

Performance Analysis of Variable Compression Ratio Diesel Engine using Calophyllum inophyllum Biodiesel

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Abstract

Objective: To analyze the performance and emission characteristics on variable compression ratio diesel engine using Calophyllum inophyllum biodiesel blends at various compression ratios. **Method/Statistical Analysis:** Blends of Calophyllum inophyllum biodiesel and diesel blends are prepared to use as fuel on variable compression ratio diesel engine. **Finding:** The variations on performance parameters like brake specific fuel consumption, brake thermal efficiency and exhaust emissions like nitric oxides, hydro carbon, carbon monoxide are assessed and analyzed. The experimental results showed reduction in brake thermal efficiency, nitric oxide and increase in brake specific fuel consumption, carbon monoxide, hydro carbon with Calophyllum inophyllum biodiesel blends than neat diesel.

Keywords: Calophyllum Inophyllum, Diesel, Engine Performance, Exhaust Emission, Variable Compression Ratio

1. Introduction

Search for the alternative sources of energy for internal combustion engine has become inevitable due to the environmental degradation and diminishing supply of petrodiesel. Biodiesel produced out of vegetable oils and animal fats are considered as the best alternative for fossil fuel. However, biodiesel feed stock produced from vegetable oils may compete with food supply. Hence much attention is paid on search for inedible vegetable oil. Calophyllum inophyllum oil is one of the solutions for the above said problem. Calophyllum inophyllum oil is an inedible vegetable oil with free fatty acids. In¹ examined the use of Calophyllum inophyllum oil (50%)-diesel (50%) blend on a diesel engine by varying the rate of injection of fuel by changing plunger

diameter. The experimental results showed higher Brake Thermal Efficiency (BTE), Carbon Monoxide (CO) and Hydro Carbon (HC) emission at 10 mm plunger diameter with Calophyllum inophyllum biodiesel blends than diesel. In² it was found that, with 100% C. inophyllum oil, the peak cylinder pressure, BTE and Nitric Oxide (NO_x) were decreased. In³ the results indicate 2.3% increase in BTE and 3% decrease in fuel consumption with 10% C. inophyllum biodiesel blend than diesel. It was also found that CO and smoke opacity reduced. In⁴ the experimental results showed 1.36% reduction in brake power and 4.9% increase in BSFC with biodiesel blends than diesel besides, increase in NO_x emission. The addition of oxidation inhibitors reduced NO_x by 2.6%. In⁵ concluded that 10% biodiesel blend showed significant reduction in CO and smoke emissions with slight increase in NO_x emis-

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sions. In⁶ they showed reduction in emissions with the turbulence created by enhancing fuel air mixture using the modified piston.

In⁷ experimental results showed greater reduction in fuel consumption at higher injection pressures with increase in NO_x emission. In⁸ peak cylinder pressure and heat release rates were higher than diesel. In⁹ experimental results showed lower NO_x and frictional coefficient than diesel. However, fuel consumption increased by 10%. In¹⁰ by using additives, exhaust gas emissions and brake thermal efficiency reduced and increased respectively. In¹¹ by adding additives, it was found that the fuel consumption and emissions are reduced.

The present study deals with the performance and emission analysis of a variable compression ratio diesel engine with Calophyllum inophyllum biodiesel blends at 16:1, 17:1 and 18:1 compression ratios.

2. Experimental Setup and Procedure

The test rig consists of a single cylinder variable compression ratio diesel engine with compression ratio in the range of 12:1 to 18:1. Eddy current dynamometer is coupled to the engine with loading unit. Air box is provided with orifice meter and a manometer for measurement of charge. Piezo sensor with range of 5000PSI is installed on the engine to analyze the combustion phenomenon. Crank angle sensor of 1 degree resolution with TDC pulse is attached to the engine. RTD K type thermocouples are fixed elsewhere to record temperatures of air intake, exhaust gas and cooling water. Strain gauge type load sensor with digital indicator is fixed on the test rig. Rotameters are provided for cooling water and calorimeter water flow measurement. Signals from various sensors are interfaced to the computer through high speed data acquisition system. Engine Soft, an engine performance analysis software is installed to analyze the P-V, P- Θ and heat release rates. The compression ratio is changed by a specially designed tilting cylinder block without stopping the engine. A five gas analyzer is attached to measure the concentration of emission. The line diagram of the experimental setup is shown in Figure 1 and the engine specifications are shown in Table 1.

1. VCR engine. 2. Eddy current dynamometer. 3. Data acquisition system. 4. Computer. 5. Air filter. 6. Exhaust gas analyzer. 7. Encoder. 8. Fuel tank. 9. Coupling. 10. Measuring burette.

