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Performance Evaluation of CI Engine Using Cottonseed Oil as an Alternate Fuel

Milind A. Pelagade[1], Madhavi S. Harne[2], Dr. Ramakant Shrivastava[3]
[1, 2, 3] Department of Mechanical Engineering, Government College of Engineering, Aurangabad (M. S.), India

ABSTRACT

Biodiesel is the alternative fuel that is produced from renewable resources. It is being extensively used around the world thus making it incumbent to fully understand its effects on the combustion process in CI Engine and formation of pollutants. It is the mono-alkyl ester of long chain fatty acids derived from renewable feedstock such as vegetable oils or animal fats. The present study depicts, the performance analysis and exhaust gas analysis of single cylinder water cooled diesel engine different blends of Cottonseed oil (B10, B20, and B30) which were compared for both performance characteristics with pure Diesel. The performance was evaluated for the parameters viz. Break Thermal Efficiency, Break Specific Fuel Consumption, Air Fuel Ratio, Exhaust Gas Temperature, Smoke Opacity and Volumetric Efficiency against different loads. It was found that blends of the methyl ester used in present study can be used as an alternative fuel without any engine modification.
Keywords : - Biodiesel, Alternative Fuel, Diesel Engine, Performance, Emissions

I. INTRODUCTION

In Recent survey on the world energy consumption conducted in the year 2013, it was highlighted that combustion of fossil fuels was highest amongst consumption of energy worldwide. Out of all fossil fuels, liquid petroleum fuels contributed maximum because of their natural physiochemical and combustion properties. The maximum use of liquid petroleum fuels causing pollution and endangering environment [1]. The burning of these fuels contributes to increase the level of CO_2 in the atmosphere which is directly responsible for global warming [3]. The reserves of fossil fuels are limited and are on the verge of extinction. Efforts are being made throughout the World to adapt alternate fuels as a substitute for liquid petroleum fuels having near about same physiochemical properties. Subsequently, there has been a renewed interest in the production and use of fuels derived from plants or organic waste [4]. This fuel is called as Biodiesel which is a methyl ester formed by the reaction of vegetable oil with alcohol in presence of strong acid or base. The very first engine that was invented was demonstrated to run on Vegetable oil made from Peanut in 1900.But at that time the fossil fuel reserves were ample, Also direct use of vegetable oil in engine caused problems like less fuel atomization, thickening of engine oil and injector coking because of higher viscosity of vegetable oil. To overcome the problem of higher viscosity of vegetable oil there are four processes which are dilution with diesel fuel, micro emulsification, pyrolysis and trans-esterification. Out of these processes Trans-esterification is most commonly used. The process of formation of biodiesel from vegetable oil is called Trans-esterification. Biodiesel which is methyl ester formed from the reaction of triglyceride (Vegetable oil) and alcohol in presence of strong acid or base as catalyst. The molar ratio of vegetable oil to alcohol is 1:3 in trans-esterification [5].
Geyer et al. [6] investigated performance of direct injection diesel engine run on cottonseed oil methyl ester as a fuel and deduced the increase in thermal efficiency, decrease in smoke opacity wherein NOx emissions was increased at subsequent level.

Rakopoulos et al. [7] investigated the effect of use of bio-diesels of various origins including the same of cottonseed oil as a Substitute to conventional diesel fuel in a direct injection (DI) diesel engine. The engine was tested using two blends of cottonseed oil having oil percentage of 10%, 20%. There was notable reduction in smoke density using biodiesel blends compared to that of pure diesel.

Carraretto et al. [8] conducted a study on CI engine using Cottonseed oil methyl ester reported that the performances in terms of torque power were reduced while there was decrease in SFC (Specific Fuel Consumption) was increased considerably with the use of Cottonseed oil methyl ester compared to that of pure diesel .With the use of Cottonseed oil methyl ester CO emissions were reduced but NOx were increased evaluated to that of pure diesel.

Ilkılıç and Yu¨ cesu [9] conducted study to determine the results of cottonseed oil methyl esters on engine performance in a single cylinder CI engine. They observed that at medium and higher speeds there was no significant difference between the torque and power output of Cottonseed Oil Methyl ester and pure diesel.

II. BLENDED FUELS

The Biodiesel fuel chosen for performance of testing on CI engine was Cottonseed oil. Three blends (B10, B20, and B30) of Cottonseed oil or Cottonseed oil methyl ester (CSOME) were taken for testing reviewing previous literature [10, 11]. The properties of the three blends are shown in table 1.The Biodiesel blend is designated as BXX where XX is the volumetric percentage of the type of vegetable oil in the blend when it is mixed with pure diesel.

