Experimental Studies on a VCR Diesel Engine using Blends of Diesel Fuel with Karanja Bio-Diesel

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Abstract - Increasing fuel prices and depleting fossil fuel resources in recent years drawn attention towards the use of alternative fuels for diesel engines. The use of vegetable oil is popular, economic and implementable source among the various fuel alternatives. As the petroleum reserves are depleting at a faster rate due to the growth of population and more energy needs, leads to serious search for renewable alternative fuels. A single cylinder computerized variable compression ratio engine was operated successfully using karanja bio-diesel and its blends of karanja oil methyl ester. The following conclusions are made based on experimental results.

With the increase in load, mechanical efficiency of B20 increased in 17.5:1 compression ratio. With the increase in load, specific fuel consumption of B10 decreased in 17.5:1 compression ratio. With the increase in load, brake thermal efficiency of B10 increased in 17.5:1 compression ratio. With the increase in load, mechanical efficiency of B10 increased in 21:1 compression ratio. With the increase in load, break thermal efficiency of B20 increases in 21:1 compression ratio. With increase in load, specific fuel consumption of B10 decreases in 21:1 compression ratio. The blends B10 and B20 can be used as alternate substitutes for neat diesel. These blends sustain performance on par with neat diesel and also safe pollution levels.

Keywords - VCR engine, Emissions, Combustion, Karanja bio-diesel and Neat diesel.

I. INTRODUCTION

Fast depletion of the fossil fuels, increasing threat to the environment from exhaust emissions and global warming have generated intense interest in developing alternate fuels for engines all over the world. In the context of fast depletion of fossil fuels and increasing of diesel engine vehicle population, the use of renewable fuels like vegetable oils becomes more important. Among all petroleum based fuels, diesel oil used in a diesel engine that dominates the field of commercial transportation and agricultural machinery due to its ease of operation and higher efficiency. The consumption of diesel oil is several times higher than that of petrol. The increasing number of auto mobiles has lead to increase in demand of fossil fuels. The import bill is directly in proportionate with increasing cost of petroleum and hence a concern for developing countries. Energy security and environmental protection are important. Limited life of Fossil fuels and their ever increasing cost led to the search of renewable fuels for various sectors like transportation, agriculture and industries are using diesel fuel as a major source of power. With ever-in- creasing population, the usage of automobiles also increased, which leads to the consumption of higher amount of fossil fuels. Bio-diesel is a cleaner burning replacement fuel for diesel available from natural sources such as virgin and used vegetable oil, algae and animal fats.

Bio-diesel emerges as one of the most energy-efficient environmentally friendly options in recent times to full fill the future energy needs. During the last 15 years, bio-diesel has progressed from the research stage to a large scale production in many developing countries. In Indian context, non-edible oils are emerging as a preferred feedstock and several field trials have also been made for the production of bio-diesel.

The present work studies the results of application of a Karanja bio- diesel on a practical heavy-duty VCR diesel engine, with the aim of knowing their impact on exhaust emissions and performance. The goal of this experimental study is to analyze the new fuel contributions to potential performance and efficiency loss. An attempt is made to assess the combustion and performance phenomenon of Karanja bio-diesel fuel. An investigation covering the performance, emissions is dealt with to evaluate the engine under various fuel blend implementations.

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II. LITERATURE REVIEW

Nagarhalli M. V. et al., [1] have tested KOME and found that HC emission decrease by 12.8% for B20 and 3% for B40 at full load. NOx decreased by 39% for B20 and 20% for B40 at full load. BSFC increased by 7% for B20 and 1.9 % for B40 at full load. A B40 blend has been recommended by the author.

H. Raheman et al.,[2] Emissions and Performance of Diesel Engine from Blends of Karaja Oil Methyl Ester(KOME) and Diesel have used for test. They found the average BSFC was 3% lower than diesel in case of B20 and B40. Maximum BTE was found to be 26.79% for B20 which is 12% higher than diesel. They concluded that B40 could replace diesel.

Sivakumar et al. 2010 [3] in their study titled " Performance and Emission characteristics of a 4 stroke CI engine operated on Honge methyl ester using artificial neural network" bio-diesel was prepared from Honge oil (Pongamia) and used as a fuel in C.I engine. An improvement in BTE was observed for higher compression ratios. Brake specific energy consumption for bio-diesel blends is more than that of diesel and decreases for higher compression ratios.

