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Experimental Investigation of Diesel Engine Performance Burning Preheated Jatropha Oil

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Abstract: Jatropha biodiesel fuel blends are mixed by volumetric percentages of 5, 20, 40, 70 and 100% with diesel fuel. Jatropha oil fuel is preheated at different preheating temperatures of 50, 70, 80 and 90°C and burned in a diesel engine to study engine performance and emission. These tests were performed on a four stroke, single cylinder, water cooled diesel engine at different loads and rated speeds of 1500 rpm. This research reveals that there is an increase in specific fuel consumption, exhaust temperature and air-fuel ratio in preheated Jatropha oil and biodiesel blends (B5, B20, B40, B70 and B100) than diesel fuel. The results show a decrease in thermal efficiency and volumetric efficiency for preheated Jatropha oil, unheated Jatropha oil and biodiesel blends (B5, B20, B40, B70 and B100) than diesel fuel. The research exhibits a decrease in CO_2, CO and HC for diesel- biodiesel blend and preheated oil than diesel fuel. NO_x and O_2 emissions increased with the use of biodiesel blends as compared to neat diesel. There is a decrease in NO_x and O_2 for preheated and unheated Jatropha oil as compared to pure diesel.

Key words: Brake power・HC emission・Preheated Jatropha oil・Specific fuel consumption・Volumetric efficiency

INTRODUCTION

Due to the gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need for suitable alternative fuels for use in diesel engines. In view of this, vegetable oil is a promising alternative because it has several advantages; it is renewable, environmentally friendly and produced easily in rural areas, where there is an acute need for modern forms of energy [1, 2]. The vegetable oil properties such as viscosity, density and surface tension which affect the spray pattern and lead to poor atomization, improper mixing with air and finally result in curtailing thermal efficiency and increase in emissions. Fuel type, quality and characteristics have a prominent role to meet the current and future standards. Also, a preheating based engine control enhances the performance and, therefore, emissions in the case of a vegetable oil-fueled engine. The neat vegetable oil cannot be used directly due to its high viscosity and low volatility. These properties might affect the performance of a diesel engine by moderate changes in spray characteristics of fuel emerging from the injector. So, viscosity is the viable property that changes the spray patterns of fuel. The high viscosity leads to stoppage of fuel in fuel supply lines, fuel filter and high nozzle valve opening pressure and poor atomization finally leading to incomplete combustion. The high viscosity is due to chemical structure and molecular weight of vegetable oils.

This property also causes the operational problems like cold starting and reducing thermal efficiency. Therefore, vegetable oils cannot be used directly in the diesel engine, especially at room temperature. The possible methods for reducing viscosity are transesterification and preheating. Transesterification is the most convenient method to reduce viscosity and mixing with diesel also reduces viscosity, but at the cost of reduction in calorific value. The preheating is also applied to reduce viscosity of inlet fuel and is implemented as envisaged by many studies [3, 4]. Raghu and Ramadoss [5] performed experimental investigations on a single cylinder, four strokes, constant RPM,

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stationary, air cooled, compression ignition engine run on preheated rice bran oil at different injection pressure and injection timing. The exhaust gases were used for preheating the oil by means of a heat exchanger. The temperature of rice bran oil could be raised to 158°C at the full load. It was found that the preheated rice bran oil exhibits a closer performance as compared to rice bran biodiesel. Hence it can be considered as a better substitute for rice bran biodiesel. The oxides of nitrogen for preheated oil were found to be higher than for diesel fuel. Martin and Prithviraj [6] investigated the performance of diesel engine burning preheated cotton seed oil. A single cylinder compression ignition engine was operated successfully on preheated and neat cotton seed oil. Lower thermal efficiency is found in neat cotton seed oil compared to diesel fuel. However, preheating the mixture increases the thermal efficiency. The exhaust gas temperature is higher for cotton seed oil compared to diesel fuel. This is due to the late burning of oil. It is further reduced with preheated oil and diesel mixture. Marginal increase in NO emission with preheated mixture of cotton seed oil and diesel fuel than neat oil because of increased fuel preheating temperature leads to high combustion temperature. Agarwal and Dhar [7] tested the performance of diesel engine burning preheated Jatropha oil. The performance and emission tests were conducted with diesel, preheated and unheated Jatropha oils at different engine loads and constant speed of 1500 rpm. The results show that preheating the Jatropha oil improves its properties as alternative fuel for diesel engines. Exhaust gases are used to preheat the oil and this preheating significantly improves the performance and emission characteristics of Jatropha oil. Specific fuel consumption and exhaust gas temperatures for preheated Jatropha oil were found to be higher compared to diesel. Thermal efficiency was lower for preheated Jatropha oil compared to diesel. CO_2, CO and HC emissions were lower for preheated Jatropha oil compared to that of mineral diesel. However, NO emissions increased by preheating the Jatropha oil.

