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Experimental Investigation of Performance Characteristics of Calophyllum Inophyllum Biodiesel in CI Engine by Varying Compression Ratio

Rahul Krishnaji Bawane, S.V. Channapattana, Nilima Baliram Gadge, Sandip M. Ingole

***Abstract*— In a modern day world alternative source of energy are given importance due to gradual depletion of fossil fuels reserves vegetable oils can be used as an alternative to diesel in CI engines. The use of vegetable oils in CI engine results in low CO and HC emissions compared to conventional diesel fuel. The present study covers the various aspects of biodiesels fuel derived from calophyllum inophyllum oil, which is converted to calophyllum inophyllum methyl esters (CIME) by transesterification process. An experiment is conducted to obtain the operating characteristics of the variable compression ratio (VCR) engine run on biodiesl made from calophyllum inophyllum oil, at various compression ratio, and the results are compared with diesel. From the comparison of results, it is inferred that the engine performance is improved with significant reduction in emissions for the chosen biodiesel without any engine modification. The effective compression ratio can be fixed based on the experimental results obtained in the engine since the findings of the present research work infer that the biodiesel obtained from Calophyllum Inophyllum oil is a promising alternative fuel for direct-injection four-stroke VCR engine.**

***Index Terms* — Biodiesel, Calophyllum Inophyllum oil, Transesterification, Various Compression Ratio, Performance and Emission Characteristics**

I. INTRODUCTION

The twenty-first century introduced an era of increased global petroleum demand that has not been met with an increase in oil production. The most practical and least disruptive strategy to achieve the objective of lowering dependency on petroleum is to use alternative fuels. Biodiesel is a diesel fuel alternative produced from oil seeds, primarily soy, and can be grown and produced domestically. Among the many alternative fuels biodiesel are considered as a most desirable fuel extender and fuel additive due to its high oxygen content and renewable in nature. Alternative fuel termed as Biodiesel is obtained from non-edible oil seeds, vegetable oil, and Animal fats. Chemically biodiesel is referred as mono-alkyl esters of long chain fatty acid derived from renewable biological sources.

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It can be directly used in the compression ignition engine. Biodiesel fuel is a clean burning alternative fuel that comes from 100% renewable resources. Many people believe that Biodiesel is the fuel of the future. Sometimes it is also known as Bio-fuel. Biodiesel does not contain petroleum, but petroleum can be mixed to produce a biodiesel blend that can be used in many different vehicles. Pure biodiesel fuel though, can only be used in diesel engines. Biodiesel is biodegradable and non-toxic.The main objective of this work is to analyze the engine emission characteristics of diesel engines fuelled with biodiesel produced from 'Calophyllum Inophyllum Linn (honne) Oil' and/or its blends with diesel fuel, which will help in both the direction of reducing emission problems and search of alternative fuel for CI engines.

II. MATERIAL AND METHOD

Calophyllum Inophyllum Linn (hone) oil contains 19.58% free fatty acids. The methyl ester is produced by chemically reacting Calophyllum Inophyllum Linn (honne) oil with an alcohol (methyl), in the presence of catalyst (Sodium Hydroxide). A two stage process is used for the transesterification of Calophyllum Inophyllum Linn (honne) oil. The first stage (acid catalyzed) of the process is to reduce the free fatty acids (FFA) content in oil by esterification with methanol (99% pure) and acid catalyst sulfuric acid (98% pure) in one hour time at 57ºC in a closed reactor vessel. The oil is first heated to 50ºC then 0.7% (by wt. of oil) sulfuric acid is to be added to oil and methyl alcohol about 1:6 molar ratio (by molar mass of oil) is added. Methyl alcohol is added in excess amount to speed up the reaction. This reaction was proceeding with stirring at 650 rpm and temperature was controlled at 55-57ºC for 90 min. The fatty ester is separated after natural cooling. At second level, the separated oil from the separating funnel has to undergo transesterification. Methoxide (methanol + sodium hydroxide) is added with the above ester and heated to 65°C. The same temperature is maintained for 2 hr. with continuous stirring, and then, it undergoes natural cooling for 8 hr. Glycerol will deposit at the bottom of the flask, and it is separated out by a separating funnel. The remnants in the flask are the esterified vegetable oil (biodiesel). The separated biodiesel from the above-mentioned method contains various impurities like traces of glycerol, unused methanol, soap particles, etc. Water washing is carried out to remove all impurities.