Table 1: Properties of fuel samples

Fuel / Property	Diesel	B10	B20	B30	Protocol
Density (Kg/m^3)	823	832	834	840	**ASTM D 1448**
Kinematic Viscosity (cSt)	3.9	4.89	4.92	4.96	**ASTM D 2217**
Flash Point (°C)	64	71	79	90	**ASTM D 93**
Calorific Value (MJ/Kg)	43.20	42.40	42.29	42.11	**ASTM D 6751**

III. EXPERIMENTAL SETUP AND PROCEDURE

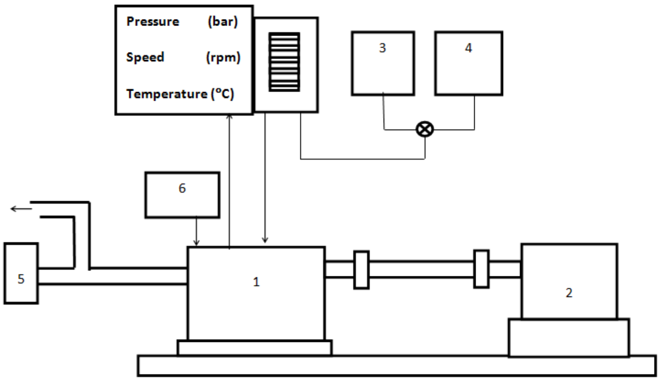
3.1 Experimental Setup

The present study was carried out in the research facility available with institute. The detailed Engine specifications are given in Tab. 2. The engine test rig is a Kirloskar make single cylinder, water cooled, four stroke diesel engines (10 kW), connected to Rope brake dynamometer for loading. One Piezo sensor is mounted on engine head through a sleeve and other mounted on fuel line near injector for measurement of pressures. The test rig has transmitters for air and fuel flow measurements. Provision is also made for measurement of temperature of exhaust, cooling water and calorimeter water inlet and outlet and load on the engine. The block diagram of Test rig is shown in Fig.1

Table 2: Engine Specifications

Description	**Type**
Make of the Engine	Kirloskar oil Engine
Type of Engine	Vertical, 4S, High speed, CI Engine
No. of cylinders	1
Max. Rated speed	1500 rpm
Injection Pump & Type	Single Cylinder Flange Mounted
Specific Fuel Consumption (SFC)	25 gm/KWh
Governor Type	Mechanical Centrifugal Type
Brake Horse Power (BHP)	10KW (7.4 BHP)
Type Of Dynamometer	Rope Brake Dynamometer
Method of cooling	Water cooling
Thermocouples	K-Type
Sensors	Piezo electric sensor

Figure 1. Photographic View of Test Rig



1. Engine 2. Rope Brake Dynamometer 3. Diesel tank 4. PetrolTank 5. SmokeMeter 6. Air box

Figure 2. Block Diagram of Experimental Setup

3.2 Experimental Procedure

Initially the engine was allowed to run on idle using Diesel so that it gets warmed up. Upon warming up for certain time limit reading were noted for manometer, engine speed, rota meter reading, and load on engine in kg, fuel consumption for a fixed time limit, calorimeter temperature. Later on load was given to the engine using Rope brake dynamometer which increased torque on engine. Increase in torque caused change in the speed which was maintained constant at 770 rpm by adjusting acceleration throttle. Then different data were recorded. This way six tests were performed keeping speed of the engine constant and reading were noted. The engine was allowed to cool for an hour before testing another blend of the fuel. The testing was carried out on different loads viz. 0kg(No Load),4kg, 6kg,8kg. The parameters like fuel consumption and torque were measured at above loads at constant speed for diesel and with various blends of Cottonseed oil. Volumetric Efficiency, Air Fuel ratio, and brake thermal efficiency was calculated using the collected test data. Also the smoke opacity was tested using gas analyser.

IV. RESULTS AND DISCUSSIONS

4.1 Break Thermal Efficiency

Fig shows variation of Break Thermal Efficiency at all loads for all blends as a function of Load. It was then compared to neat diesel. It was incurred that BTE increases up to 80% load and then decreases at full load. The Brake thermal efficiency was found to be slightly increased for B10 and B20 compared to diesel. Because of complete combustion the BTE was slightly higher than diesel fuel. It was attributed in the study [16] that extra oxygen content in the blend is sustained in diffusive combustion phase and leads to complete combustion by improving ignition delay in the combustion analysis. The increase in Break Thermal Efficiency credited to good combustion characteristics of biodiesel blends. There was slight difference in Break thermal efficiencies of Diesel and B30.

