

## Production and Performance of Bio-Diesel from Pongamia Oil Methyl Ester

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Diesel engines are widely used for different applications in industrial power plant, transportation, agriculture etc. despite these advantages, environmental pollution, cost increment, depletion of crude oil becomes a major concern throughout the world. A methyl ester of pongamia was prepared and blended with diesel in four different compositions varying from 25% to 100%. Methyl esters of pongamia oils has several outstanding advantages among other new renewable and clean engine fuel alternatives and can be used in any diesel engine without modification. The engine performance and emission characteristics of pongamia bio-diesel (Pongamia 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 engine, 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:** Pongamia Oil, Bio-Diesel, Blends, Performance, Combustion, Emissions

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## 1. Introduction

Because of the reduction of petroleum reserves and air pollution emerged from exhaust emissions, there have been great efforts to use alternative fuels in diesel engines for substitution of diesel fuel. Different vegetable oils such as soybean oil, castor oil, rapeseed oil, jatropha curcas oil, pongamia oil is considered as alternative fuels for diesel engines. The important advantages of vegetable oils as fuel are that they are renewable, can be produced locally, cheap and less pollutant for environment compared to diesel fuel. According to literature, use of vegetable oils as fuel in diesel engines causes several problems, namely poor fuel atomization and low volatility originated from their high viscosity, high molecular weight and density. these problems may cause important engine failures. To improve fuel properties and decrease viscosity and density of oils, various methods such as heating the vegetable oils, mixing with diesel fuel, emulsion with alcohol and transesterification have been employed. Many experiments have clearly revealed that the widely applied and convenient method for reduction of viscosity and density of vegetable oils is transesterification. The fuels produced via transesterification of the oils are called bio-diesel. An important property of bio-diesel is its oxygen content of about 10%, which is usually not contained in diesel fuel. In spite of transesterification treatment, viscosity and density of bio-diesel is still higher than that of diesel fuel. It is well known that viscosity of fuels affects some processes such as atomization, vaporization and fuel- air mixing in the engine. The engine performance and emissions of diesel engines fueled with bio-diesels have been examined by many investigators. The bio-diesels used in the experiments performed by these investigators were produced from different vegetable oils such as cottonseed, sunflower, rapeseed, soybean, karanja, rubber seed, pongamia etc. In this study, the performance parameters and thermal efficiencies of a single-cylinder, four-stroke diesel engine using diesel fuel and bio-diesel, which is pongamia oil methyl ester (POME), have been calculated. The calculations are done from theoretical data for petroleum diesel, jatropha bio-diesel and pongamia oil methyl ester.

India is the second largest producer of cotton seed in the world next to china with the potential of 4.6 million tonnes of oil seeds per annum.

With the rapid development of rural agricultural production and rapid growth of local industry in India, the discrepancy between demand and supply of energy has become an increasingly acute problem. Due to seasonality of farm work, a temporary shortage of fuel will bring about unexpected and irreparable loss to peasants. The limited (and fast diminishing) resources of fossil fuels, increasing prices of crude oil, and environmental concerns have been the diverse reasons for exploring the use of vegetable oils as alternative to diesel oil [1-4]. Vegetable oils offer almost the same output with slightly lower thermal efficiency when used in diesel engines [5-7]. Reduction of engine emissions is a major research aspect in engine development with the increasing concern over environmental protection and the stringent exhaust gas regulation [8]. Some of the common problems posed by using vegetable oils in diesel engines are coking and trumpet formation on the injectors, carbon deposits, oil ring sticking and thickening and gelling of lubricating oil as a result of contamination by the vegetable oils. Different methods such as preheating, blending and transesterification are being used to reduce the viscosity and to produce bio-diesel, suitable for engine applications. In the present investigation, bio-diesel is prepared from pongamia oil. The fuel properties of the synthesized bio-diesel were determined and their performance, emission and combustion characteristics were studied on a four-stroke, single cylinder, variable compression ratio direct-injection diesel engine to ensure their suitability as CI engine fuel.

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 bio-diesel 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 B-0, B-25, B-50, B-75 and B-100 as fuel is presented.

### 1.1 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. Transesterification Procedure

Generally, vegetable oils contain fatty acids (palmitic, stearic, oleic, linoleic, lignoceric, eicosenoic, arachidic and behenic). Of these pongamia 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 pongamia 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 stoichiometrically, 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 bio-diesel of low viscosity and high conversion. Among all alcohols that can be used in the transesterification process are methanol, ethanol, propanol 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. Pongamia oil is transesterified using methanol as reagent and NaOH as catalysts, to yield bio-diesel (Pongamia Oil Methyl Ester).