Exhaust emissions Smoke, CO, HC were reduced for Diesel-bio-diesel blends when compared with diesel values for all compression ratios and higher compression ratios have the advantage further reduction in those emissions

Gaurav Dwivedi& M.P. Sharma 2013 [4]In this study "Performance Evaluation of Diesel Engine Using Bio-diesel from Pongamia Oil" focused on the work done in the area of production of bio-diesel from Pongamia and the characterization of properties of various blends of Pongamia bio-diesel. The work also includes the impact analysis of Pongamia oil and its bio-diesel on engine performance and exhaust emission. S. K. Acharya et al [5], Investigated the effect of preheated karanja and kusum oil on its emission characteristics. Emission characteristics were evaluated by preheating of karanja and kusum oil in a shell and tube type heat exchanger. This study was carried out on a single cylinder, four strokes, water cooled engine with constant compression ratio (16.5:1) and 1500 rpm. The emission components such as carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO2) were increased with increase the engine load and oxide of nitrogen (NOx).

Nobukazu Takagi et al [6] conducted experiments on a single cylinder Direct Injection diesel engine with palm oil, rapeseed oil and the blends of palm oil and rapeseed oil with ethanol and diesel fuel at different fuel temperatures. They found that the performance and engine exhaust emission levels were in the acceptable limits for the vegetable oils and their blends. When compared with diesel, the methyl esters of rapeseed oil and palm oil offered lower smoke and lower NO_X emission, and engine noise and higher thermal efficiency.

Kalligeros et al. [7] conducted experiments on a single cylinder direct injection diesel engine using olive oil and sunflower oils as fuels in different proportions with marine diesel. They observed small amount of un-burnt HC, CO, NOx and particulate matter with blends compared to neat vegetable oils.

O. M. I. Nwafor et al.[8] studied the emission characteristics of a diesel engine operating on rapeseed methyl ester and found that rapeseed methyl ester and its blends with diesel fuel emitted high carbon dioxide as compared to diesel fuel. Drastic reduction of HC in exhaust emissions was recorded when running on rapeseed methyl ester. Hydrocarbon emissions observed to increase with increased amount of diesel fuel in the blend.

A. Senatore et al. [9] conducted experiments on rapeseed oil methyl ester and concluded that heat release takes place earlier than mineral diesel, because fuel injection starts earlier in the case of bio-diesel blends due to their high density, leading to high peak cylinder temperatures.

McDonald et al [10] obtained the heat release from the actual pressure angle diagram with soya bean oil methyl ester as a fuel in an indirect injection diesel engine and concluded that the overall combustion characteristics were quite similar to diesel operation except shorter ignition delay for soya bean methyl ester.

Niehaus R. A. et al [11] conducted experiments with thermally unstable soybean oil and found that, the fuel produced slightly less power than diesel fuel and also observed low levels of hydrocarbons and NO_X emissions. The heat release rate was lowered with thermally cracked soybean oil as compared to diesel. They suggested that by advancing the injection timing, combustion temperatures can be increased and a higher maximum rate of cylinder pressure rise and higher levels of premixed burning with the oil can be achieved.

III. EXPERIMENTATION

A. Experimental Set Up:

"Direct Injection, VCR Diesel engine is utilized for the experimentation. Experimentation is carried out at various engine loads (Engine Loading device is eddy current dynamometer) to record the cylinder pressure and finally to compute heat release rates with respect to the crank-angle. Engine performance data is acquired to study the performance and engine pollution parameters.

The exhaust gas analysis of different components of exhaust gas are measured and compared and engine performance is analyzed for the parameters mentioned

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above with the implementation of blends of neat diesel with Karanja bio- diesel at different compression ratios. The engine setup is shown in Figure.1 and 1a.

