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An Experimental Investigation of Diesel Engine Performance Using Jatropha Biodiesel

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Abstract: In this study, Jatropha biodiesel fuel blends are mixed by volumetric percentage of 20, 40, 70 and 100% with diesel fuel 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 speed of 1500 rpm. This research reveals that there is an increase in specific fuel consumption, exhaust temperature and air-fuel ratio in diesel- biodiesel blends (B20, B40, B70 and B100) than diesel fuel. The results show a decrease in thermal efficiency and volumetric efficiency for diesel-biodiesel than diesel fuel. The research exhibits a decrease in CO_2, CO and HC for diesel- biodiesel blend than diesel fuel. NO_x and O_2 emissions increased with the use of biodiesel blends as compared to neat diesel fuel.

Key words: Biodiesel · Diesel engine · Exhaust gas temperature · NO_x emission · Performance

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 authors mentioned that the use of non-edible vegetable oils compared to edible oils is very significant because of the tremendous demand for edible oils as food and they are far too expensive to be used as fuel at present. Rapid increase in the prices of petroleum products and harmful exhaust emissions from engines jointly created renewed interest among researchers to find the suitable alternative fuels [3, 4]. It is concluded that the use of any vegetable oil posses some problems when subjected to prolonged usage in Internal Combustion Engines. These problems are attributed to high viscosity, low volatility and polyunsaturated character of neat vegetable oils. High viscosity of vegetable oil causes some problems in atomization by injector systems and combustion in cylinders of diesel engines. Some of the common problems in the long run are coking and trumpet formation on the injectors, carbon deposits, oil ring sticking and gelling of lubricating oil as a result of contamination by the vegetable oils. There are different methods for reducing viscosity of vegetable oils such as preheating, blending and transesterification [5, 6]. Jatropha oil has better yield as well as thermophysical properties near to diesel fuel. As the edible oil prices are escalating day by day so that researchers are working on non-edible oils. In this study, the experimental tests are conducted on a single cylinder diesel engine using transesterified Jatropha oil and diesel blended fuel. The performance parameters like thermal efficiency, specific fuel consumption, volumetric efficiency, brake power and exhaust emission concentrations are determined experimentally. It is concluded that Jatropha oil could be used as an alternative fuel in the blending form [7, 8].

Experimental Set up and Test Rig: In this study, transesterfaction of the oil was carried out in the laboratory using standard procedure. The properties of prepared diesel-biodiesel blends (D100, B20, B60 and B100) were tested in the laboratory using standard test

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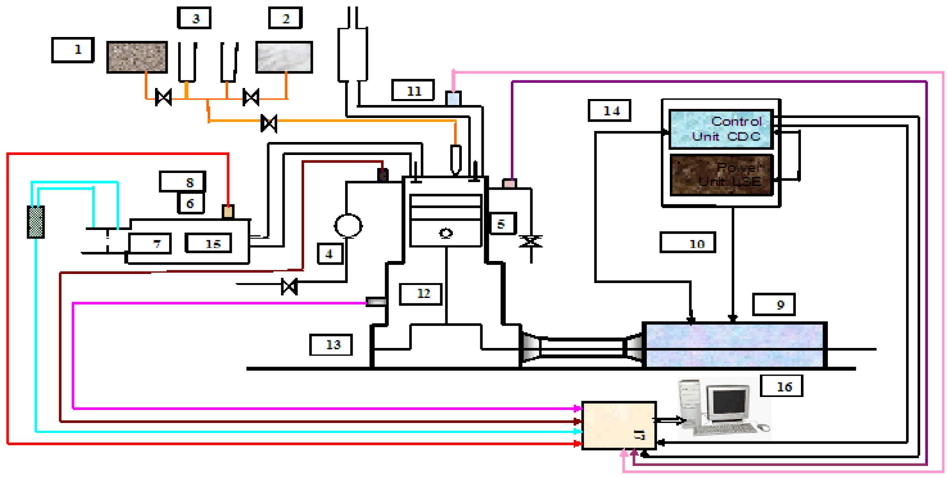

1. Diesel Tank
2. Biodiesel Tank
3. Burette
4. Inlet Water Temperature Sensor
5. Outlet Water Temperature Sensor
6. Intake Air Temperature Sensor
7. Orifice
8. Pressure Differential Sensor
9. Dynamometer
10. Power Unit
11. Exhaust Temperature Sensor
12. Oil Temperature Sensor
13. Diesel Engine
14. Control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

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

Table 1: Evaluated properties of diesel- biodiesel blends.

Properties	Test Method	Diesel	B20	B60	B100
Density	PAAR	834	840	850	860
Heating Value	ASTM D 240	42045	39775	39299	38286
Dynamic Viscosity	ASTM D 445	3.294	5.03	7.606	11.375
Flash Point	ASTM D 92	68	75	110	153
Cetane Number	ASTM D 976	49	50	51	52

Table 2: Test engine specifications.

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

procedures are listed in Table 1. The properties tested were relative density, heating value, dynamic viscosity, cetane number and flash point.

The test engine is a Kirloskar make, single cylinder, four stroke, water cooled, direct injection, AV1 model diesel engine. The specifications of the engine are given in Table 2.

The engine was connected to an eddy current dynamometer to measure the power output and torque. The engine was equipped to measure 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. 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. 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 a 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 emission concentrations of 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 to be fed 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 fixed 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. The same conditions, methods and procedures were used for both the experiments of biodiesel and diesel fuels. For each engine load, the engine was operated for around 10 minutes until 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 blends of diesel and Jatropha biodiesel (B20, B40, B70 and B100). 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), oxygen emission (O_2) and unburned hydrocarbons (HC).

