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An Experimental Study Based Comparison of Engine Performance Characteristics Using Natural Seed and Animal Fat Based Bio-Fuels

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Abstract

Bio-fuels are the most energy efficient and environmental friendly viable options in the back drop of burning scarcity coupled with spiraling prices of conventional oils. Given the volume of diesel burning vehicles, it is the high time we replaced this conventional fuel either on partial or full scale, in the coming years. Given the fact that little or no modification is needed in the engine design or running conditions, bio-diesel is a potential candidate to accomplish this task. It is a renewable diesel substitute obtained by combining chemically any natural oil or fat with alcohol. Many traditional oil seeds like Pongamia, Neem, Jatropha, Rubber seed, Peanut, Cotton seed, Rape seed, Simarouba and Mahua etc are available abundantly in India and have been used for biodiesel production purpose. Many vegetable oils, animal fats and recycled cooking greases can also be transformed into biodiesel.

This paper is an outcome of experimental runs using Cotton seed – Simarouba oil (CS), Cotton seed –Mahua oil (CM) and Fishery Oil (FO), at two different blends under different engine running conditions, with a fixed compression ratio. The main objective is to make a comparison between vegetable and animal fat based biodiesels and their suitability as a partial replacement to conventional Diesel. Testing was done using a single cylinder CI engine using blending with diesel in two blending ratios (B10 and B20). Engine performance parameters like brake specific fuel consumption, total fuel consumption, brake power, brake thermal efficiency, exhaust gas temperature were measured to evaluate and compare the behavior of diesel engine running on biodiesel at normal injection timing and pressure with a fixed compression ratio of 17.5:1. Performance study and subsequent comparison revealed that lower blend is superior to or on par with diesel, in both the bio-diesel blend combinations and could be a substitute for diesel.

Keywords: *Fish Oil, Blend, biodiesel, performance*
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1. Introduction

Bio-fuels are the most energy efficient and environmental friendly viable options in the back drop of burning scarcity coupled with spiraling prices of conventional oils [1-20]. Given the volume of diesel burning vehicles, it is the high time we replaced this conventional fuel either on partial or full scale, in the coming years to curb the dominant global source of CO_2 emissions-triggered threat to clean environment.

Since it requires little or no modification in the engine design or running conditions, bio-diesel obtained by combining chemically any natural oil or fat with alcohol is a potential substitute for Diesel. Vegetable oils have been considered as appropriate alternatives to the conventional liquid fuels, due to their prevalent fuel properties, transformation from 'as a feasible option' during the earlier days to 'as an essential option' in the recent times. In view of this, continuous research is going on internationally in the area of vegetable oils as alternate fuels.

Many traditional oil seeds like Pongamia, Neem, Jatropha, and Rubber seed, Peanut, Cotton seed, Rape seed, Simarouba and Mahua etc. Which are available abundantly in India and have been used for biodiesel production purpose. Many vegetable oils, animal fats and recycled cooking greases can also be transformed into biodiesel.

In this background, the present paper presents an experimental study based comparison of engine performance characteristics using natural cotton seed-Simarouba (CS), cotton seed-Mahua (CM) and animal fat based bio-fuels Fish Oil(FO) blends and the relative merits and demerits.

2. Literature Review

Ever since a diesel engine was run by peanut oil at the Paris Exposition in the year 1900 [1], it has been established from there onwards that the high temperature of diesel engine is able to run on variety of vegetable oils [2]. Biodiesel is a processed fuel derived from a biological source [3, 4]. Simarouba is a medium sized evergreen tree (height 7-15 meters) the seeds of which contain 60-75% oil that can be easily refined, bleached, deodorized, and fractionated [5]. Mahua is a large-sized evergreen or semi-evergreen tree from the Sapotaceae family. Mahua oil contains approximately 41–51% oleic acid. Other fatty acids are also present in the oil, such as stearic (20.0–25.1%), palmitic (16.0–28.2%), and linoleic acids (8.9–18.3%) [6-8]. Cottonseed oil has highest linoleic acid percentage (about 55.2%) i.e., poly-unsaturation compared to others which affects physical and thermal properties of biodiesel [9].

