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A Study of Performance and Emissions of Diesel Engine Fuelled With Blends of Cotton Seed Oil Methyl Ester and Petro-Diesel

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ABSTRACT: *The engine performance and emission characteristics of Cotton Seed oil biodiesel (Cotton Seed Oil Methyl Ester) and its blends with petro-diesel are presented. The engine tests are conducted on a 4-Stroke Tangentially Vertical (TV1) single cylinder kirloskar 1500 rpm water cooled direct injection diesel engine with eddy current dynamometer at nozzle opening pressure 230 bar with standard static injection timing of 23° bTDC maintained as constant throughout the experiment under steady state conditions at full load condition. From the test results, it could be observed that the B25 blend gives optimum performance like higher brake thermal efficiency lower specific fuel consumption and lower emissions like lower in smoke density and oxides of nitrogen. The research findings show that B25 gives lowest emissions which make it a good alternative fuel to operate diesel locomotives without any modification in existing diesel engine.*

Keywords: *Cotton Seed Oil; Biodiesel; Nozzle Opening Pressure; Static Injection Timing; Performance; Combustion; Emissions*

I. Introduction

Researchers of internal combustion engine group have always focused towards engine performance and emission control in economical and environmental aspects. Diesel engine which is being used in various sectors like transportation, railways and agriculture has high thermal efficiency durability and reliability of usage. India being an agricultural country, producing a large variety of vegetables, a thorough and wide investigation is required to find an appropriate vegetable to produce biodiesel. This research attempts to use radish seed oil to investigate its suitability as a biodiesel as radish seed oil has cetane number as close to that of neat diesel fuel. In the forthcoming decades, the eco-friendly and vital biofuels will serve as an alternative for conventional petroleum fuel which will be under hectic shortage. A brief literature review of research work carried out by various researchers is presented below. The cotton seed oil methyl ester gives optimum performance compared to neem oil methyl ester [1]. The performance and emission control characteristics of various biofuels have been carried out [2, 3]. Vegetable oil as a suitable alternate fuel for compression ignition engine is in its pure form or blended with petroleum diesel. Moreover biodiesel is better than diesel based on some of its physical properties like sulfur content, flash point, aerometric content and biodegradability [4]. The diesel engine operation was carried out with 1,4 dioxine- ethanol-diesel blends on diesel engines with and without thermal barrier coating. The blend ratio of 70% diesel, 20% ethanol and 10% dioxane blend gives better performance and lower emissions [5]. The operation was carried out on a DI diesel engine fuelled with pure Mahua oil methyl ester (B100) and neat diesel (B0). The B100 gives the lower emissions as compared with B0 [6]. The report of the biodiesel preparation was done and discussed its performance and emission characteristics of diesel engine with B0 and B100 fuel. The Mahua Oil Methyl Ester (B100) burn more efficiently than diesel (B0) and the emissions of B100 is lower than that of B0 [7]. The neat Marotti Oil Methyl Ester (MOME) gives lower emissions like hydrocarbon and oxides of nitrogen as compared to neat diesel for all load conditions [8]. From the previous studies, it could be observed that most of the studies are mainly related to the performance and emission characteristics of diesel engine using biodiesel as fuel. In this paper an analysis of four stroke TV single cylinder

DI with different nozzle opening pressures of 230 bar and with a constant static injection timing of 23° bTDC at full load condition of the diesel engine with eddy current dynamometer using B0, B25, B50, B75 and B100 as fuel is presented.

II. Materials And Methods

2.1 Characterization of the Oil

The properties of the oil were first measured to determine if pretreatment is necessary or not before alkaline transesterification. It was found that the free fatty acid value of the oil is 0.23% of NaOH by volume which is high for direct alkaline transesterification as it can react with the catalyst to form soap which can inhibit methyl ester yield. The water content is 10% which is a little bit too high for uninhibited transesterification hence the oil is heated to 110° C and held constant for 30 minutes to allow some of the water to evaporate.

2.2 Transesterification Procedure

Generally, vegetable oils contain fatty acids (palmitic, stearic, olenic, linoleic, lingnoceric, eicosenoic, arachidic and behenic). Of these cotton seed oil contains the saturated fatty acids palmitic (hexadecanoic acid) and stearic (octadecanoic acid) and the unsaturated acids oleic (octadec-9-enoic acid) and linoleic (9,12-octadecadienoic acid). The cotton seed oil is commercially available in the local market and used as the raw material. Transesterification process is the reaction between a triglyceride and alcohol in the presence of a catalyst to produce glycerol and ester. To complete the transesterification process stiochiometrically, 3:1 molar ratio of alcohol to triglycerides is needed. However, in practice, higher ratio of alcohol to oil ratio is generally employed to obtain biodiesel of low viscosity and high conversion. Among all alcohols that can be used in the transesterification process are methanol, ethanol, proponal and butanol. Methanol and ethanol are widely used and especially methanol because of its low cost. Vegetable oil is made to react with methanol in the presence of catalyst which produces mixture of alkyl ester and glycerol. This oil can be produced by a base catalyst process. Cotton seed oil is transesterified using methanol as reagent and NaOH as catalysts, to yield biodiesel (Cotton Seed Oil Methyl Ester).