Experimental Set up and Test RIG: The test engine is a Kirloskar make, single cylinder, water cooled, direct injection, AV1 model diesel engine. The technical specifications of the engine are given in Table 1.

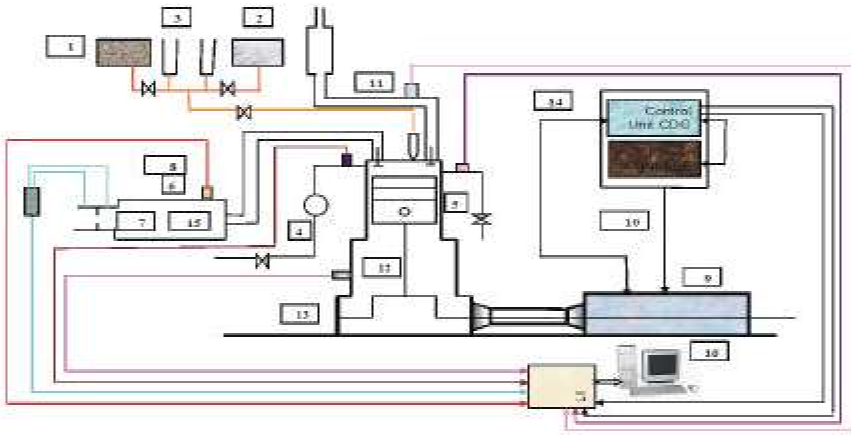
The engine was connected to an electrical dynamometer to measure the power output and torque. The engine was equipped to measure several parameters: fuel consumption, engine speed and exhaust gas temperature. The engine receives air through an air box fitted with an orifice for measuring the air consumption.

Table 1: Test engine specifications.

Items	Specifications
Rated Output	5 KW/1500 rpm
Bore x stroke	85x110 mm
Compression ratio	17.5:1

The intake air flow rate is determined by measuring the pressure difference between the two sides of the orifice (inside and outside the air box). A pressure differential meter is used to measure the difference in pressure between the two sides of the orifice. The engine was loaded with an eddy current dynamometer. A surge tank was used to damp out the pulsations produced by the engine, for ensuring a steady flow of air through the intake manifold. The fuel consumption rate was determined using the glass burette and stop watch. The engine speed was measured using a digital tachometer. MRU DELTA 1600-V gas analyzer was used for measuring the exhaust gas components as CO, HC, CO_2 and NO_x. The exhaust gas temperature was measured by k-type thermocouple. A digital photo tachometer model (BRI 5045) was used for engine speed measurement. A data acquisition card (National Instrument 6210) is used to acquire data and send it to personal computer. The experimental set up and test rig is shown in Fig.1.

Experimental Procedure: Before starting the measurements, some important points should be considered in order to get meaningful data from the experiments. The engine was warmed up prior to data acquisition. The tests were carried out for different engine loads ranging from low load to maximum load conditions at rated speed of 1500 rpm. At each operating condition measurements of various parameters were taken. The test engine usually started at lower engine speed until achieving the stable condition. Then the engine speed was increased gradually up to 1500 rpm. For each engine load, the measurements of fuel consumption, air consumption, exhaust gas temperature; brake power, specific fuel consumption, thermal efficiency and volumetric efficiency were recorded. A shell and tube heat exchanger is used to preheat Jatropha oil by heating water by three electric coils, each of them is 500 Watt. The temperature of preheating is controlled by digital thermostat. Preheating Jatropha oil is carried out at different preheating temperatures of 50, 70, 80 and 90°C. The same conditions, methods and procedures were used for both the experiments of preheated Jatropha oil, unheated Jatropha oil and diesel fuels. For each engine load, the engine was operated for around 10 minutes until



