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Performance Analysis of Variable Compression Ratio Diesel Engine using Methyl Ester of Cotton Seed Oil blend with Diesel

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ABSTRACT

Variety of vegetable oils are available as alternate fuels but due to their high viscosity and low volatility, they are blended with diesel. Aim of the present work is to evaluate performance of diesel engine fuelled with blends of methyl ester of cotton seed oil and diesel. Filtered cotton seed oil is converted into its methyl ester using transesterification process. Engine used is four stroke, single cylinder, variable compression ratio water cooled engine. Results show higher brake thermal efficiency and lower brake specific fuel consumption for B10 as compared to other blends.

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Introduction

Among many issues India has to tackle on its way to sustainable development prominent are Energy, fuels and pollution. Energy sector is highly reliable on imports of petroleum products. Petroleum products import have increased by 170% in quantity and 363% by value from 2004-05 to 2011-12. [1] The major contribution to energy consumption comes from diesel engines used in various fields like Transport, Agriculture, Constructions, passenger cars, etc., thanks to subsidised rates of the fuel. Diesel engine exhaust is a rich source of air pollutants like SPM and NOx. Use of alternative technology and alternate fuels is a solution to overcome these issues. [2][3]

Any alternative fuel to be used as substitute or diesel should be checked for its feasibility. Then only it can be produced on a mass scale for commercial use making its price affordable for end users. The potential alternative fuels available are Alcohols (Methanol and Ethanol), Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), Hydrogen and Vegetable oils. Any vegetable oils can be directly mixed with diesel. The use of vegetable oils as engine fuels can help to reduce the environmental hazards of fossil fuels. Vegetable oils have good ignition characteristics. But they also have demerits such as build-up of carbon deposits, high density, more molecular weight, high viscosity, lower calorific value and poor combustion. These problems lead to poor thermal efficiency. These problems can be remedied by using methods like Dilution (blending), Pyrolysis (cracking), Micro-emulsification and transesterification which reduce the viscosity of vegetable oils. [4]

Biodiesel is fuel derived from renewable biological resources for use in diesel engines. It is a liquid fuel with similar combustion properties to petrol or diesel. Biodiesel is oxygen rich fuel so emissions of carbon monoxide and soot are reduced. Source for biodiesel is mostly vegetable oils/animal fats. Thus it may improve the energy security and economic independence. Further biodiesel obtained from vegetable sources does not contain any sulphur, aromatic hydrocarbons, metals or crude oil residues. [5]

Transesterification

Transesterification is the chemical process used to convert the vegetable oil by reaction with alcohol, typically methanol, to form esters and glycerol. The factors which affect the process are alcohol used, molar ratio of glycerides to alcohol, catalyst, reaction temperature, reaction time and water content of vegetable oils. The PH value of cotton seed oil is beyond 7, so NaOH is used as catalyst for the transesterification process.

The cotton seed oil is heated up to 60°C on a hot plate. Then the methanol 30ml and the catalyst (NaOH) 0.5gm per 100ml of oil are added. The mixture is stirred continuously at a fixed speed. Heat up to three hours and switch off the system until cooled. The Glycerin present in the vegetable oil settles down at the bottom as it is heavy. The esters are at top layer being lighter can be separated from the Glycerin by using the separating funnel. The biodiesel is washed with water repeatedly for 4 to 5 times to make sure no glycerin is left. Further the biodiesel is heated at about 100°C to remove any water content. Approximately 0.8 liter Methyl ester of Cotton seed oil is obtained per liter of raw cotton seed oil. [6]

Properties of fuels

Table 1. property of fuels

Property	Diesel	Methyl ester of Cotton Seed oil
Density(kg/m^3) at 15 °C	821.5	875
Kinematic viscosity (cSt)	3.01	5.2
Flash point °C	53	171
Fire point °C	61	182
Calorific Values(KJ/kg)	43000	39648
Cetane No	52	51

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Properties of Blends

Blends of ester with diesel are prepared in quantity of 4 liter each for B10, B25 and B50.

Table 2. Property of Blends

Property	Diesel	Methylester of Cotton Seed oil	B10	B25	B50
Density(kg/m^3) at 15 ^oC	821.5	875	826.85	834.875	848.25
Kinematic viscosity (cSt)	3.01	5.2	3.229	3.5575	4.105
Flash point ^oC	53	171	64.8	82.5	112
Fire point ^oC	61	182	73.1	91.25	121.5
Calorific Values(KJ/kg)	43000	39648	42664.8	42162	41324
Cetane No	52	51	51.9	51.75	51.5

Eexperimental Set Up

The experimental set up used in this experiment consists of a single cylinder, four stroke, constant speed, water cooled, variable compression ratio, and direct injection compression ignition engine. The specifications of the engine are shown in Table 3.The engine was coupled to an eddy current dynamometer with a load cell. The In-cylinder pressure was measured by piezoelectric pressure transducer fitted on the engine cylinder head. A crank angle encoder was used to sense the crank position. Variable compression ratio is achieved using tilting head method. Compression ratio can be varied using manual adjustment provided at rear of engine. The test rig is in communication with computer. Using ICEngineSoft software data can be retrieved and stored as well as results obtained are exported using an excel sheet. Multi layered plots can be generated. Computerized test rig helps to save time for test runs using different blends.