III. Experimental Setup And Procedure

Experiments have been conducted on a 4 stroke, kirloskar, Tangentially Vertical single cylinder (TV1) direct injection (DI) diesel engine developing power output of 5.2 kW at 1500 rpm connected with water cooled eddy current dynamometer.

IV. Results And Discussion

4.1 Specific Fuel Consumption (SFC)

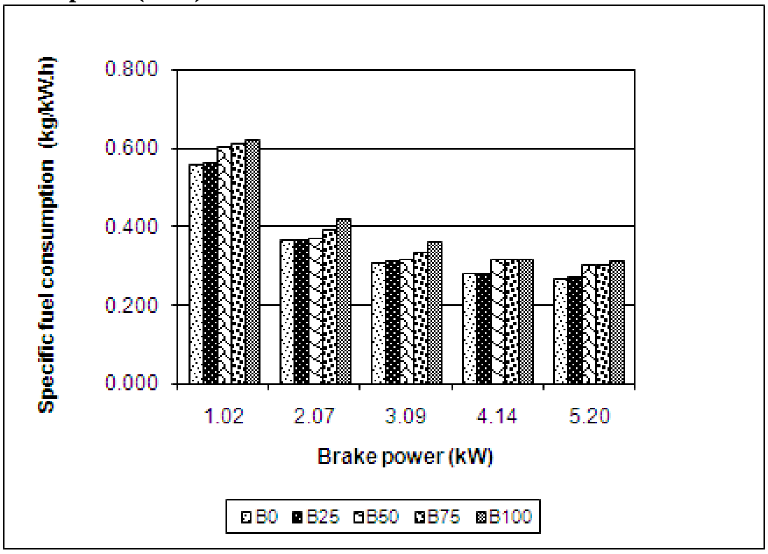

Figure 1: Specific Fuel Consumption vs Brake Power

The variation in specific fuel consumption for B100 to B0 is shown in Figure 1. From this figure, it is seen that the B0 and B25 give lowest specific fuel consumption of 0.54 and 0.29 kg/kWh respectively for both the fuel at no load and full load. However, the B100 gives the highest specific fuel consumption of 0.64 and

0.32 kg/kWh respectively at no load and full load. For B100, the percentage increase in specific fuel consumption at no load and full load is 11.39% and 16.23% respectively as compared to B0 and B25. The same trend is observed for all blends of fuel. The Specific fuel consumption decreases with the increase in load for all blends of fuel. However, at each load B0 and B25 have the lowest specific fuel consumption and these increase with the blend value. This is due to comparatively higher viscosity and lower calorific value. This is due to increase in fuel quantity with increase in load which causes better utilisation of air leading to better combustion. At no load, diesel engines operate with very lean mixture.

4.2 Brake Thermal Efficiency (BTE)

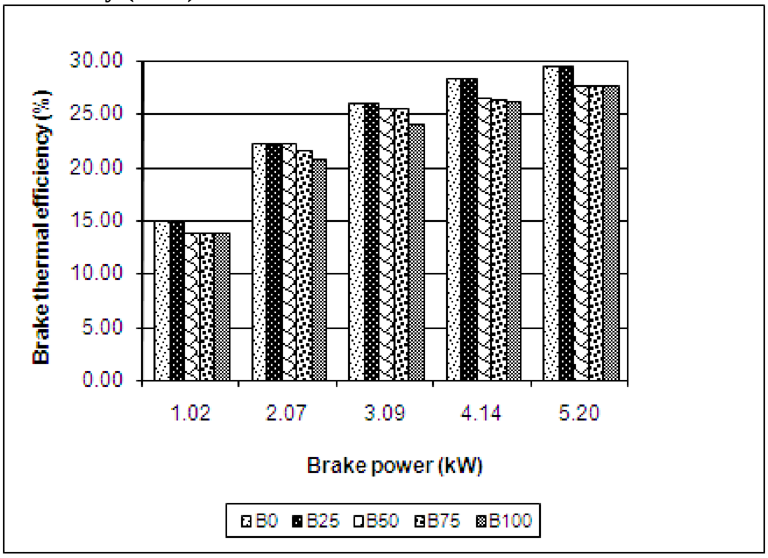

Figure 2: Brake Thermal Efficiency vs Brake Power

Figure 2 shows variation of brake thermal efficiency with respect to brake power for B100 to B0. As can be seen, B0 and B25 have almost the same maximum brake thermal efficiency of 14.72% and 29.34% for both the fuel at no load and full load condition, respectively. It may be noted that at all loads, B100 gives lower brake thermal efficiency. At no load and full load, the brake thermal efficiency for B100 is 7.35% and 6.35% is lower compared to B0 and B25 fuel. The same trend is observed for all blends of fuel. The Brake thermal efficiency depends on heating value and specific gravity. The combination of heating value and mass flow rate indicate energy input to the engine. This energy input to the engine in case of B50, B75 and B100 are more compared to neat diesel. This may be the reason to have lower brake thermal efficiency for all blends of fuel as compared with B0.