Figure.1, Computerized VCR Engine Test Rig

Figure.1a, Computerized VCR Engine Test Rig

Table 1, Specification of the Di-Diesel Engine

Rated Horse power:	6 kW
Rated Speed:	1500rpm
No of Strokes:	4
Mode of Injection	Direct Injection
Injection pressure	200 kg/cm^2
No of Cylinders:	1
Stroke	116 mm
Bore	102 mm
Compression ratio	17.5:1 and 21:1

This experimental investigation were carried out on a Kirloskar made VCR engine. It was connected with the control panel unit which consist rotameter, water temperature indicator, loading switch, speed indicator and fuel flow transmitter etc. The engine performance and combustion parameters such as brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), mechanical efficiency (MEFF), heat balance, cylinder pressure and heat release rate were determined by engine performance analysis software.

B. Indus Pea 205, (Exhaust Gas Analyzer):

The PEA 205 [Figure.2] measures the exhaust emissions such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydro Carbon (HC), Oxygen (O_2) by means of Non-Dispersive infrared (NDIR) measurement.

Figure.2, Indus PEA 205 Exhaust Gas Analyzer

C. Trans esterification Process:

Trans esterification of natural glycerides with methanol to methyl esters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. The transesterification process is the reaction of a triglyceride with an alcohol to form esters and glycerol. During the Transesterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or bio-diesel, and crude glycerol.

1. Production of Karanja oil Methyl ester:

Karanja oil is a bio-diesel produced by using raw Karanja seed oil. Due to high content of FFA of Karanja oil, the objective has been achieved in two steps namely (i) acid esterification, (ii) alkaline esterification.

2. Acid esterification:

The acid esterification was carried out at 4:1-6:1 molar ratio with varied H_2SO_4 (0.5- 2.0%) at 50-60°C and 60-90 min reaction time. Preheated oil, methanol and acid H_2SO_4 were mixed together as per desired proportion and stirred at 200 rpm. After completing the acid esterification reaction, treated was taken into beaker (Figure. 4 (a)) and heated up to 60°C.

3. Alkaline esterification:

After acid treatment, 50 g oil was taken in a 250 ml flask and preheated up to 100°C to eliminate dissolved moisture content in the Karanja oil. The required amount of methanol (4:1, 6:1, 8:1) was mixed with distinct percentage of KOH catalyst concentration (0.5, 1.0, and 1.5). This homogeneous mixture of methanol and catalyst KOH was mixed with the Karanja oil and stirred with 200 rpm at varied reaction temperature 50-60°C. The reaction was stopped after 60, 75 and 90 min. After completion of trans esterification reaction, Karanja oil methyl ester was separated from glycerol by separating funnel (Figure.(4b))

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and then the separated methyl ester was washed with hot distilled water. At last bio-diesel was heated in the hot air oven to remove excess water content, and collected in jar as shown in the Figure 4(c).

Figure. 4a, Acid Esterification

Figure. 4b, Alkaline Esterification

Figure.4c, Karanja Bio-Diesel

4. Experimental Procedure:

The experimentation is conducted on a single cylinder direct injection VCR diesel engine operated at normal room temperatures of 28^{0}C to 33^{0}C.

The series of exhaustive engine tests were carried out on a compression ignition diesel engine using diesel and Karanja oil bio-diesel blends. Several blends of varying concentration of Karanja oil methyl ester (bio-diesel) with diesel were prepared as follows:

B10- This is the blend containing 10% bio-diesel and 90% neat diesel

B15- This is the blend containing 15% bio-diesel and 85% neat diesel

B20- This is the blend containing 20% bio-diesel and 80% neat diesel

B25- This is the blend containing 25% bio-diesel and 75% neat diesel

Performance and emission tests were conducted under different loading condition on these various diesel-bio-diesel blends. The optimum blend was found out from the graphs based on maximum thermal efficiency, minimum brake specific energy consumption and safe emission at all load.