Table 3. Engine Specifications

Particular	Details
Make	Kirloskar engines Ltd, Pune,
Engine	Single Cylinder, Four Stroke, Constant Speed, Water Cooled, Variable Compression Ratio, Direct Injection Compression Ignition Engine
Rated Power	3.7 kW at 1500 RPM
Bore x Stroke	80 mm x 110 mm
Compression Ratio	12.5 to 21.5 (Manual Adjustment)
Dynamometer	Eddy current dynamometer with a load cell
Software	ICEngineSoft V8.5

Experimental Procedure and precaution

Experiment were carried out for pure Diesel (B0), 10% Bio Diesel (B10), 25% Bio Diesel (B25) and 50% Bio Diesel (B50). For each blend, Compression ratio were to be varied in steps of 14, 16 and 18. Hence twelve engine run are required to analyze the engine performance. Matrix generated from these is used for final result. For each test, engine load is varied from 0.5 kg to 15 kg in steps of 3 kg.

The important operating parameters to note down are engine speed, brake power, fuel consumption, and cylinder pressure were measured. Significant engine performance parameters evaluated are Brake Specific Fuel Consumption (BSFC) and Brake Thermal Efficiency (BTE) for each blend.

Before start of new engine test, fuel blend from previous test left in the supply lines was consumed entirely by running engine idle for couple of minutes. Engine readings were reported only after steady state is achieved after running engine for few minutes further and by observing the exhaust gas temperatures. Following flow chart illustrates the procedure adopted for the experiment.

Result and discussion

Performance Characteristics

Performance Characteristics of the Engine like Brake Specific Fuel Consumption (BSFC) and Brake Thermal Efficiency (BTE) for each blend and effect of variation in Compression Ratio are calculated and plotted on graph.

The fuel consumption characteristics of an engine are expressed in terms of specific fuel consumption in kilograms of fuel per kilowatt-hour. It reveals how good the engine performance is.

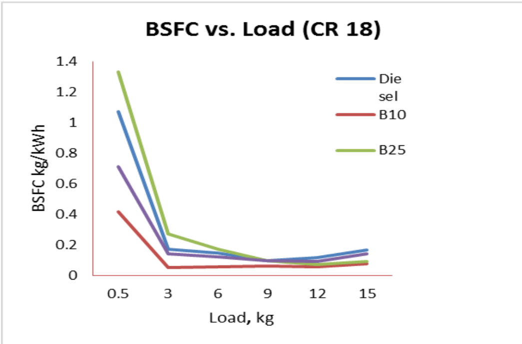

Figure 1. Brake Specific Fuel Consumption against load at CR 18 for various blends.

For compression ratio of 18:1, blend of B10 shows the minimum fuel consumption than other blend and diesel as seen from figure 1. This advantage is significant at part loads and diminishes as the engine is run at full load and above.

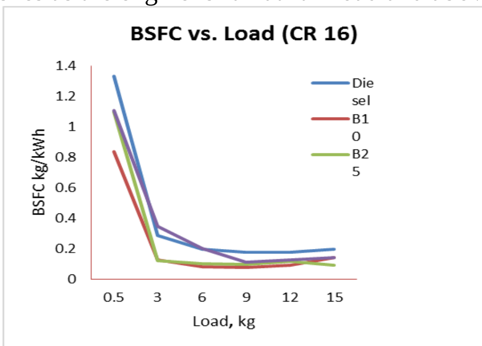

Figure 2. Brake Specific Fuel Consumption against load at CR 16 for various blends.

For compression ratio of 16:1, blend of B10 shows the minimum fuel consumption than other blend and diesel as seen from figure 2. This advantage is significant at part loads and diminishes as the engine is run at full load and above

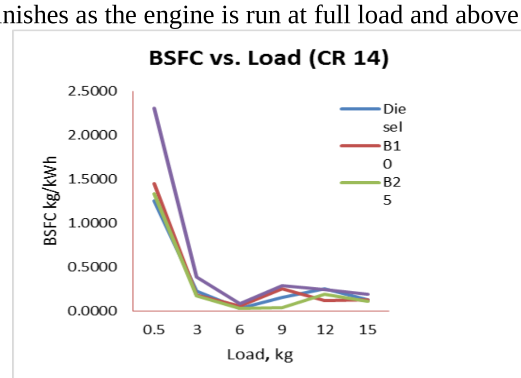

Figure 3. Brake Specific Fuel Consumption against load at CR 14 for various blends.