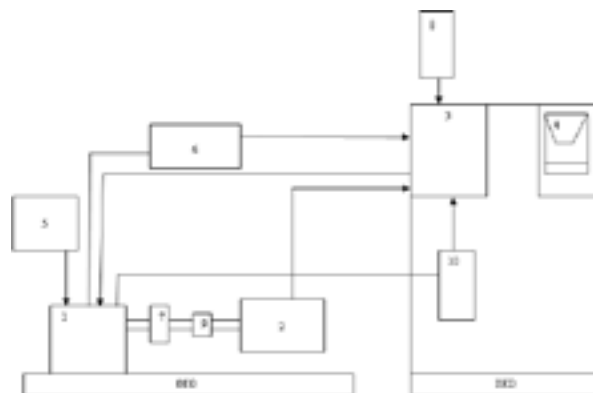


Figure 1. Line diagram of experimental setup.

Table 1. Specifications of the engine

Particulars	Specifications
Engine make	Kirloskar, Type 1
No of cylinders	Single
No. of strokes	Four
Bore & Stroke	87.5mm & 110mm
Power & Speed	5.5kW & 1500 rpm
Compression ratio range	12:1 to 18:1
Injection Pressure	200bar

Lubricating oil level and water supply is ensured before starting the engine and the engine is run at no load. The fuels used are D100 (Diesel 100%), C10D90 (Calophyllum inophyllum 10% + Diesel 90%) and C20D80 (Calophyllum inophyllum 20% + Diesel 80%). The tests are conducted at 25%, 50%, 75% and 100% load at compression ratios of 16:1, 17:1 and 18:1. In every test current, voltage, air consumption, speed, exhaust gas temperatures and exhaust gas emissions are recorded. The experiments are repeated twice and the average values are taken for calculations. From the recorded readings, brake power, BTE, BSFC are assessed and analyzed. The experimental setup is shown in Figure 2.

3. Results and Discussion

3.1 Brake Specific Fuel Consumption

Figure 3 shows the variation of BSFC for various blends of Calophyllum inophyllum biodiesel. It shows a gradual decrease in BSFC on increasing loads and by reduction in heat loss and better combustion at higher loads. Under full load conditions C10D90 and C20D80 exhibited more

BSFC than neat diesel. The BSFC increased by 17%, 18% and 16% for D100, C10D90 and C20D80 respectively by increasing in compression ratio. The BSFC increased by 8%, 13% and 9% for C10D90 than D100 at 18, 17 and 16 compression ratios respectively. This increase in BSFC with addition of Calophyllum inophyllum is due to the lower heating value of Calophyllum inophyllum biodiesel blends.



Figure 2. Experimental setup.

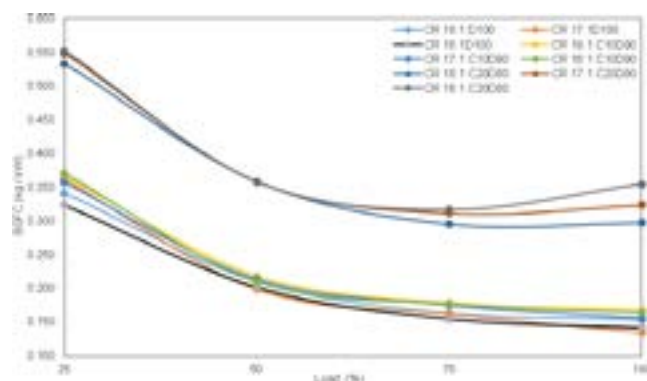


Figure 3. Brake specific fuel consumption vs load.

3.2 Brake Thermal Efficiency

The variation of BTE for different blends of fuel at varying compression ratios is shown in Figure 4. BTE steadily increased with increase of loads and with increase in compression ratio from 16 to 18. Higher power is developed due to the better mixing of fuel and air at higher loads and higher compression ratios. Hence, the BTE increases. There was 9%, 10.2% and 10.7% increase in BTE for D100, C10D90 and C20D80 respectively as the compression ratio was increased from 16 to 18. Neat diesel showed higher BTE than blends of Calophyllum inophyllum. This is due to the lower heating value and ignition delay of Calophyllum inophyllum biodiesel blends. With the

increase in composition of Calophyllum inophyllum, the BTE reduced further due to the increase in cetane number and viscosity.

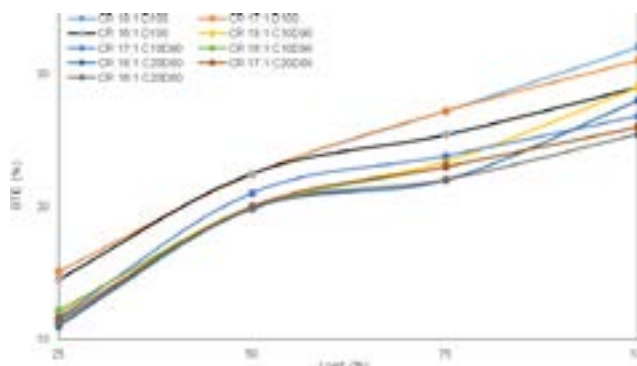


Figure 4. Brake thermal efficiency vs load.