IV. RESULTS & DISCUSSIONS

CVD (Calorific value of diesel) =44,631 kJ/kg
CVB10 (Calorific value of B10) =44,201.6kJ/kg
CVB15 (Calorific value of B20) =43,986.9kJ/kg
CVB20 (Calorific value of B30) =43,772.2kJ/kg
CVB25 (Calorific value of B50) =43,557.5kJ/kg

1. **Observations with Compression Ratio 17.5:1**

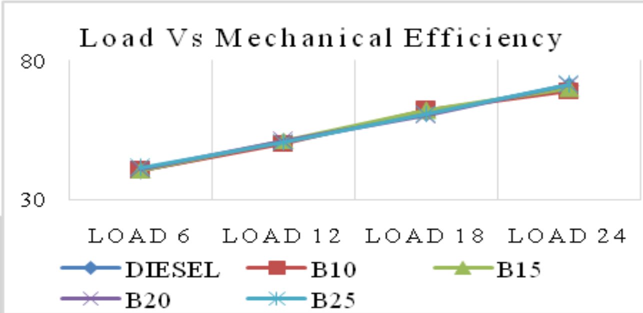

Figure.5, Load Vs Mechanical Efficiency Graph with Compression Ratio 17.5:1 at Various Loads

The maximum mechanical efficiency of the engine was 71.219% for karanja bio-diesel B20 at 24kg load (Figure:5).

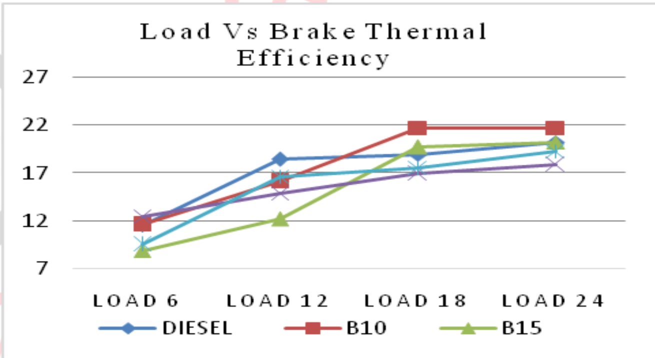

Figure.6, Load Vs Brake Thermal Efficiency Graph with Compression Ratio 17.5:1 at Various Loads

The brake thermal efficiency of the engine was 21.695% for karanja bio-diesel B10 at 24kg load (Figure.6).

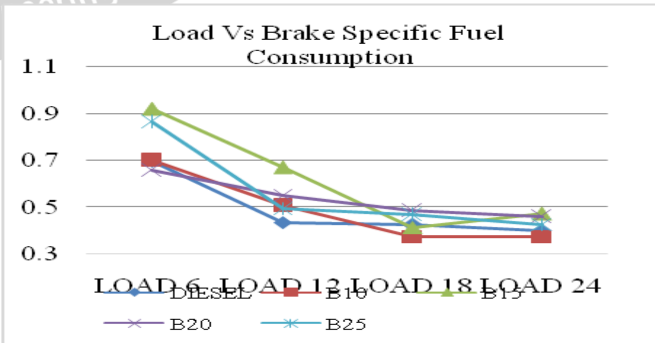

Figure.7, Load Vs Specific Fuel Consumption Graph with Compression Ratio 17.5:1 at Various Loads

The minimum brake specific fuel consumption of the engine was 0.375 kg/kwh for karanja bio-diesel B10 at 24kg load (Figure.7).

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2. Observations with Compression Ratio 21:1

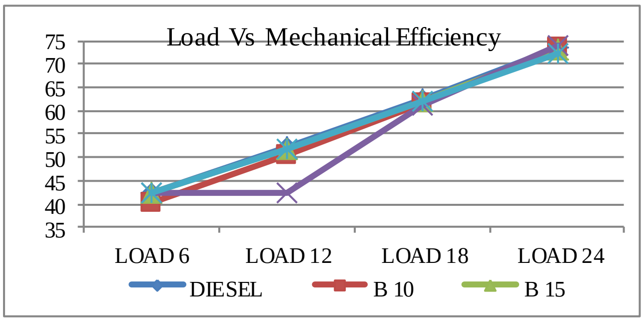

Figure.8, Load Vs Mechanical Efficiency Graph with Compression Ratio 21:1 at Various Loads

The maximum mechanical efficiency of the engine was 73.9% for karanja bio-diesel B20 at 24kg load. (Figure.8).