Many research outcome on the performance parameters such as power output, specific fuel consumption, and brake thermal efficiency of different biodiesels had been already reported, but with contrasting results.

Rizwanulet.Al. [10] reported a slight increase in brake thermal efficiency with Simarouba blend and concluded that without any modification in engine we can save diesel fuel for certain extent without any compromise with standard performance characteristics.

Yarbrough et al. [11] investigated the performance of a diesel engine with six variants of sunflower oil as fuel. Their study revealed that refined sunflower oil gives satisfactory results and prevents engine failure due to degummed and de-waxed vegetable oil. They concluded that instead of raw sunflower oil, modified sunflower oil can be used as a fuel for diesel engines.

M.K.Ghosal et al**.** [12] Investigated Mahua methyl ester and its combinations with diesel fuel for a compression ignition (CI) engine. The performance of a CI engine using Mahua methyl ester and its combinations with that of the diesel fuel has been done. Power output, engine specific fuel consumption and exhaust gas temperature of the engine under analysis improved concurrently with the decrease, increase and increase respectively of the concentration of Mahua methyl ester in its blends.

Both short and long-term engine tests were carried out by Pryor et al. [13] using a small diesel engine with neat soybean oil. Short-term tests with soybean oil indicated the performance similar to that of diesel while the long-term testing failed due to power loss and carbon build-up on the injectors. They opined that the soybean oil can be considered for short-term operation only.

Ryan et al. [14] investigated the injection and combustion properties of several vegetable oils namely peanut oil, cottonseed oil, sunflower oil and soybean oil.

Fish wastes rich in fatty acids and used as the raw material to produce biodiesel through transesterification process. Investigations showed that viscosity of the produced biodiesel was within ASTM standard. The biodiesel exhibited a lower specific fuel consumption compared to the conventional diesel. Results showed that biodiesel derived from waste fish oil can be considered as a potential source of commercial biodiesel [15].

Performance and emission characteristics of unmodified common-rail diesel engine operating with Fish oil biodiesel. Blends of biodiesel with diesel, B20, B40, B60, B80 andB100 were used in the investigation. Experimentation showed that brake specific fuel consumption and brake thermal efficiency (BTE) were higher with B100 fuel than that of diesel. The exhaust gas temperatures of B100 were lesser than that of diesel at the different loads [16].

Biodiesel is prepared by the transesterification of fish fat oil with an alcohol (methanol/ethanol) using sodium hydroxide as a catalyst. Investigation showed that compared to diesel fuel, Fish oil biodiesel is more efficient and the emissions such as carbon monoxide, sulphur dioxide, hydrocarbon are reduced [17].

Use of cotton seed oil as a fuel for diesel engine. From the experiments it is concluded that cotton seed oil can be directly used in C.I. engine without any modification [18].

From the above literature survey it is evident that there exists large scope for further investigation for a comparative study on engine performance with the combination of vegetable and animal fat based oils with Diesel fuel.

3. Experimental set up

CSS, CSM and FO oil blends with mineral diesel in a pre-defined percentages of 10% (10% by volume of respective blend in diesel, denoted as CSB10, CMB10 and FOB10) and 20% were characterized and their performance and emission characteristics were compared vis-à-vis normal diesel. The experiments were conducted on a with a single-cylinder, vertical, air cooled, constant speed (1500 rpm) four stroke TAF-1 Kirloskar oil engines (Figure 1) with a rated power of 5.75 kW at 1500rpm and a compression ratio of 17.5, coupled to an eddy current dynamometer. The pressure of the engine cylinder, fuel, airflow rate and crank angle were measured using piezo-electric sensors, differential pressure transmitter and crank angle sensor with TDC pulse.

Figure 1 Diesel Engine Test Rig.

The performance parameters like brake power, indicated power, frictional power, brake mean effective pressure (BMEP), indicated mean effective pressure (IMEP), brake thermal efficiency (BTE), indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance were evaluated by running the engine test rig and recording parameters like engine shaft speed, load on the engine, fuel consumption rate, airflow rate, temperature of engine cooling water and engine exhaust gases.