## 3. 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 (Fig. 1).

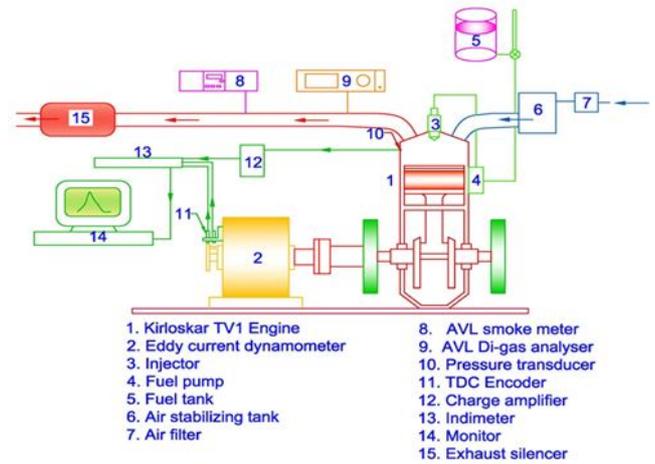


Figure 1: Schematic Diagram of Engine setup

## 4. Results and Discussion

### 4.1 Specific Fuel Consumption (SFC)

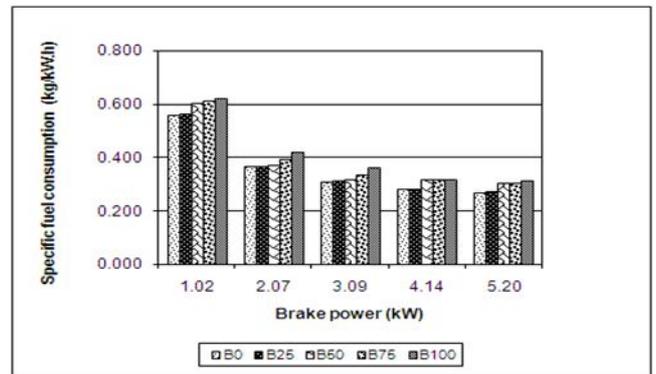
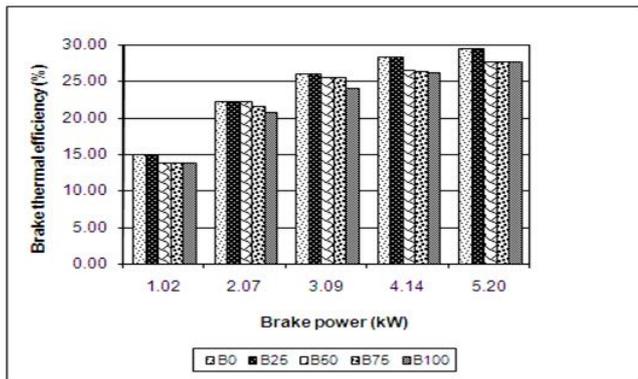


Figure 2: Specific Fuel Consumption vs Brake Power

The variation in specific fuel consumption for B-100 to B-0 is shown in Fig. 2. 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 B-100 gives the highest specific fuel consumption of 0.64 and 0.32 kg/kWh respectively at no load and full load. For B-100, the percentage increase in specific fuel consumption at no load and full load is 11.39% and 16.23% respectively as compared to B-0 and B-25. 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 B-0 and B-25 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 utilization of air leading to better combustion. At no load, diesel engines operate with very lean mixture.

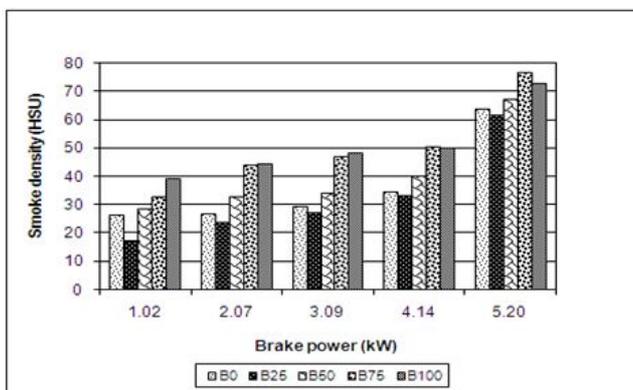
#### 4.2 Brake Thermal Efficiency (BTE)



**Figure 3:** Brake Thermal Efficiency vs Brake Power

Figure 3 shows variation of brake thermal efficiency with respect to brake power for B-100 to B-0. 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 B-100 is 7.35% and 6.35% is lower compared to B0 and B-25 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 B-50, B-75 and B-100 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 B-0.

#### 4.3 Smoke Density (SD)



**Figure 4:** Smoke Density vs Brake Power

Figure 4 shows the variation of smoke density over the complete load range. 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, B-25 has the lowest smoke density of 16.5 HSU, whereas B-100 has the highest smoke density of 38.3. It is interesting to note that B-25 emits lower smoke compared to neat diesel (B-0). This may be due to the chemistry of fuel blend which may promise conducive atmosphere for lower smoke density for B-25 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 B-25 is lower than B-0 over their load range for the reasons explained above B-75 and B-100 are almost bunching together in this load range. It can also be seen from Figure 4, 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.

## 5. Conclusions

From this study, it could be concluded that the B-25 gives optimum performance and lower emissions of SD and NO<sub>x</sub>. 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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