4.3 Smoke Density (SD)

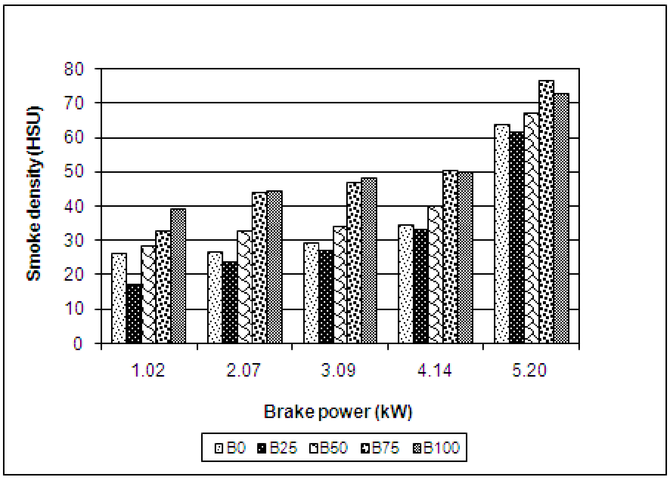

Figure 3: Smoke Density vs Brake Power

Figure 3 shows the variation of smoke density over the complete load range. It can be seen from figure 3 that for all blends including neat diesel the smoke density increases with load. This is to be expected, because in diesel engine which is a quality governed engine, the combustion depends upon the local air fuel ratio. Increase in load at constant speed is achieved by increasing the fuel quantity. It is evident that at no load, B25 has the lowest smoke density of 16.5 HSU, whereas B100 has the highest smoke density of 38.3. It is interesting to note that B25 emits lower smoke compared to neat diesel (B0). This may be due to the chemistry of fuel blend which may promise conducive atmosphere for lower smoke density for B25 compared to B0. Further at no load, the engine is operating at very lean mixture. As the load is increased from no load to 75% there is only gradual increase in smoke density. However, the smoke density for B25 is lower than B0 over their load range for the reasons explained above B75 and B100 are almost bunching together in this load range. It can also be seen from Figure 3, as the load increases from 75 to 100%, there is a steep rise in the smoke density for all the blends, as well as neat diesel. This is to be expected because more fuel is injected into the engine to take care of the load. As the engine is running at constant speed of 1500 rpm, there is less time for complete combustion to take place which can cause an increase in smoke density.

4.4 Oxides of Nitrogen (NO_x)

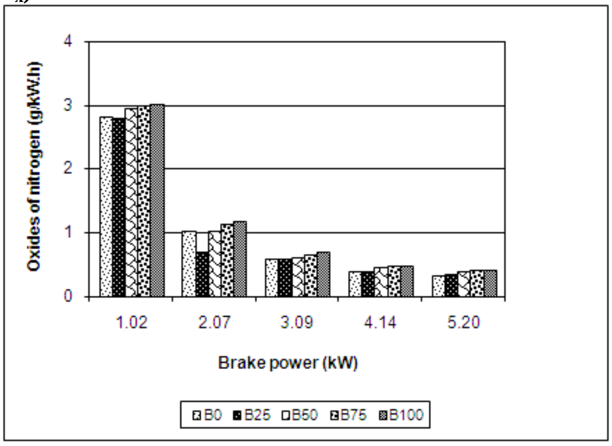

Figure 4: Oxides of Nitrogen vs Brake Power

The variation in NO_x for B100 to B0 is shown in Figure 4. It is evident that the maximum NO_x (g/kWh) is 3.34 for B100 whereas for B0 is 2.53 at no load. At full load, the maximum NO_x of 0.45 for B100 whereas for B0 it is 0.36. The variation in NO_x at full load is higher at no load condition of B100 as compared with B0 fuel. At full load, the percentage reduction in NO_x for B100 is 8.45% as compared with B0 whereas at no load the variation in NO_x is 2.45%. However, the B75 blend gives better reduction in NO_x as compared with B0, B25, B50 and B100 at full load condition. The percentage reduction in NO_x for B75 is 9.56% as compared to B0 fuel at full load condition of the engine whereas at no load, the percentage reduction in NO_x is 4.54% for B75. The percentage reduction in NO_x for B100 is 1.14% as compared to B75 fuel. This is due to decrease in exhaust gas temperature. It is well known that vegetable based fuel contains a small amount of nitrogen. This contributes towards the NO_x production.

V. Conclusions And Recommendations

From this study, it could be concluded that the B25 gives optimum performance and lower emissions of SD and NO_x. Finally, it is concluded that B25 could be used as a viable alternative fuel to operate four-stroke tangentially vertical single cylinder direct injection diesel engine with nozzle opening pressure of 230 bar and static injection timing of 23° bTDC, thereby saving 25% of the precious petro-diesel fuel.

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