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Experimental Investigation of Combustion and Emission Characteristics of Variable Compression Ratio Compression Ignition Engine Using Cotton Seed Oil Biodiesel Blends

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ABSTRACT

The increasing demand of petroleum and its availability is inversely to each other. This gives the new area to researcher to find out the solution to this problem. This problem is also concern with socioeconomically issue; the solution should be acceptable to each one. The alternative fuels derived from vegetable are the keen area of research, which are economical, environment friendly and easily available.

In this paper the cottonseed oil biodiesel blends is considered as fuel for variable compression ratio diesel engine. The combustion characteristics in terms of mass of fraction burnt is investigated for different compression ratio.

The emission characteristics are also investigated in comparison with petroleum diesel without any modification in engine. The results are compatible with petroleum diesel.

Keywords: Compression Ignition Engine, Variable Compression Ratio, Cotton Seed Oil Biodiesel, Combustion, Emission.

Introduction

All over the world, energy demand is increasing continuously, which also includes petroleum-based energy. Whereas petroleum products are the single largest energy resource that has been consumed mostly by the world's population, exceeding natural gas, coal, nuclear energy and renewables. The transport industry will utilize majorly liquid petroleum fuel, while the remaining is utilized by the industrial sector. Because of the rapid depletion of oil resources and increasing energy consumption, the attention is shifted toward alternative sources of energy that are renewable, sustainable, efficient, and cost-effective and environment friendly.

Biofuels, especially bioethanol and biodiesel, are the most viable liquid transportation fuels for the better future and can contribute significantly to sustainable development in terms of socioeconomic and environmental concerns. Liquid biofuels are manufactured from biomass that is mainly derived from agriculture resources (Soyabeen, Cottonseed, Jatropha etc.). Biofuels can be blended with conventional petroleum fuels without any major engine modification. Biodiesel is blended with petro diesel in any proportion by volume (petroleum diesel) for use in compression-ignition engines.

Furthermore biodiesel are environment friendly as it contains oxygen atom in chemical structure. They are also available generally on large scale. The crude oil is converted in to biodiesel by transesterification so as to reduce its viscosity, which may cause problem in combustion.

For the developing countries like India where most of the foreign currency is spend on petroleum purchase, biodiesel is a better option. In this work cottonseed oil biodiesel blends are preferred as fuel for CI engine. The reason is, India is second largest country in cotton seed oil production in the world.

Cottonseed Oil Biodiesel Blends

The Cotton seed oil is transesterified to get biodiesel and then Biodiesel blends were prepared by mixing the proportionate biodiesel in the diesel such as Blend B-10is prepared by mixing 10% of transesterified cotton seed oil in diesel. Similarly the other blends B-20, B-30, B- 40, & B-50 are prepared in a laboratory

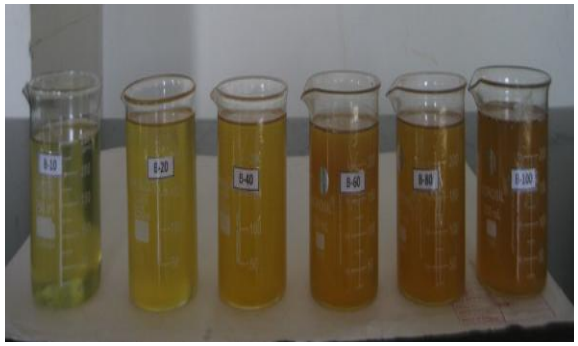


Figure 1: Cottonseed Oil Biodiesel Blends

Table 1
Properties of petroleum Diesel and Cottonseed Oil biodiesel

	Diesel	CSO Biodiesel					CSOME
		B-10	B-20	B-30	B-40	B-50	
Chemical Formula	$C_{14}H_{25}$	-	-	-	-	-	$C_{54}H_{101}O_6$
Kinetic Viscosity (mm2/s) at 400C	2.5	2.72	2.96	3.19	3.42	3.66	4.82
Density (kg/m3)	830	822.5	826	829	832.5	840	868
Higher Calorific Value (kJ/Kg)	42500	41900	41460	40870	40240	39580	37400
Flash point (OC)	66	130	140	145	148	152	156
Cetane Number	51	49	50	50	51	52	53
Cloud Point (OC)	-20	-17.5	-15	-12.5	-10.0	-7.5	-5
Pour Point (OC)	-24	-20.8	-17.7	-14.56	-11.42	-8.28	-5
Fire Point (OC)	62	57	59	61	65	70	120

Engine Specifications

The experimental test rig is suitably developed to conduct various test runs under different loading conditions to evaluate performance and combustion constituents of a bio-diesel run engine in comparison with that of a conventional diesel operated engine.