1. Diesel Tank	10. Power Unit
2. Biodiesel Tank	11. Exhaust Temperature Sensor
3. Burette	12. Oil Temperature Sensor
4. Inlet Water Temperature Sensor	13. Diesel Engine
5. Outlet Water Temperature Sensor	14. Control Unit
6. Intake Air Temperature Sensor	15. Air Tank
7. Orifice	16. Personal Computer
8. Pressure Differential Sensor	17. Data Acquisition Card
9. Dynamometer	--

Fig. 1: Schematic Diagram of Experimental Set up and Test Rig

the readings get stabilized. At the same time, the dynamometer, all analyzers and meters were switched on and the proper preparations and settings for measurements were carried out according to the recommended methods given in the makers' instruction manuals. When the test engine reached its stable condition, the experiments were started and measurements recorded. Initially the test engine was operated with base fuel diesel for about 10 minutes to attain a normal working temperature condition in order to start the measurements. The engine was then operated with preheated and unheated Jatropha oil (PHJ50, PHJ70, PHJ80, PHJ90 and J100). For every operating condition the engine speed was checked and maintained constant. The different performance and emission parameters studied in the present investigation were brake power, thermal efficiency, specific fuel consumption, exhaust gas temperature, air-fuel ratio, volumetric efficiency, carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO_x), unburned hydrocarbons (HC) and oxygen emission (O_2).

RESULTS AND DISSCUSSION

The variation of specific fuel consumption at different loads and with diesel-biodiesel blends of 5, 20, 40, 70 and 100%, preheated Jatropha oil at different preheating temperatures (PHJ90, PHJ80, PHJ70 and PHJ50) and unheated Jatropha oil J100 are shown in Fig.2. For all tested fuels, specific fuel consumption reduces with increase in load. Specific fuel consumption increase for unheated Jatropha oil J100, preheated Jatropha oil of 50, 70, 80 and 90 °C and diesel-biodiesel blends of 5, 20, 40, 70 and 100% compared with diesel fuel due to the lower calorific value of fuel. This may be due to the consumption of more fuel with Jatropha biodiesel blends, preheated Jatropha oil and unheated Jatropha oil than diesel fuel to gain the same power output owing to the lower heating value of Jatropha oil and its methyl esters.

The variation of thermal efficiency at different loads and with diesel-biodiesel blends (B5, B20, B40, B70 and B100), preheated Jatropha oil (PHJ90, PHJ80, PHJ70 and PHJ50) and unheated Jatropha oil J100 are depicted in Fig. 3. In all the tested fuels, thermal efficiency is increased due to reduction in heat loss with load increase. The decrease in thermal efficiency for diesel-biodiesel bends (B5, B20, B40, B70 and B100), preheated Jatropha oil at different preheating temperatures (PHJ90, PHJ80, PHJ70 and PHJ50) and unheated Jatropha oil J100 compared with diesel oil may be due to lower viscosity, lower calorific value and lower volatility of fuel. All these leads to poor atomization and vaporization for fuel particles of diesel-biodiesel blends, preheated Jatropha oil and unheated Jatropha oil and hence low brake thermal efficiency.

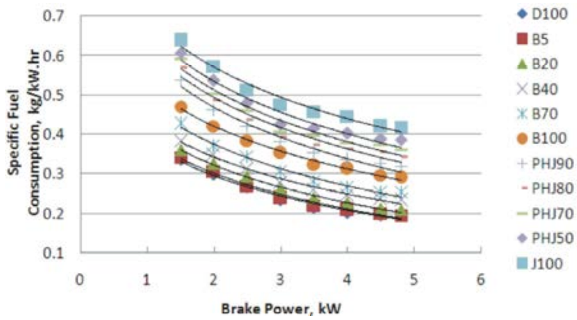


Fig. 2: Comparison between effect of biodiesel blend and preheating oil on specific fuel consumption.

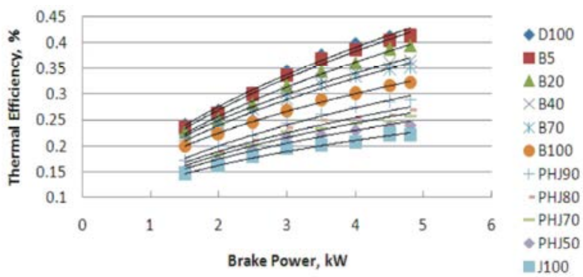


Fig. 3: Comparison between effect of biodiesel blend and preheating oil on thermal efficiency.