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Air bubble wash is one of the methods normally recommended in the laboratory level. In this method, the impure biodiesel is placed in a beaker initially. Water is added slowly through the side wall of the beaker (both are immiscible). It is ensured that the equal amount of water is added above the level of biodiesel. Air is made to pass through the biodiesel and the water from the bottom of the beaker with the help of a bubbler (electrically operated). The air will then take away all impurities from the biodiesel; they will move up as the bubbles move up, and they are added in the water. The unused methanol will be diluted in water. The traces of glycerol and soap particles make the water to become like soap water. Once the water becomes like soap water, the bubbler is stopped. After allowing some time for impurities to settle, the biodiesel is drained from the separating funnel, and pure biodiesel will be directly used, with or without blending, in the engine.

III. Methodology

As per the present authors' knowledge the use of blends of Calophyllum Inophyllum Methyl Ester – CIME in diesel engine at full load conditions and blend proportion, by varying compression ratio are not reported in the literature. The objective of the present work is to study through experiments on the performance and eimmision characteristics of CIME blends in direct injection (DI) diesel engine at various compression ratio.

Table I: Biodiesel Blends Used for Experimentation

Blend Type	*Blend*	*IOP in bars*	*Injection Timing in degree bTDC*	*Compression Ratio*
H00	100% Diesel	210	27	17.5 : 1
H25	25% CIME + 75% Diesel			16.5 : 1
H50	50% CIME + 50% Diesel			15.5 : 1
H75	75% CIME + 25 Diesel			14.5 : 1

The properties of CIME (H100) and Diesel (H00) and Calophyllum Inophyllum Oil were determined as per the methods approved by Bureau of Indian Standards.

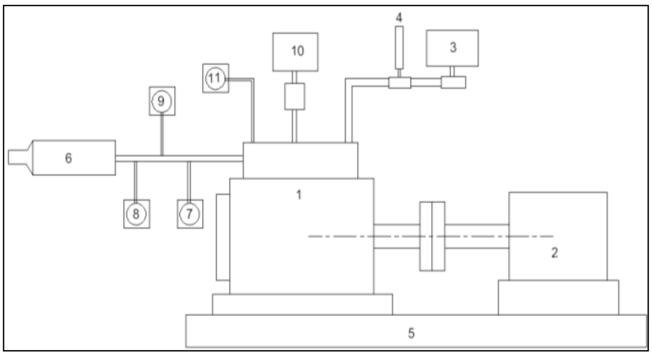
Table II: Characteristics of Fuel Used

Parameter	*Test Standard*	*Diesel (H00)*	*CIME (H100)*	*Honne Oil*
Density at 15ºC (gm/cc)	IS 1448 (P16) 2007	0.835	0.8653	0.9363
Kinematic Viscosity at 40ºC (cst)	IS 1448 (P25) 2007	3.5	1.744	51.58
Calorific Value (MJ/Kg)	IS 1448 (P6) 2007	43.00	35.37	40.27
Flash Point (ºC)	IS 1448 (P69) 2013	44	8.5	220

Table III: Engine Specifications

Sr. No.	*Description*	*Specification*
1	Make	Rocket Engineering Model VRC-1
2	Bore	80 mm
3	Stroke	110 mm
4	Swept Volume	553 mm
5	RPM	1500
6	Brake Horse Power	5 HP
7	Compression Ratio	17.5 : 1
8	Fuel Oil	High Speed Diesel
9	Coefficient of Discharge	0.65
10	Water Flow Transmitter	0 to 10 lit./min.
11	Air Flow Transmitter	0 to 250 wc
12	Piezo Sensor	0 to 5000 psi with low noise cable
13	Software	Labview

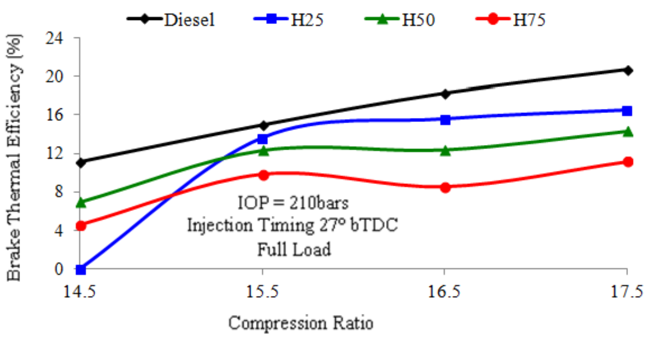
Figure I: Engine Setup



1. Test Engine, 2. Electrical Dynamometer, 3. Fuel Tank, 4. Fuel Burette, 5. Test Bed, 6. Silencer, 7. Smoke Meter, 8. HC/CO/NOx/CO2/O2 Analyzer, 9. Exhaust Temperature Sensor, 10. Air Flow Meter, 11. Stop Watch

IV. Results and Discussion

A. *Variation of Brake Thermal Efficiency*



It has been observed from the graph there is a steady increase in brake thermal efficiency as compression ratio increases.

