.5. Volumetric efficiency
Figures 19 and 20 represent effect on volumetric efficiency. For a compression ratio of 18 and 16 no any significant variation is observed for Jatropha and Karanja compare with diesel fuel. Similarly for other blends of fuel changes observed is less than 1% only.
Fig. 17. Mechanical Efficiency vs. Load on Engine (CR-18).

Fig. 18. Mechanical Efficiency vs. Load on Engine (CR-16).

Fig. 19. Volumetric Efficiency vs. Load on Engine (CR-18).
3.2.6. Emission analysis

3.2.6.1. CO emission

Figures 21 and 22 represent CO emission with increase in load on engine. For a compression ratio of 18 it is observed that at low load 2 kg CO emission was higher however, with increase in load emission reduces. This is because of increase in load increases the temperature and hence combustion is complete. At a low load of 2 kg for Karanja fuel CO emission reduces by 50% compare with diesel fuel and for Jatropha fuel it reduces by 12.5%. For the blend KJD20 has same emission as that of diesel fuel. For a blend KJD40 and K20J60D about 75% emission was reduced compare with diesel and Jatropha fuel. Compare with Karanja reduction was observed to be 50%. For K20J40D fuel CO emission was observed to be ZERO for the entire load range. Higher oxygen content of and lower carbon to hydrogen ratio of a biodiesel may tend to reduce CO emission. Also it is observed that reduction in compression ratio increases CO emission for the fuels. This is mainly because of decrease in mean gas temperature.
3.2.6.2. CO\textsubscript{2} emission

Compared with diesel fuel CO\textsubscript{2} emission for Jatropha and Karanja was observed to be lower by about 10 to 15\% (Figs. 23 and 24). This is mainly due to the fact that biodiesel has low carbon to hydrogen ratio compare with diesel fuel. For the blend K20J40D it is observed that the emission was by about 25 to 30\% with increase in load compare with diesel, Jatropha and Karanja fuel. This is due to improved combustion characteristics.

Fig. 23. CO\textsubscript{2} Emission vs. Load on Engine (CR-18).
3.2.6.3. NOx Emission

Figures 25 and 26 represent effect on NOx emission with increase in load on engine. It is observed that increase in load increases the combustion temperature that increases NOx. It is observed that for Jatropha and diesel fuel NOx emission was same. For Karanja fuel for a load range, NOx emission was low about 20 to 22% compared with diesel fuel. For blends K20J40D at maximum load of 10 kg NOx emission was 70% lower than diesel and Jatropha fuel. This is due to the fact that the mean gas temperature for this fuel was 807 °C whereas the mean gas temperature of diesel fuel was 858 °C. Due to low combustion temperature NOx emission was low at compression ratio 18. Decreasing the compression ratio to 16 NOx emissions was 64% less than diesel fuel. Improved combustion and low mean gas temperature may be the cause of reduction in NOx.
4. Conclusion

Test was conducted on VCR diesel engine to study the effect of multiple blends of biodiesel on engine performance. Results of blends of biodiesel were compared with diesel fuel as well as biodiesel. Following is the summary of findings:

- Higher density of biodiesel fuel and blends resulted in a longer delay period. This causes higher peak pressure. It is observed that start of combustion occurs at earlier stage for K20J40D fuel, 21 degree BTDC compared with diesel Jatropha and Karanja.
- K20J40D has low mean gas temperature that results in low NOx emission compared with other blends and fuels.
- For every biodiesel fuel and its blends it is observed that the loss of heating value is more than the increase of density which is the main cause of increase fuel consumption.
- Decrease in compression ratio decreases the thermal efficiency of all the fuels significantly, however for K20J40D fuel it is observed that the change is less than 1%.
- Among all the fuels it is observed that K20J40D fuel is observed to be environmental free as it has very low CO and NOx emission. However further study is required with injection pressure variation and ignition advance.
References