The experimental test rig consists of a variable compression ratio compression ignition engine, eddy current dynamometer as loading system, fuel supply system for both Diesel oil supply, biodiesel supply, water cooling system, lubrication system ,various sensors and instruments integrated with computerized data acquisition system for online measurement of load, air and fuel flow rate, instantaneous cylinder pressure, injection pressure, position of crank angle, The setup enables the evaluation of performance and combustion characteristics of the VCR engine. The performance parameters include brake power, brake mean effective pressure, brake thermal efficiency, and brake specific fuel consumption, and the combustion parameters such as, cylinder pressure, Net heat release rate, cumulative heat release rate, mean gas temperature, cylinder volume and mass of fraction burnt. Commercially available Engine Performance & combustion Analysis software package 'ICEnginesoft' is used for on line evaluation.

Table 2
Technical Specifications of Variable Compression Ratio Diesel Engine

Make & Model	Kirloskar Oil Engine TV1
Type	Four stroke, Water cooled, Diesel
Number of cylinder	One
Bore and Stroke	87.5 mm and 110 mm
Cubic capacity	0.661 liters
Compression ratio	17.5 :1 (modified to work at 12.5, 13.5, 14.5, 15.5, 16.5)
Peak cylinder pressure	77.5 kg/cm2
Fuel injection timing for standard engine	23^0 BTDC
Valve clearances at inlet and exhaust	0.18 mm and 0.20 mm
Connecting rod length	234 mm

Method

- Start the engine by hand cranking and allow it to run at idling condition for 5 minutes.
- Click on "Scan Start" on the monitor
- Ensure that Speed, Temperatures and Manometer reading are correctlydisplayed on the PC. These readings should tally with those displayed on theengine panel.
- Increase the load on the engine by rotating knob on the DLU and confirm the load reading on the indicator and computer are same.
- Adjust DLU knob and to set 0.5 kg load on Load Indicator. Wait for 3 mins. ensure that load is constant during this period. Change the Fuel cock position from "Tank" to "Measuring". Click "Log on" on. The fuel metering is ON for next 60 seconds. During first 30 seconds enter engine water flow, calorimeter jacket cooling water flow in LPH (and compression ratio for VCR engine). Click OK after recording fuel reading. Enter the file name under which the records to be stored. The first reading data is now saved. Change the Fuel cock position from "Measuring" to "Tank".
- Adjust DLU knob and to set 3 kg load on Load Indicator. Wait for 3 mins., ensure that load is constant during this period. Change the Fuel cock position from "Tank" to "Measuring". Click "Log on" on. The fuel metering is ON for next 60 seconds. During first 30 seconds enter engine water flow, calorimeter jacket cooling water flow in LPH (and compression ratio for VCR engine). Click OK after recording fuel reading. The second reading data is now saved. Change the Fuel cock position from "Measuring" to "Tank".
- Repeat above step for various loads

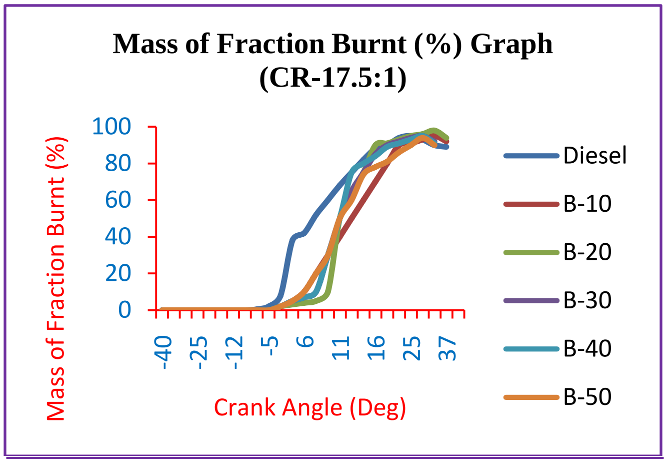
Results:

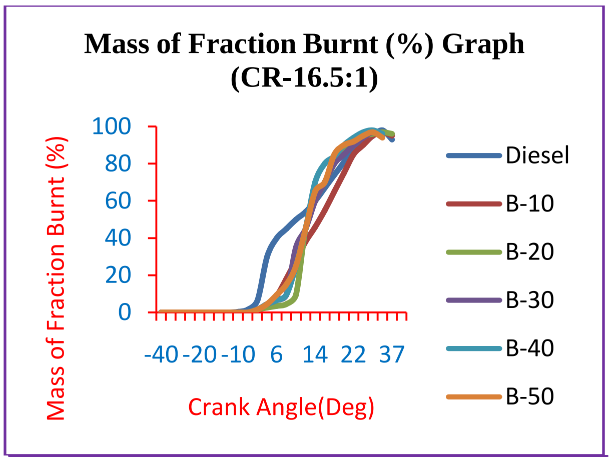
The combustion process of test fuel consists of two phases, phase of premixed combustion followed by a phase of diffusion combustion. Premixed combustion phase is controlled by the ignition delay period and spray pattern of the injected fuel. Therefore, the viscosity and volatility of the fuel plays a very important role to increase atomization rate and to improve air-fuel mixing formation.
In this work combustion properties such as mass of fraction burnt is investigated with respect to crank angle.

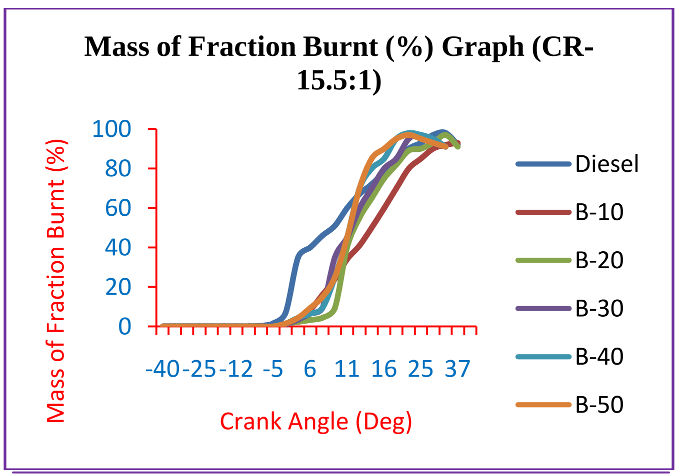
1. **Combustion characteristics**

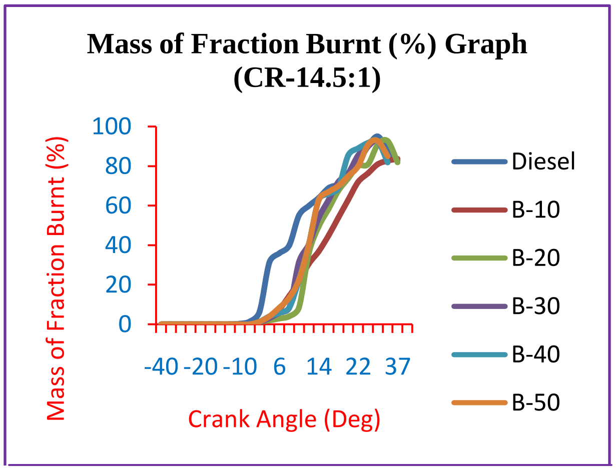
1.1 The Mass Fraction Burnt

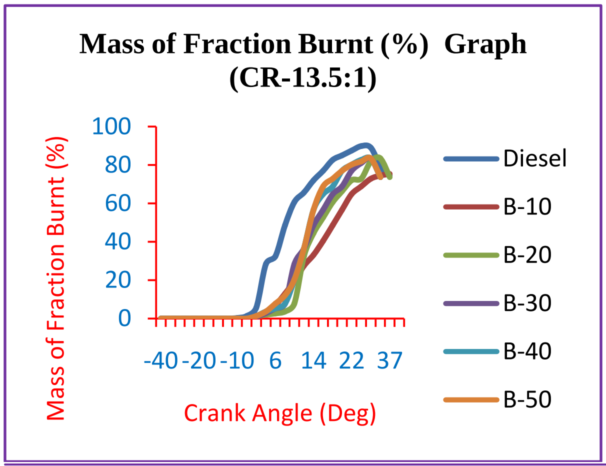
The mass fraction burnt for cotton seed oil biodiesel blends is slightly higher at lower compression ratios and closely follows the standard diesel at higher compression ratios. The mass fraction burnt of cotton seed oil biodiesel blends is slightly higher than that of standard diesel. Total duration of combustion is shorter for biodiesel and diesel blends while comparing with standard diesel. As the calorific value of the biodiesel blends is lower than diesel, a higher quantity of fuel is consumed to keep the engine speed stable at different loads. (Figure 2)