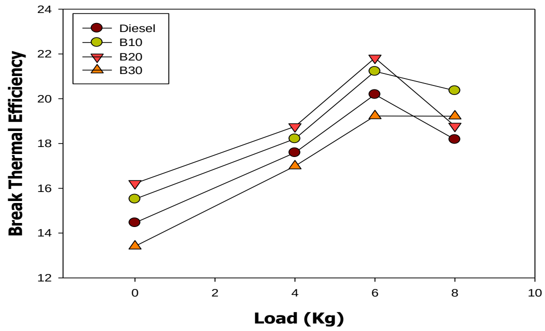


Figure 3. Graph showing Break Thermal Efficiency against different Load (Kg) for pure diesel and combination of CSOME blend

4.2 Break Specific Fuel Consumption

Fig shows the break specific fuel consumption for biodiesel blends and diesel fuel. The lowest BSFC was measured for B10 at 80% load (6kg).However highest BSFC was obtained for B30.Lower viscosity and density of B10 decreased BSFC compared to other blends. It was presented in the study [17] that decrease in BSFC occurred due to better physical and chemical properties of biodiesel blends for combustion. The higher blends (B20**,** B30) showed increase in BSFC due to their lower calorific values. It's because the fuel consumption by B20 and B30 is more than B10 and neat diesel to develop same power. Similar trends of decrease in BSFC for B10 and increase in BSFC for higher blends to B10 were reported in the study [18].

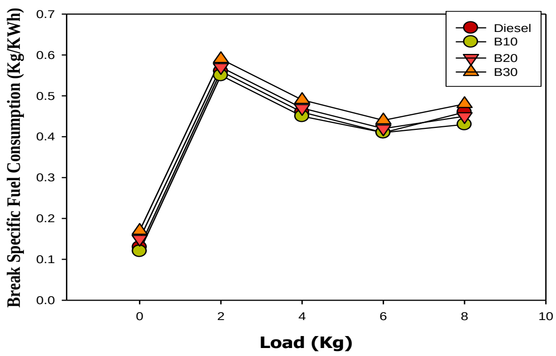


Figure 4. Graph showing Break Specific Fuel Consumption against different Load (Kg) for pure diesel and combination of CSOME blend

4.3 Air Fuel Ratio

Air fuel ratio is defined as the ratio of air mass flow to rate of fuel flow rate. In this study it was observed that A/F ratio decreases with increase in load. The graph showing A/F ratio to different loads is shown in Fig. The diminishing behaviour of A/F ratio with increasing loads is due to higher fuel requirement for higher loads.

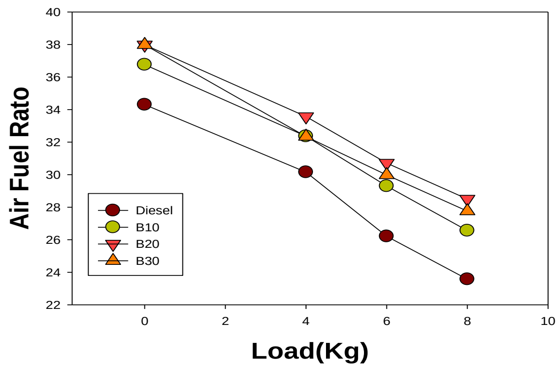


Figure 5. Graph showing Air-Fuel rat against different Load (Kg) for pure diesel and combination of CSOME blend

4.4 Exhaust gas temperature

The exhaust gas temperature increases with increase in concentration of the cottonseed oil in the blend .Highest exhaust gas temperature was attained at full load for each blend. Higher exhaust gas temperature is because of the presence of more number of oxygen atoms in each blend. Thus with increase in load exhaust gas temperature increases as more fuel is burnt [13].Also Exhaust gas temperature is affected by the changes in ignition delay. More the ignition delay there will more delay in combustion and higher exhaust gas temperature. Longer ignition delay period is because of lower cetane number. Exhaust gas temperature rises as a result of combustion which prolong power period in the cylinder [14]. The experimental plot between Exhaust gas temperatures against each load can be seen in Fig. It was found that at full load highest Exhaust gas temperature was found in B30 .Yu et al. [15] in their study found that biodiesel blends generally consists some constituents which have higher boiling points. These constituents are not adequately evaporated during the main combustion phase and continue to burn in the late combustion phase, resulting in a higher exhaust temperature and a lower thermal efficiency.