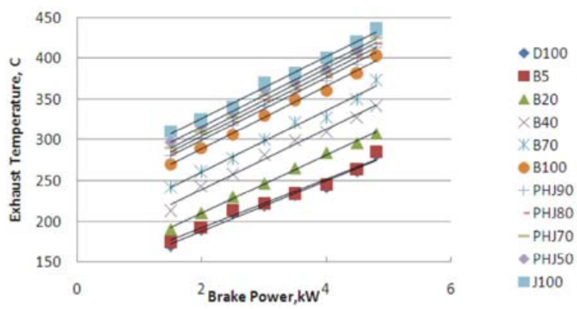


Fig. 4: Comparison between effect of biodiesel blend and preheating oil on exhaust gas temperature.

The variation of exhaust gas temperature at different loads and with diesel-biodiesel blends (B5, B20, B40, B70 and B100), preheated Jatropha oil (PHJ90, PHJ80, PHJ70 and PHJ50) and unheated Jatropha oil J100 are shown in Fig. 4. The increase in exhaust gas temperature may be due to higher temperature inside the engine cylinder as more fuel is burnt to meet the higher load demand. The oxygen content in Jatropha oil is about 10% extra over diesel fuel. This leads to the better utilization of oxygen and the lower viscosity of diesel-biodiesel blends, preheated Jatropha oil and unheated Jatropha oil which promotes the combustion process and the resulting increase of peak temperature leads to increase of exhaust gas temperature.

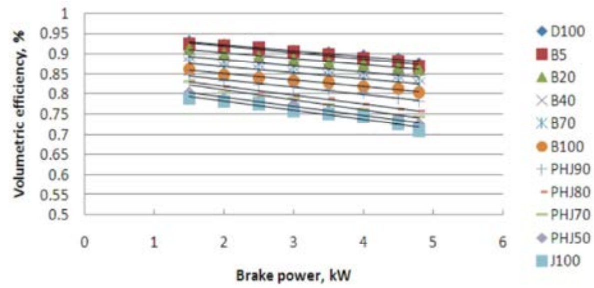


Fig. 5: Comparison between effect of biodiesel blend and preheating oil on volumetric efficiency.

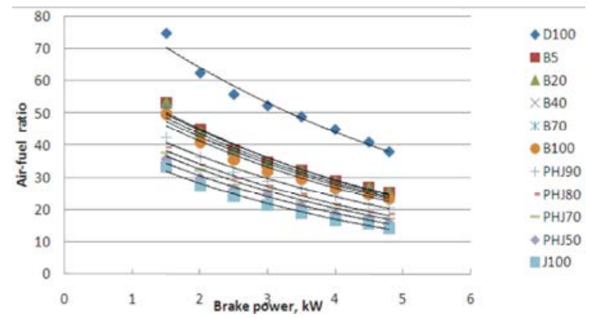


Fig. 6: Comparison between effect of biodiesel blend and preheating oil on volumetric efficiency.

The variation of volumetric efficiency at different loads and with diesel-biodiesel blends (B5, B20, B40, B70 and B100), preheated Jatropha oil (PHJ90, PHJ80, PHJ70 and PHJ50) and unheated Jatropha oil J100 are presented in Fig. 5. It is seen that that the volumetric efficiency decreases with increase in the load for all the tested fuels. This may be due to flow restrictions presented by the air filter, intake manifold and intake valves at higher loads. Volumetric efficiency decreases with the increase in the percentage of biodiesel fuel in the blend compared with diesel oil. Volumetric efficiency increases with increase in preheating temperature compared with unheated Jatropha oil. Biodiesel blends and Jatropha oil contain oxygen which leads to decrease in the amount of air needed for the combustion.