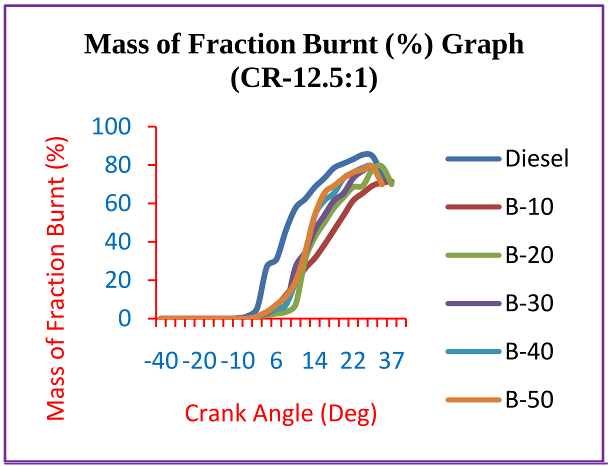


Figure 2. Variation of mass of fraction burnt with crank angle

2. **Emission Characteristics**

2.1 Carbon Monoxide Emission

The variation of CO emission with different compression ratios for different blends of Cottonseed oil biodiesel (B10, B20, B30, B40 and B50) and diesel at different load is given in Figure 3. It shows that the CO emission is found to be decreasing with increase in compression ratios. This may be due to better air fuel mixing at higher compression ratio leading to proper atomization of the fuel while presence of additional oxygen molecule in the blends improves the combustion resulting decrease in CO emission.

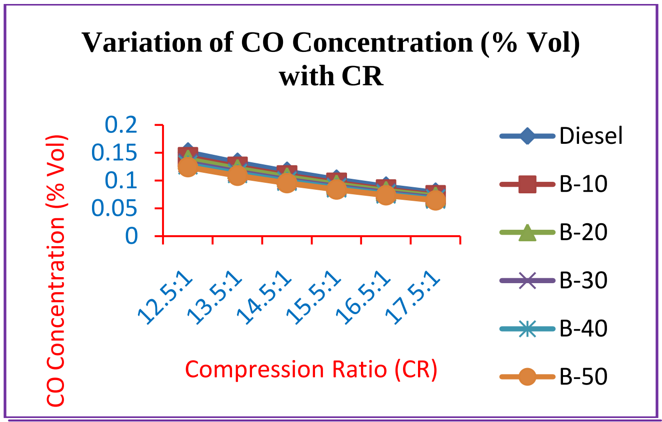


Figure 3: Variation of CO emission with compression ratio for diesel and all cotton seed oil methyl esters at different load conditions

2.2 Hydrocarbon Emission

HC emission is a complex issue in which the fuel composition can be of great importance. It consists of fuel that is completely unburnt, or only partially burned. Typically, HC emissions are serious problem at light loads for diesel engines. The variation of hydrocarbon emission with different compression ratios for blends of Cottonseed oil biodiesel (B10, B20, B30, B40 and B50) and diesel is shown in Figure 4. Increase in CR decreases the ignition delay of the biodiesel blends which improves the combustion process. At the same time, higher blends affect the atomization due to higher viscosity compared to conventional diesel leading to increase in HC emission.

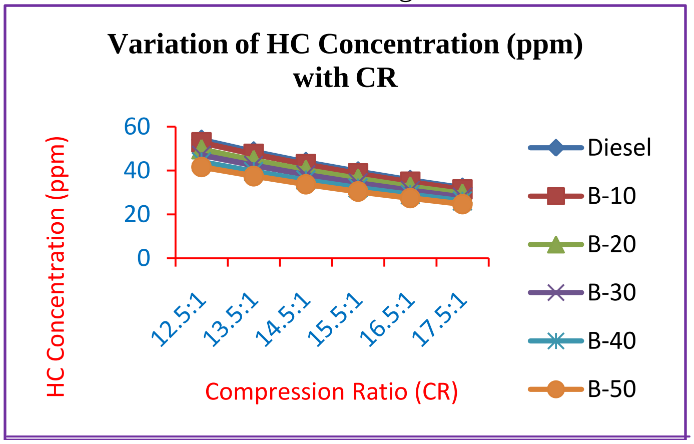


Figure 4: Variation of HC emission with compression ratio for diesel and all cotton seed oil methyl esters at different load conditions