4. RESULTS AND DISCUSSION

4.1 Engine Performance

The performance parameters were calculated using the fundamental relations between these measurements while varying the load on the engine from 0% to 100% in approximate steps of 25%. During the short run testing, following performance parameters such as BSFC, BTE, EGT and p-θ profile for normal diesel, and B10 and B20 blends of CSS, CSM and FO were tested. The experimental outcomes are discussed in the following sub section.

4.1.1 Brake thermal efficiency

Figure 2 shows the plot of brake thermal efficiency with load for different blends (CSS, CSM and FO). From figure it may be observed that there is a steady increase in efficiency as the load increases in the diesel and biodiesel blends. Beyond 75% load, the brake thermal efficiency remains more or less the same irrespective of load or slightly decreases, except for FO blends. It can be further observed that the BTE of all blends is lower than that of petro-diesel except for FO which recorded marginally higher values of 32.6% and 29.51% for blends FOB10 and FOB20 respectively. The BTE of all blends of CSM is also lesser when compared to CSB and FO blends. This may be due to higher viscosity of the blends resulting in poorly formed fuel sprays and air entrainment affecting the combustion in the engine [23] and further due to lower volatility of vegetable oils.

The blend CSB20 and FOB20 recorded peak efficiency namely 28.20% and 29.09% and it is on par with Diesel fuel.

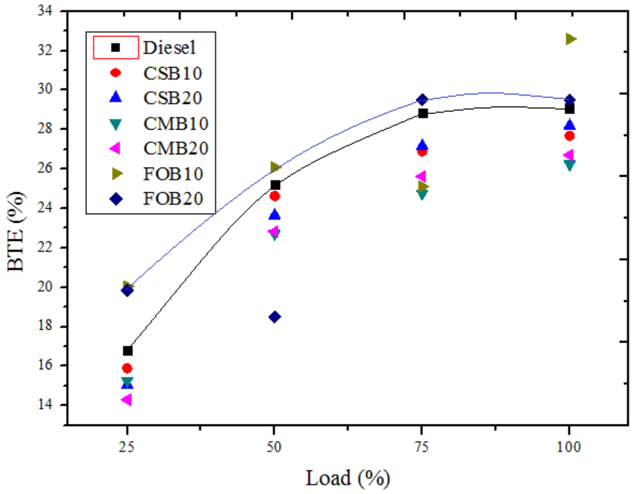

Figure 2 Brake thermal efficiency v/s Load

4.1.2 Brake specific fuel consumption (BSFC)

Variation of brake specific fuel consumption of different blends of CSB, CSM and FO biodiesel and normal diesel at different loads is shown in Figure 3.It can also be seen that with increasing blend percentage the BSFC is also increasing. This may be attributed to the lower calorific value and higher density of oil blends. The increase in brake specific fuel consumption at higher blends may be attributed to the lower heating value. Also it is observed from the figure that the brake specific fuel consumption of CSB10, FOB10 and FOB20 biodiesel blend is almost closer to normal diesel at lower loads. However, at higher loads (75% to 85%) blend CMB20 and FOB20 are on par with diesel which is normally the optimum loading for any diesel engine. Hence, from BSFC point of view both FO blends are superior compared to CM and CS blends offering more fuel economy. It is observed that BSFC for all blends at all loads is more than 3–9%, compared to normal-diesel, the only exception being FOB10.

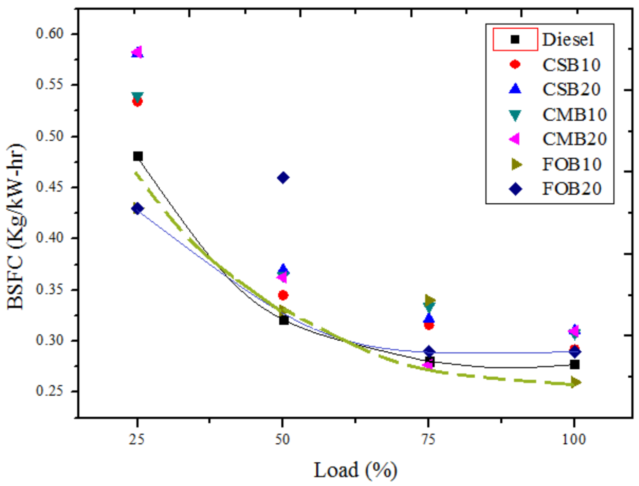

Figure 3 Brake Specific Fuel Consumption (BSFC) v/s Load

4.1.3Exhaust Gas Temperature (EGT)