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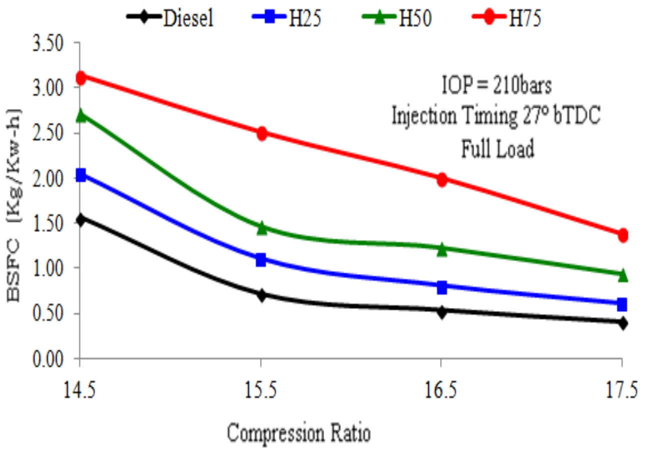
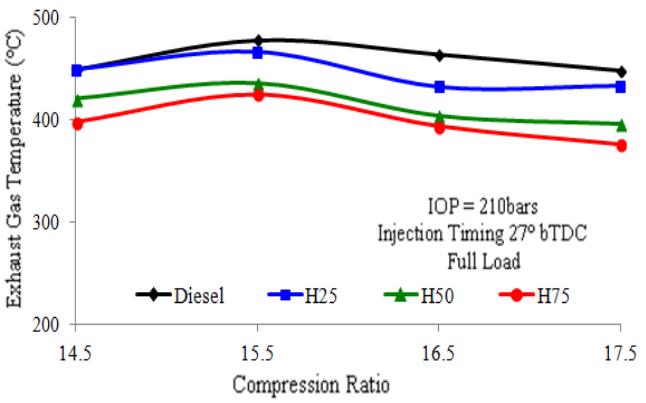
Biodiesel and its blends results in decreased brake thermal efficiency as compared to diesel over the entire range of compression ratio., which is as per expected, due to oxygen present in the Calophyllum Inophyllum oil molecules improves the combustion characteristics but poor volatility result in poor atomization and poor spray characteristics. The poor spray pattern may affect the homogeneity of air fuel mixture which in turn lower the heat released rate thereby reduction in brake thermal efficiency than diesel. Also the lower heating value of biodiesel leads to injection of higher quantities of fuel as compared to diesel for the same load conditions hence, decrease in brake thermal efficiency.

B. Variation of BSFC



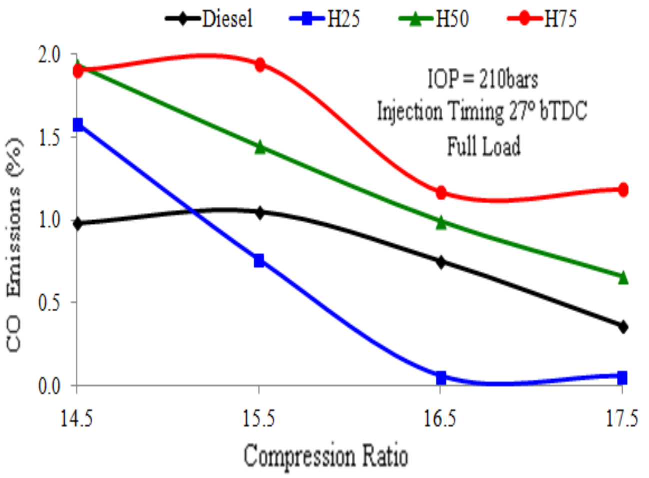
The brake specific fuel consumption (BSFC) decreases with the increase in compression ratio, as expected. This is because of , at higher compression ratio power generated is more, with respect to fuel consumption rate. BSFC for biodiesel and its blends are higher than that of diesel. This is due to lower heating value of biodiesel, lower the power generation for the same fuel consumption rate as compared to diesel.