2.3 Nitrogen Oxides Emission

Generally, NOx forms at the high temperature burnt gas regions. The variation of NOx emission with respect to different compression ratios for all fuels is shown in Figure 5. The NOx emission for diesel and other blends increase with increasing compression ratio. This may be due to better mixing of fuel and air at higher compression which ratios improves the combustion process leading to higher combustion temperature. Simultaneously, additional oxygen molecules present in the biodiesel increases the oxygen concentration in the combustion chamber which enhances NOx emission.

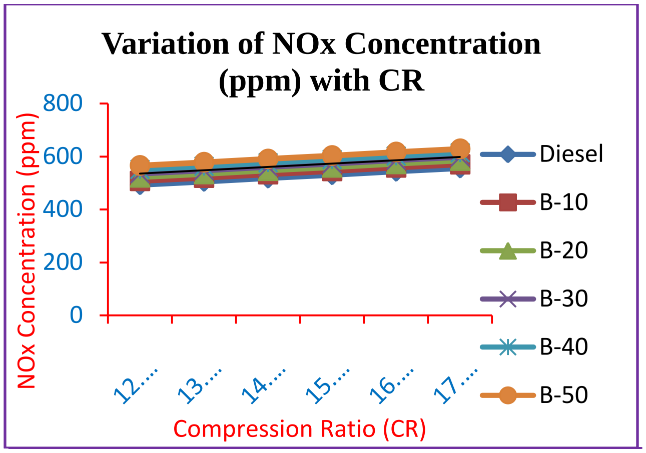


Figure 5: Variation of NOx emission with compression ratio for diesel and all cotton seed oil methyl esters at different load conditions

2.4 Smoke

The variation of smoke with respect to different compression ratios for different blends of Cottonseed oil biodiesel (B10, B20, B30, B40 and B50) and diesel is shown in Figure 6. The formation of smoke primarily results from the incomplete combustion of the hydrocarbon fuels. It is observed that smoke decreases with increase in compression ratio. This may be due to better mixing of fuel and air at higher compression ratios. B10 and B20 give higher smoke compared to diesel.

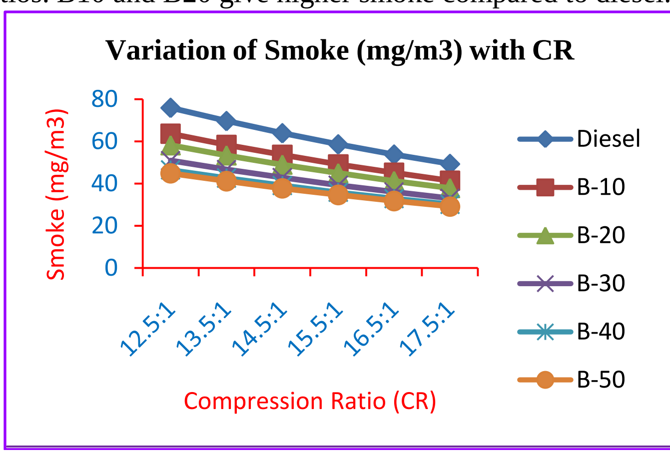


Figure 6: Variation of Smoke emission with compression ratio for diesel and all cotton seed oil methyl esters at different load conditions

CONCLUSION

- The mass fraction burnt of cotton seed oil biodiesel blends is slightly higher than that of standard diesel
- In the case of biodiesel blends more fuel is required because of less calorific value of these blends than diesel. These factors lead to longer combustion duration for biodiesel blends.
- CO emission is found to be decreasing with increase in compression ratios.
- Higher blends affect the atomization due to higher viscosity compared to conventional diesel leading to increase in HC emission.
- The NOx emission for diesel and other blends increase with increasing compression ratio.
- smoke decreases with increase in compression ratio

- Engine operation was observed satisfactory with cottonseed oil biodiesel blend fuels. Hence it can be concluded that biodiesel (cottonseed methyl ester) and its blends can be used in the engine without any modification.

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