Fig. 6 shows the variation of the air-fuel ratio with load for preheated Jatropha oil, unheated oil and diesel – biodiesel blends. With increase in load, the air-fuel ratio is decreased for all tested fuels. The air-fuel ratio is estimated on mass basis. It was observed that there was not much variation in air-fuel ratios for diesel-biodiesel blends, preheated oil and unheated oil, but these ratios were lower than diesel oil. All these due to increased fuel consumption with increase percentage of biodiesel; also, this may be due to the oxygen content in

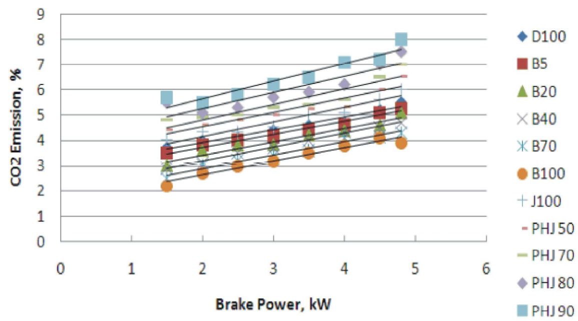


Fig. 7: Comparison between effect of biodiesel blend and preheating oil on CO_2 emission.

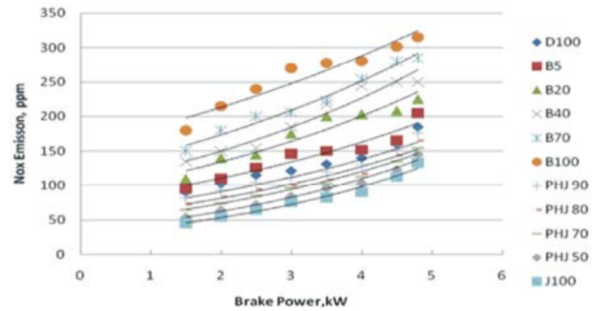


Fig. 9: Comparison between effect of biodiesel blend and preheating oil on NO_x emission.

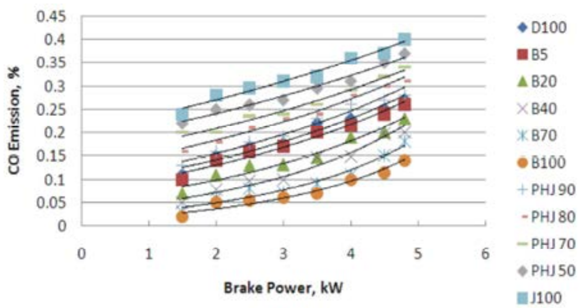


Fig. 8: Comparison between effect of biodiesel blend and preheating oil on CO emission.

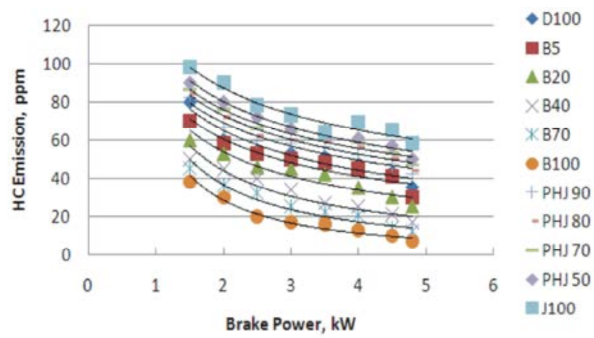


Fig. 10: Comparison between effect of biodiesel blend and preheating oil on HC emission.

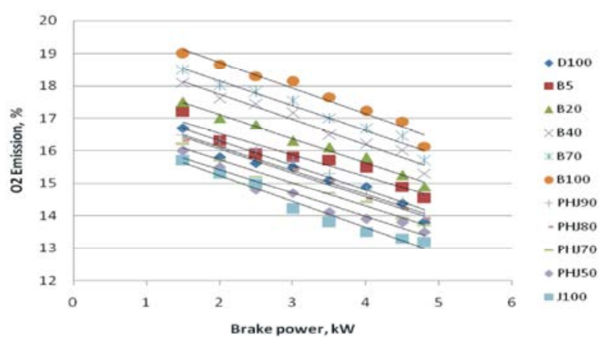


Fig. 11: Comparison between effect of biodiesel blend and preheating oil on O_2 emission.

diesel-biodiesel blends which leads to lower air consumption. Increasing the preheating temperature leads to increase of air-fuel ratio.