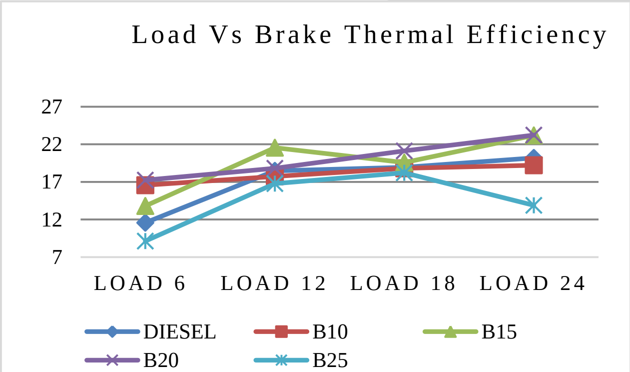

Figure.9, Load Vs Mechanical Efficiency Graph with Compression Ratio 21:1 at Various Loads

The brake thermal efficiency of the engine was 23.23% for karanja bio-diesel B20 at 24kg load (Figure.9).

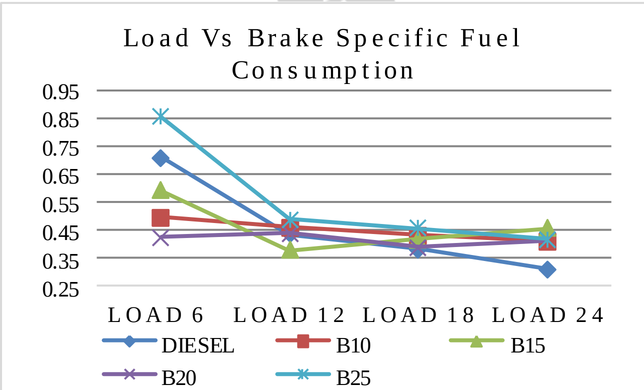

Figure.10, Load Vs Specific Fuel Consumption Graph with Compression Ratio 21:1 at Various Loads

The minimum brake specific fuel consumption of the engine was 0.312% for neat diesel at 24kg load (Figure.10).

3. Emission Analysis:

The emissions obtained during the experimentation at different loads are obtained by using a 5- gas emission analyzer. The experiment is done by diesel, karanja bio-diesel blends and pure karanja bio-diesel. The emission analysis for CO, CO2, HC, O2, is done. The Figures 11 to 14 shows the emission values for diesel and bio-diesel blends.

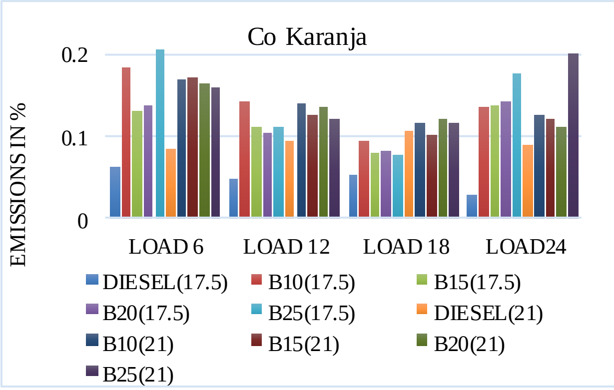

Figure. 11, Load Vs Co Comparison Graph

The variation of carbon monoxide with load and compression ratio of the engine is shown in Figure 25. It is observed that carbon monoxide emission decreases when to diesel. it means that proper combustion has not carried out for bio-diesel. The minimum carbon monoxide emissions were obtained for diesel (Figure.11).

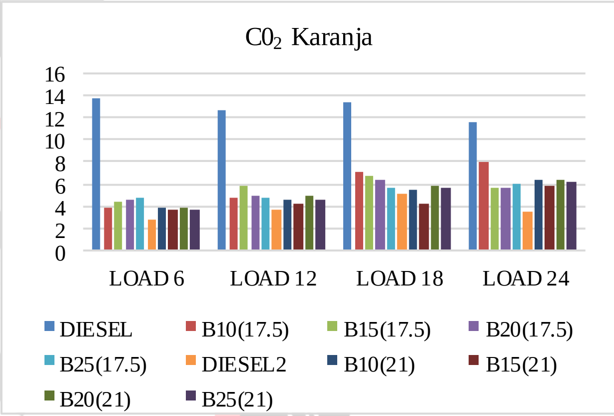

Figure. 12, Load Vs Co2 Comparison Graph

The variation of carbon dioxide emission for various blends at varying loads. The carbon dioxide emission for the blends is higher than diesel for all loads and blends and decreases with compression ratio. Carbon dioxide is formed on complete combustion of the fuel in oxygen. As the calorific value of the fuel is low, more fuel needs to be burnt to get equivalent power output. So combustion of more carbon compounds leads to higher carbon dioxide emissions (Figure.12).