C. Variation of Exhaust Gas Temperature (EGT)



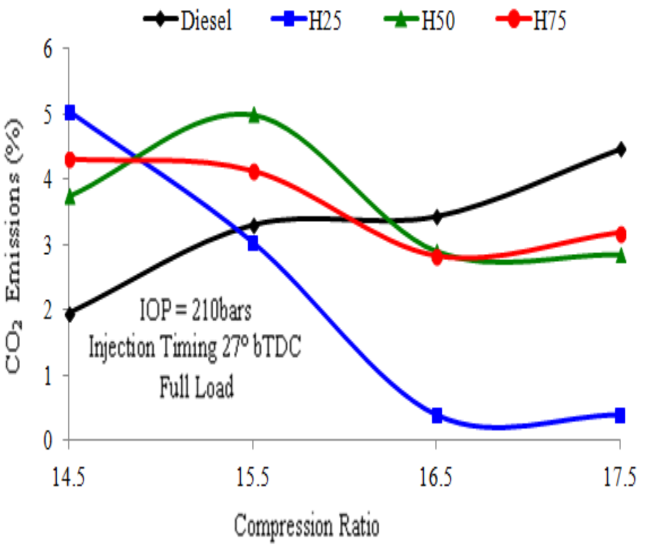
The result indicates that the variation in exhaust gas temperature is minimal and showing the same trend at full load condition, irrespective of blend proportion. These performance characteristic curves of the biodiesel and its blends have been compared by with the diesel and found at all conditions, Exhaust Gas Temperature are lower than that of diesel. When the compression ratio is increased, EGT decreases, this could be due to low viscosity of biodiesel, which improve the spray formation in combustion chamber and thus leads to a less dominant diffusion combustion phase than diesel.

D. Variation of Carbonmonoxide (CO)



The percentage of CO emission for low compression ratio increases due to the rising temperature in the combustion chamber. The CO emission of the biodiesel and its blends are found to be lower for high compression ratio. The effects of compression ratio on CO emissions are higher at lower compression ratio, however, decreased at higher compression ratio. This is due to relatively complete combustion takes place at higher compression ratio. The CO emissions for biodiesel and its blends are higher, compared to diesel over the entire range of fuel blends, except H25, due to poor volatility of biodiesel resulting in poor mixing, rich pockets formed in combustion chamber, and consequently, poor combustion, which leads to higher CO emission.

E. Variation of Carbondioxide (CO_2)



From the graph, the biodiesel and its blends emits lower percentage of CO2 as compared to diesel at higher compression ratio, this is because of the vegetable oil contains oxygen contents in it, so the carbon content is relatively lower in the same volume of fuel consumed at the same compression ratio, due to this CO2 emissions would have been decreased compared to diesel.

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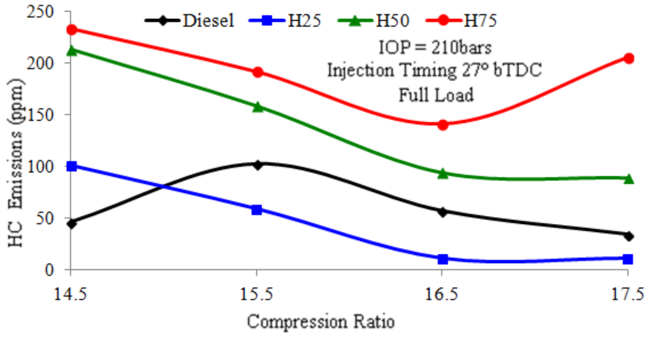
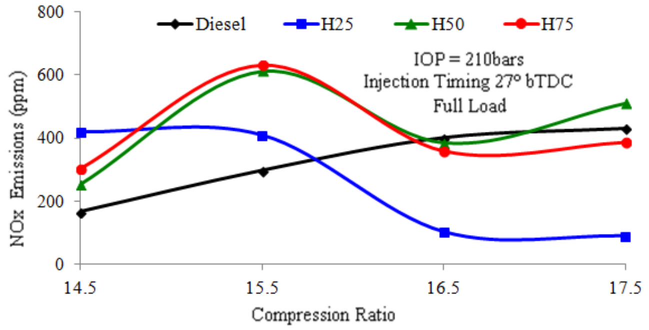
At lower compression ratio, incomplete combustion of high carbon content diesel fuel causes less CO2 emissions as compared to biodiesel and its blends, but in the present work CO2 emissions of H25 blend which have minimum biodiesel, shows highest CO2. This requires further investigations.