Fig. 7 gives the variation of CO_2 emissions with brake power for diesel, preheated Jatropha oil, unheated Jatropha oil and biodiesel blends. It is observed that for diesel-biodiesel blends, CO_2 emissions are lower than diesel oil and it reduces with increase in blend proportion. For preheated Jatropha oil, CO_2 emissions are higher than diesel oil and increases with increase in fuel oil preheating temperature. The reductions in CO_2 emissions for diesel-biodiesel blends are because of the high oxygen content in the biodiesel. Higher density of preheated oil increases the fuel flow rate as the load increases which in turn increase CO_2 emission compared with diesel oil.

The variation of carbon monoxide produced with diesel-biodiesel blends, preheated and unheated Jatropha oils are presented in Fig.8. The decrease in carbon monoxide emissions for biodiesel and its blends are due to more oxygen molecules present in the fuel, lower density and lower viscosity as compared to that of fossil diesel which lead to better combustion. Increasing the fuel oil preheating temperature leads to decrease in CO emissions due to decrease in oil viscosity and density. CO emissions for diesel-biodiesel blends are lower than preheated and unheated Jatropha oils.

The variation of nitrogen oxide emissions with brake power for diesel- biodiesel blends, preheated and unheated Jatropha oils are shown in Fig. 9. The formation of NO_x is significantly influenced by the cylinder gas temperature and the availability of oxygen during combustion, in addition to residence time. It is observed that the increase in NO_x emissions for diesel-biodiesel blends may be due to more oxygen molecules present in the biodiesel. Increasing preheating temperature leads to increase of NOx emissions compared with unheated Jatropha oil due to the increase in cylinder gas temperature.

The variations of unburnt hydrocarbon emissions at different engine loads for diesel-biodiesel blends, preheated and unheated Jatropha oils are depicted in Fig.10. The presence of oxygen in diesel-biodiesel blends aids combustion and hence the HC emissions to be reduced. Increasing fuel oil preheating temperature leads to decrease of HC emissions compared with unheated oil due to the increase in cylinder gas temperature. Increasing preheating temperature for oil leads to reducing viscosity and density, improved vaporization and fuel air mixing rates combustion becomes complete and results in low hydrocarbon emissions.

Fig. 11 shows the variations of oxygen emissions at different engine loads for diesel-biodiesel blends, preheated and unheated Jatropha oils. The oxygen emissions increase with increasing blend proportion for diesel-biodiesel blends due to the presence of oxygen molecules in biodiesel. Increasing preheating temperature leads to increasing CO_2 and NO_x emissions and hence reduction of oxygen emissions. The difference between oxygen emissions was small at all loads for unheated and preheated oils. Oxygen emissions for diesel-biodiesel blends are higher than preheated, unheated Jatropha and diesel oils.

CONCLUSION

Biodiesel-diesel blend fuels show increase in fuel consumption, which is often encountered due to the lower calorific value of biodiesel. Biodiesel blends show decrease in engine thermal efficiency, volumetric efficiency and air- fuel ratio as compared with diesel fuel. The exhaust gas temperature increased with the combustion of biodiesel blends over that for diesel fuel. There is an improvement in engine performance for preheated Jatropha oil than unheated Jatropha oil. Preheated and unheated Jatropha oils show increase in fuel consumption and decrease in thermal efficiency due to the lower calorific value of oil. Preheated and unheated oils show decrease in volumetric efficiency and air- fuel ratio as compared with diesel fuel. The exhaust gas temperature increased with preheated and unheated Jatropha oil over that for diesel fuel. The exhaust pollutants such as CO_2, CO and HC are reduced with the use of biodiesel blends as compared to pure diesel. NO_x and O_2 emissions are increased with the use of biodiesel blends as compared to neat diesel. Most of the major exhaust pollutants such as CO_2, CO and HC are increased with the use of preheated oil as compared to neat diesel. Exhaust emissions such as NO_x and O_2 are decreased with the use of preheated and unheated oils as compared to neat diesel. Due to high viscosity, the diesel engine is to be modified to adapt the fuel and the fuel to adapt to the engine. The ignition delay and fuel injection pressure for diesel engine should be modified. The modification of engines or manufacturing engines to run on Jatropha oil requires the addition of new injector, glow plugs, filter and heat exchanger to the present diesel engine design. The second option is conversion of Jatropha oil to biodiesel. Therefore, it is necessary to increase the inlet preheating temperature of Jatropha oil.

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