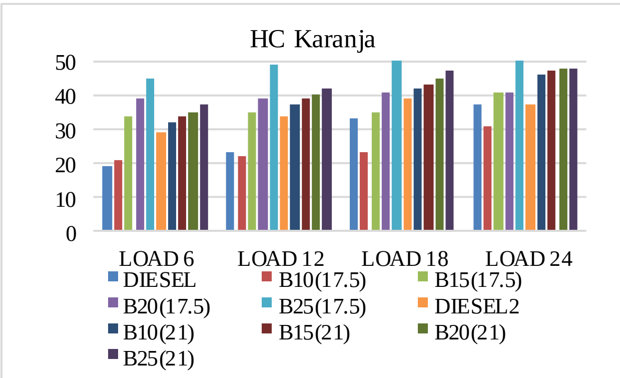

Figure. 13, Load Vs HC Comparison Graph

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The hydro carbons variation with load for the karanja bio-diesel and diesel are shown in figure 13. The hydro carbons are higher for all the blends for the karanja bio-diesel compared with diesel. The results depend on oxygen quantity and fuel viscosity, in turn atomization (Figure.13).

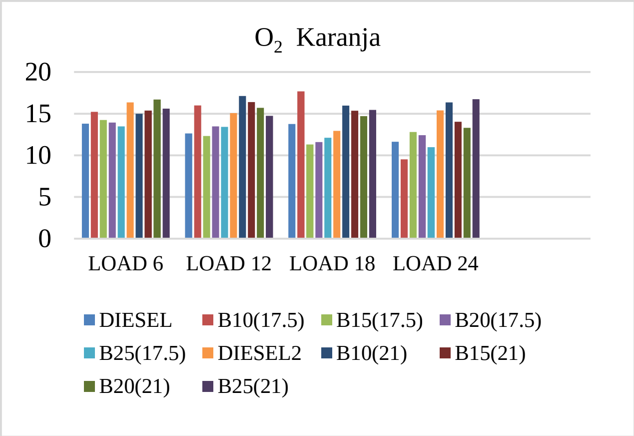

Figure. 14, Load Vs O_2 Comparison Graph

The oxygen emission for the blends is higher than diesel for all loads and blends and increases with compression ratio. But the blend B10 has less emissions of O_2 at 10 kg load (Figure 14).

V. CONCLUSIONS

A single cylinder computerized variable compression ratio engine was operated successfully using karanja bio-diesel and its blends of karanja oil methyl ester. The following conclusions are made based on experimental results. Mechanical efficiency of engine is increased by the blends of karanja oil with diesel. The brake thermal efficiency of the engine with karanja methyl ester-diesel blend was marginally better than with neat diesel fuel. Brake specific energy consumption is lower for karanja methyl ester-diesel blends than diesel at all loading. With the increase in load mechanical efficiency of B20 increases in 17.5:1 compression ratio. With the increase in load specific fuel consumption of B10 decreases in 17.5:1 compression ratio. With the increase in load brake thermal efficiency of B10 increases in 17.5:1 compression ratio.

With the increase in load mechanical efficiency of B20 increases in 21:1 compression ratio. With the increase in load brake thermal efficiency of B20 increases in 21:1 compression ratio. With the increase in load, the specific fuel consumption of B10 decreases in 21:1 compression ratio.

Hence the blends B10 and B20 can be used as alternate substitutes for pure diesel. These blends sustain performance on par with pure diesel and also the pollution levels. Though a little higher carbon content is observed with this bio fuel in the exhaust, it can be dispersed in some liquid like water. With almost negligible extra maintenance, the bio fuels can replace pure diesel. More bio fuels have to be investigated and tested for their performance and pollution compatibility in the near future to safe guard the coming generations and to alleviate the fear of depleting fossil fuels.

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