F. Variation of Hydrocarbon (HC)



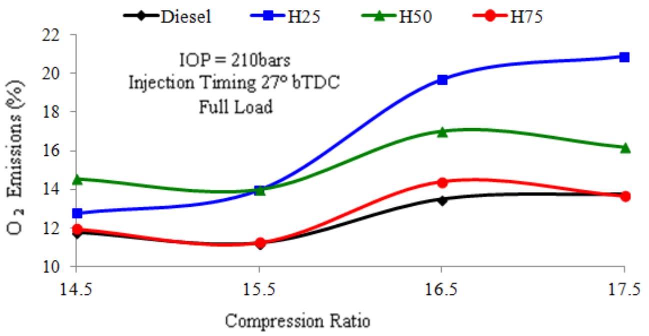
The HC emission decreases with increase in compression ratio for the entire range of fuels, this is due to the complete combustion of fuel at a higher compression ratio, hence less amount of HC will emits. The effects of compression ratio on HC emissions is higher at lower compression ratio, as expected, this is due to relatively less compression which retard the reactions of combustion, because of poor volatility, the poor spray characteristics, poor mixing, rich pockets formed in combustion chamber.

G. Variation of Oxides of Nitrogen (NO_x)



From the graph, it is observed that the NOx emission for entire range of fuel is higher at the compression ratio 15.5, this is due to highest temperature is observed at this compression ratio. But the expected was, highest NOx emission obtained at highest compression ratio 17.5, as the higher peak temperature observed with higher compression ratio. This requires further investigations.

H. Variation of Oxygen (O_2)



The O2 emission increases continuously with increases in compression ratio, this is due to increases in compression ratio , there is complete combustion thus oxygen requirement is mainly for CO2, but at lower compression ratio, there is more oxygen used in formation of CO, NOx in addition to that of CO2, thus oxygen content in exhaust gases is decreased. Biodiesel and its blends shown higher O2 emission as compared to diesel for full load conditions, this is because of vegetable oil contains oxygen consent in it, so the overall carbon content is relatively lower, thus excess oxygen is remains in exhaust emissions.

V. CONCLUSIONS

The study aims to evaluate the suitability of using biodiesel as an alternative fuel in VCR engine. Experimental investigations were carried out on the operating characteristics of the engines. The following conclusions are drawn from the investigations,

- Biodiesel and its blends results in slightly decreased brake thermal efficiency as compared to diesel over the entire range of compression ratio. – This is due to biodiesel from Calophyllum Inophyllum oil, have poor volatility result in poor atomization and poor spray characteristics, which lead to poor homogeneity of air fuel mixture which in turn lower the heat released rate thereby reduction in brake thermal efficiency than that of diesel.
- BSFC for biodiesel and its blends are higher than that of diesel. – This is due to lower heating value of biodiesel, lower the power generation for the same fuel consumption rate as compared to diesel.
- Exhaust Gas Temperature, EGT, for the biodiesel and its blends found lower at all conditions as compared to diesel. – This could be due to low viscosity of biodiesel, which improve the spray formation in combustion chamber and thus leads to a less dominant diffusion combustion phase than diesel.
- The CO emissions are higher at lower compression ratio, and decreased at higher compression ratio. – This is due to relatively complete combustion takes place at higher compression ratio.
- The CO emissions for biodiesel and its blends are higher, compared to diesel over the entire range of fuel blends. – This is due to poor volatility of biodiesel resulting in poor mixing, rich pockets formed in combustion chamber, and consequently, poor combustion, which leads to higher CO emission
- The biodiesel and its blends emits lower percentage of CO2 as compared to diesel at higher compression ratio. –This is because of the vegetable oil contains oxygen contents in it, so the carbon content is relatively lower in the same volume of fuel consumed at the same compression ratio.
- The HC emission decreases with increase in compression ratio for the entire range of fuels, and for biodiesel and its blend it is higher than diesel. – This is due to the complete combustion of fuel at a higher compression ratio, hence less amount of HC will emits. Biodiesel and its blends, due to poor volatility and poor mixing retard the chemical reaction which results in higher HC emission as compared to diesel.

- The NOx emission for entire range of fuel is higher at low compression ratio this is due to highest temperature is observed at this compression ratio. But the expected was, highest NOx emission obtained at highest compression ratio as the higher peak temperature observed with higher compression ratio.
- The O2 emission increases continuously with increases in compression ratio – This is due to increases in compression ratio , there is complete combustion thus oxygen requirement is mainly for CO2, but at lower compression ratio, there is more oxygen used in formation of CO, NOx in addition to that of CO2, thus oxygen content in exhaust gases is decreased.
- Biodiesel and its blends shown higher O2 emission as compared to diesel – This is because of vegetable oil contains oxygen consent in it, so the overall carbon content is relatively lower, thus excess oxygen is remains in exhaust emissions.

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