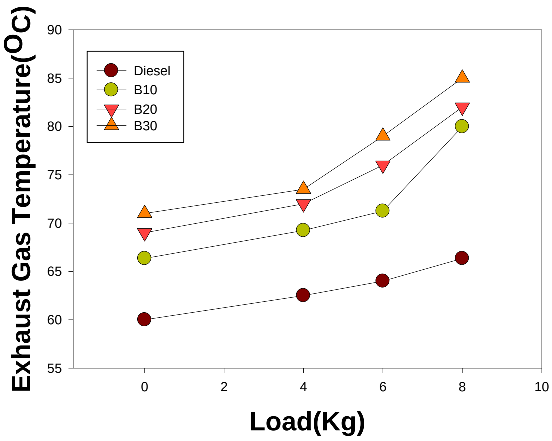


Figure 6. Graph showing Exhaust Gas Temperature against different Load (Kg) for pure diesel and combination of CSOME blend

4.5 Smoke Opacity

Fig shows variation of smoke opacity for diesel and different blends as a function of load. Smoke opacity increases with increase in load. Diesel has higher smoke opacity at lower load compared with the blends. Aromatic content in the fuel leads to increased smoke opacity. Aromatic content in the diesel are higher compared to the blends. The study shows that higher the blend lower is the smoke opacity as comparatively less content of aromatic constituents than that of lower blends. The same trend in lower smoke opacity of biodiesel blends was reported in the study [17].The lower smoke opacity of biodiesel blends is due to uneven fuel spray pattern in combustion chamber, owing to vapour locking in pump and pipe line[20]. Due to lower smoke opacity the biodiesel blends tend to form lower soot and carbon residue [19].

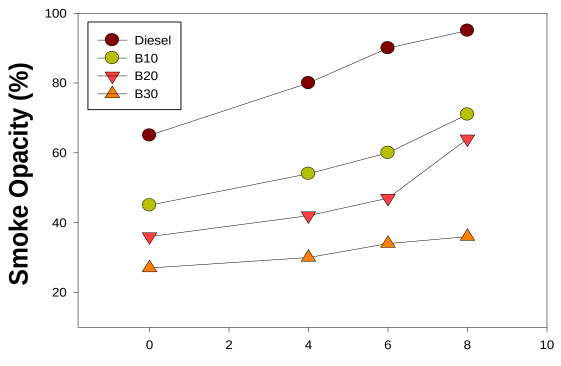


Figure 7. Graph showing Smoke Opacity against different Load (Kg) for pure diesel and combination of CSOME blend

4.6 Volumetric Efficiency

Fig.8 shows variation of volumetric efficiency against different loads. It was found that blend B20 was having higher volumetric efficiency compared to other blends and pure diesel. This is because of slightly lower Exhaust gas temperature of B20.

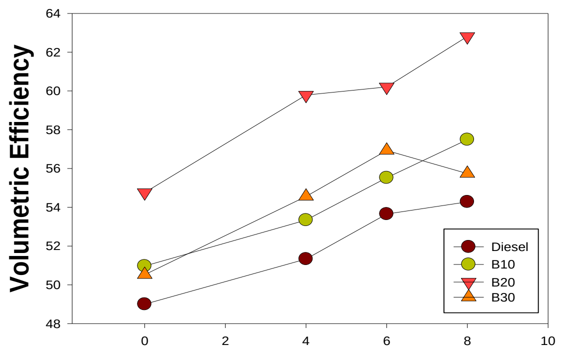


Figure 8. Graph showing Volumetric Efficiency against different Load (Kg) for pure diesel and combination of CSOME blend

V. CONCLUSIONS

A single cylinder CI Engine was successfully operated using cottonseed oil as an alternative fuel without making any modifications in the engine. The performance characteristics of CI Engine using methyl esters of cottonseed oil were compared to that of pure diesel. It was found that

1. Due to complete combustion the Break Thermal efficiency of methyl ester of cottonseed oil was found to be relatively higher to that of pure diesel. Out of three blends (B10, B20, B30) the B20 had highest break thermal efficiency. Hence the biodiesel blends can be used efficiently in CI engine.
2. As the load increased there was increase in A/F ratio of CI Engine as more fuel requirements for higher loads. The blend B20 had maximum A/F ratio compared to different blends and pure diesel.
3. The exhaust gas temperature was found to be maximum for B30 because of higher concentration of cottonseed oil which in turn providing more number of oxygen during combustion thus giving rise to higher exhaust gas temperature.
4. During the study it was found that the opacity of smoke after combustion was higher in pure diesel than that of the biodiesel blends. This is because of the lower content of aromatic compounds compared to pure diesel.
5. The volumetric efficiency of B20 was found to be greater than that of other blends.

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