3.3 Nitric oxide

Figure 5 shows the variations of NO_x emissions at various compression ratios for various blends of fuel. At higher temperatures in the combustion chamber, the monoatomic nitrogen is highly reactive which leads to the formation of nitric oxides. The NO_x emission was reduced as the compression ratio was reduced from 18 to 16. There was 36%, 43% and 42% reduction in NO_x for D100, C10D90 and C20D80 respectively. The richness of oxygen and longer residence time in Calophyllum inophyllum biodiesel blends caused the reduction in NO_x . With increase in the composition of Calophyllum inophyllum, the NO_x emission reduced further.

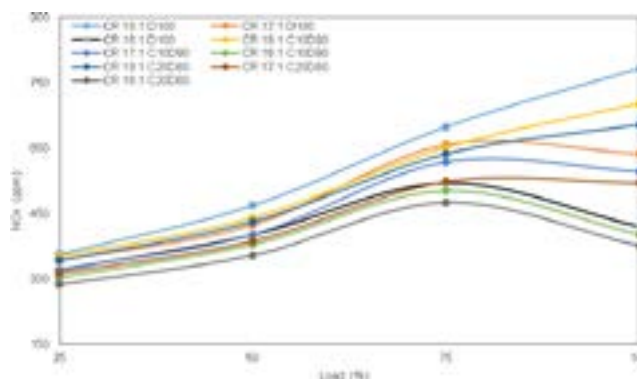


Figure 5. Nitric oxide vs load.

3.4 Hydro Carbon

The variations of HC emissions for various blends at various compression ratios are shown in Figure 6. As the compression ratio was reduced from 18 to 16, the HC emission was increased, there was 25%, 15% and 18%

increase for D100, C10D90 and C20D80 respectively. However, C10D90 blend at 18 compression ratio showed less HC emission than other blends. Due to the poor combustion at lower compression ratios lead to the increase in HC emission. Nevertheless, the HC emission reduced at higher compression ratios due to better air fuel mixture formation and higher charge turbulence.

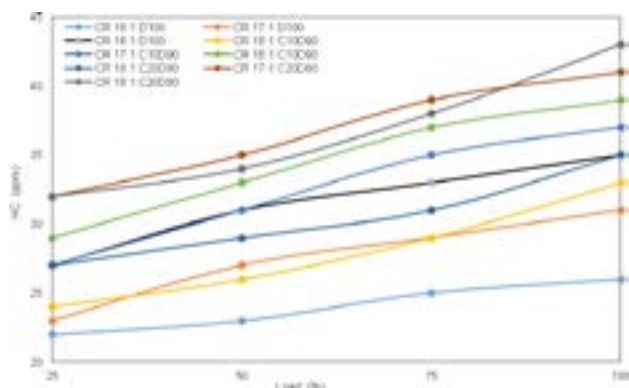


Figure 6. Hydro carbon vs load.

3.5 Carbon Monoxide

Figure 7 illustrates the CO emission for different blends at different compression ratios. The experimental results showed 25%, 21% and 13% increase for D100, C10D90 and C20D80 respectively as the compression ratio reduced from 18 to 16 under full load conditions. The deficiency in the oxygen lead to the increase in CO emission at lower compression ratios. However, the increase in CO emission is less for Calophyllum inophyllum biodiesel blends than diesel. Also, the reduction in peak cylinder temperature at lower compression ratios is inevitable for higher CO emission. C10D90 blend at 18 compression ratio recorded lower CO emission than other blends.

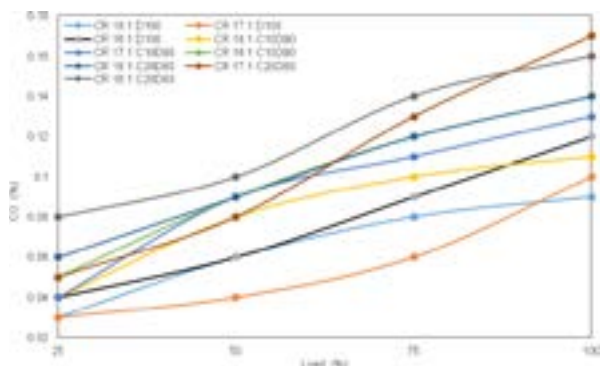


Figure 7. Carbon monoxide vs load.

4. Conclusions

An experimental study, to evaluate and analyze the performance and exhaust emissions of Calophyllum inophyllum biodiesel blends at various compression ratios on a variable compression ratio diesel engine and the conclusions are drawn as follows:

- As the compression ratio increases, the BSFC increases at full load. The BSFC for C10D90 and C20D80 are 0.141 kg/kWh and 0.298 kg/kWh respectively. The average increase in BSFC was 13% for Calophyllum inophyllum biodiesel blends.
- As the load increases, BTE of the fuel blends also increases. The maximum BTE for C10D90 and C20D80 were found to be 29% and 28% respectively. Whereas for D100, it was 32%.
- With the higher amount of oxygen and lower heating value of Calophyllum inophyllum biodiesel blends, NO_x emission reduced by 43% and 42% for C10D90 and C20D80 blends respectively.
- HC emission increased by 15% and 18% for C10D90 and C20D80 blends respectively.

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