Figure 4 shows the variation of exhaust gas temperature with load. The exhaust gas temperature increases with increase in load for all blends. From the graph it may be observed that the exhaust gas temperature is lower for different blends when compared to that of diesel at all the loads. This could be attributed to additional oxygen present in blends which enhance the combustion process. Among CS, CM and FO blends, the CMB blends have lower exhaust gas temperature in excess of 25% loading. The highest temperature recorded was 460ºC for CMB10 at full load. Among the blends CMB20 and FOB20 biodiesels shows lower Exhaust temperature at all loads as compared to normal diesel and CS biodiesel.

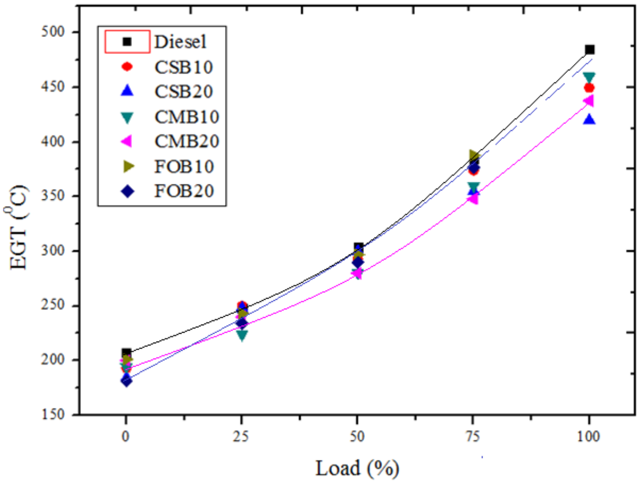

Figure 4 Exhaust Gas Temperature (EGT) v/s Load

4.1.4 Combustion analysis (p-θ diagram)

The p-θ diagrams for different load conditions are represented in figure 5 and 6. Cylinder pressure data was analyzed to obtain the heat release rate for diesel, CS and CM blends and plotted as shown in Figure 5 and figure 6. It is observed that diesel displays higher first heat release peak followed by CSB20 and CMB20 blends at half load and full load conditions.

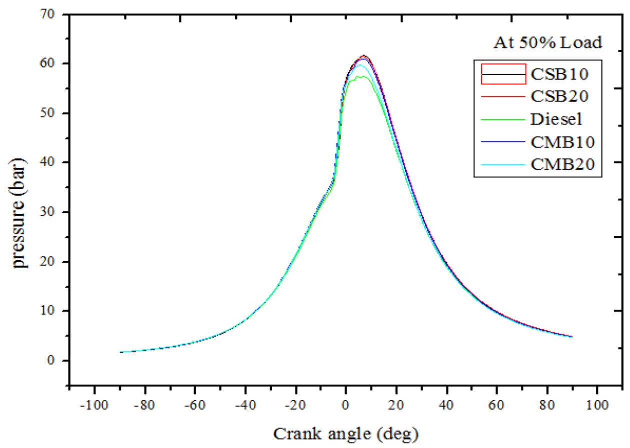

Figure 5 Pressure v/s Crank angle (p-θ) diagram (50% load)

At no load conditions, the peak pressure attained by the diesel was 48bar as against for CSB20 blend which was 50bar (at 4 deg ATDC). At 50% and full load condition at 7 Deg ATDC and at 9 Deg ATDC respectively similar trends were observed. However, the CSM blends had higher peak pressures compared to CSB blends and normal-diesel at full load conditions.