For compression ratio of 14:1, Diesel shows the minimum fuel consumption than other blend as seen from figure 3.

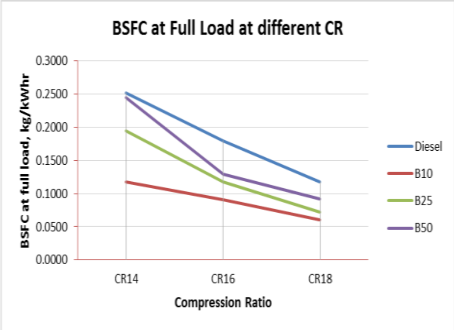

Figure 4. Brake Specific Fuel Consumption at Full load for various blends against CR.

From figure 4, it is clear that,

1. Brake Specific Fuel Consumption, BSFC is the worst at Compression Ratio of 14 and it improves with increase in Compression Ratio.
2. Blend B10 offers minimum Brake Specific Fuel Consumption, BSFC at any given compression ratio for engine running at full load while diesel has maximum BSFC in given range.

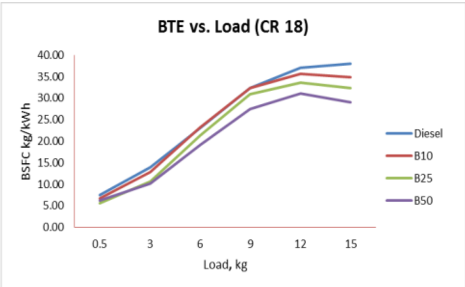

Figure 5. Brake Thermal Efficiency against load at CR 18 for various blends.

From figure 5, it is seen that at Compression Ratio of 18, brake thermal efficiency given by Diesel is slightly better as compared to B10 for entire range of engine load and it improves after full load.

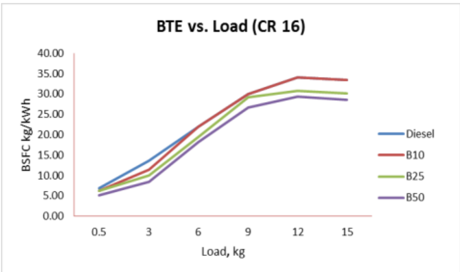

Figure 6. Brake Thermal Efficiency against load at CR 18 for various blends.

From figure 6, it is seen that at Compression Ratio of 16, brake thermal efficiency given by Diesel is slightly better as compared to B10 for entire range of engine load.

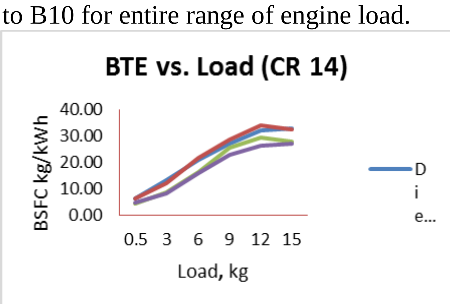

Figure 7. Brake Thermal Efficiency against load at CR 18 for various blends.

From figure 7, it is seen that at Compression Ratio of 14, brake thermal efficiency given by B10 is slightly better as compared to Diesel for full load run of engine.

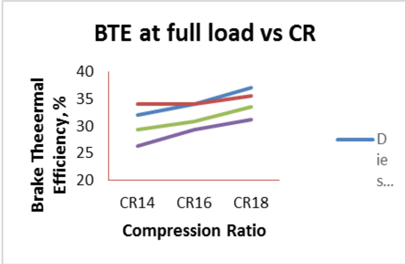

Figure 8. Brake Thermal Efficiency at Full load for various blends against CR.

From figure 8, it is clear that,

3. Brake Thermal Efficiency, BTE is the least at Compression Ratio of 14 and it improves with increase in Compression Ratio.
4. Blend B10 offers maximum BTE at compression ratio of 14 for engine running at full load while diesel has maximum BTE at compression ratio of 18.

Conclusion

The experiment is carried out on a direct injection, compression ignition single Cylinder Variable Compression ratio Diesel Engine by using blends of Diesel and methyl ester of Cotton seed oil. Performance characteristics of the engine is analyzed by varying compression ratio from 14 to 18. The experiment confirms that blend of B10 can be successfully used as fuel in CI engines as verified from performance analysis.

The conclusions are summarized as, for a diesel engine operating in limited Compression Ratio of 14-18,

1. The blend B10 shows marginally better brake specific fuel consumption than diesel while other blends B25 and B50 have poor BSFC.
2. The diesel clearly has better brake thermal efficiency than blends B10, B25 and B50 over range of CR.
3. Comparison of overall engine performance shows that CR 18 has better performance than CR 14 and CR 16.

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