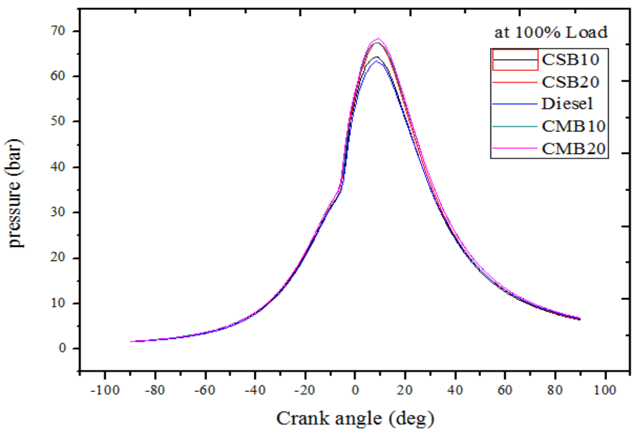

Figure 6 Pressure vs. Crank angle (p-θ) diagram (100% load)

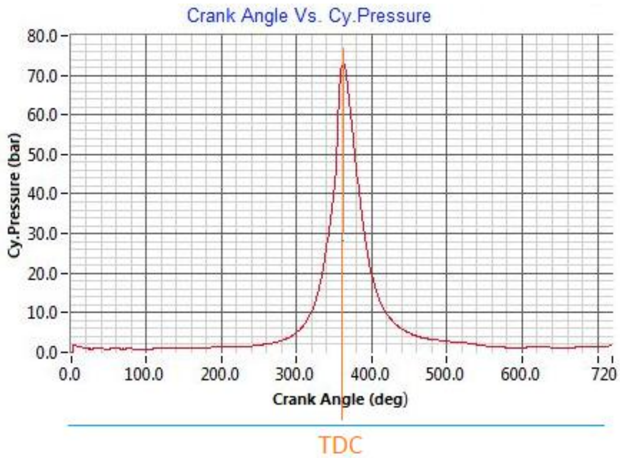

Figure 7 Pressure vs. Crank angle (p-θ) diagram for B10 FO Biodiesel

Figures 7 and 8 show the pressure versus crank angle diagrams for Fish Oil blends 10 and 20 respectively, at full load conditions. From the figure 7 it is observed that peak pressure occurs at 72 bar for both the blends around 4 degrees after TDC, the trend observed similar to CS and CM blends. As compared to other blends FO blend shows maximum peak pressure.

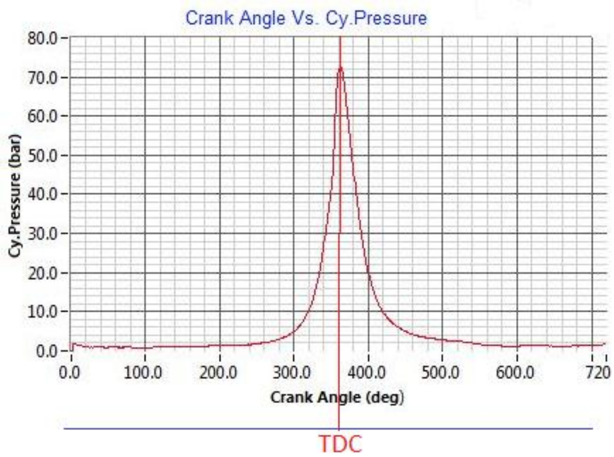

Figure 8 Pressure vs. Crank angle (p-θ) diagram for B20 FO Biodiesel

5 CONCLUSIONS

Based on the experimental investigations it may be concluded that the engine performance using CS, CM and FO blends is comparable with that of normal diesel. The engine power output and fuel consumption of the engine are almost the same when the engine is fueled with lower CS - diesel blends compared with those of petroleum diesel, in particular CSB10 and FOB 10 blends. A comparison among different vegetable and animal fat based blends clearly shows that FOB10 is a better substitute as a partial replacement for normal diesel, based on engine performance. Further it may be concluded that among the different blends used FO, CM and CS blends are preferred in the same order as they appear as good substitute fuels for diesel engines.

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