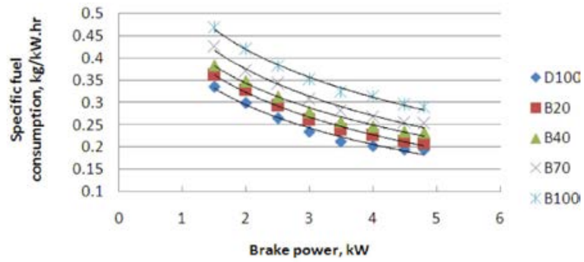

Fig. 2: Variation of specific fuel consumption with brake power for diesel- biodiesel blends.

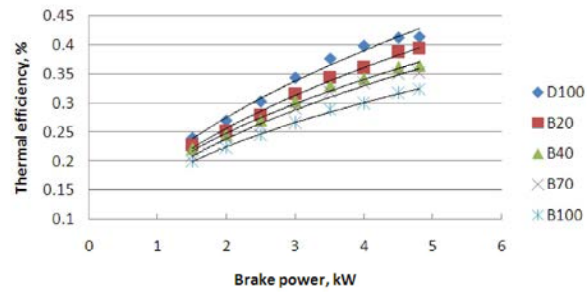

Fig. 3: Variation of thermal efficiency with brake power for diesel-biodiesel blends.

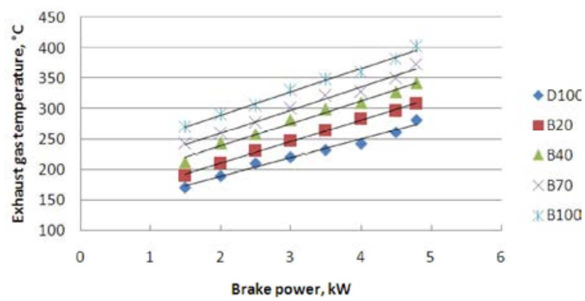

Fig. 4: Variation of exhaust gas temperature with brake power for diesel-biodiesel blends.

RESULTS AND DISCUSSION

The variation of brake specific fuel consumption for biodiesel blend B20, B40, B70 and B100 at different loads is shown in Fig.2. For all cases specific fuel consumption reduces with increase in load. The reverse trend in the specific fuel consumption may be due to increase in biodiesel percentage ensuring lower calorific value of fuel. Another reason for the change in specific fuel consumption in biodiesel in comparison to petroleum diesel may be due to change in the combustion timing caused by the higher cetane number of biodiesel as well as injection timing. It is observed that the specific fuel consumption is higher for B100 compared to that of diesel fuel and all diesel-biodiesel blends. This may be due to the consumption of more fuel with Jatropha biodiesel blends than diesel fuel to gain the same power output owing to the lower heating value of Jatropha biodiesel and its blends as compared with diesel fuel.

The variation of brake thermal efficiency for biodiesel blend B20, B40, B70 and B100 at different loads is given in Fig. 3. At different loads, the brake thermal efficiency is increased due to reduced heat loss with increasing the load. The decrease in thermal efficiency for B100 compared with diesel fuel and all diesel-biodiesel blends may be due to lower viscosity, lower calorific value and lower volatility of fuel which leads to poor atomization and vaporization for fuel particles of biodiesel and hence low thermal efficiency.

Fig. 4 illustrates the variation of the exhaust gas temperature with brake power. The exhaust gas temperature increases with increase in the load for all blends. The ignition delay is longer for diesel- biodiesel blends than diesel fuel resulting in slow combustion which reflects in the higher exhaust gas temperatures. Also, the exhaust gas temperature is higher for B100 Jatropha biodiesel compared to diesel oil and all diesel-biodiesel blends. The oxygen content in biodiesel is about 11%. This may be due to the better utilization of oxygen and the low viscosity of biodiesel, which promotes the combustion process and the resulting increased peak temperature leads to increased exhaust gas temperature.

In Fig.5, the volumetric efficiency increases with the increase in engine load. This is due to the less flow restrictions in the air filter and intake manifold. This leads to increase in the amount of air enters the cylinder. It is seen that volumetric efficiency is lower for B100 Jatropha biodiesel compared to diesel oil and all diesel- biodiesel blends. The volumetric efficiency decreases with the increase in biodiesel percentage in the blend because biodiesel fuel contains oxygen which decreases the amount of air needed for complete combustion.

Fig. 6 shows the variation of Air-fuel ratio for diesel- biodiesel blends B20, B40, B70 and B100 with load. Increasing load results in a decrease in air-fuel ratio (A/F) for biodiesel blends, indicating that a richer mixture is required at higher loads. At low loads the air-fuel ratio is higher for biodiesel blends as compared with diesel fuel because of fuel mass increasing. But as load increases the A/F ratio is lower for biodiesel blends as compared with diesel fuel because of fuel mass increasing.

Fig. 7 depicts that CO_2 emissions of diesel- biodiesel blends fuels have the tendency to increase with increase in engine load due to the higher fuel entry as the load increases. Biodiesel blends emit the lowest level of CO_2 emissions. Higher percentage of biodiesel in the blend emits low amount of CO_2 emissions as a consequence of higher viscosity of biodiesel. Biodiesel blends contain lower carbon content as compared to diesel fuel.

The variation of CO emissions produced from burning diesel and biodiesel blends are presented in Fig. 8. CO formation results from the incomplete combustion due to the insufficient amount of air in the air-fuel mixture or insufficient residence time in the cycle for the completion of combustion. The decrease in carbon monoxide emission for biodiesel and its blends is due to more oxygen content present in the fuel and lower viscosity as compared to that of diesel which lead to better combustion. The variation of nitrogen oxide

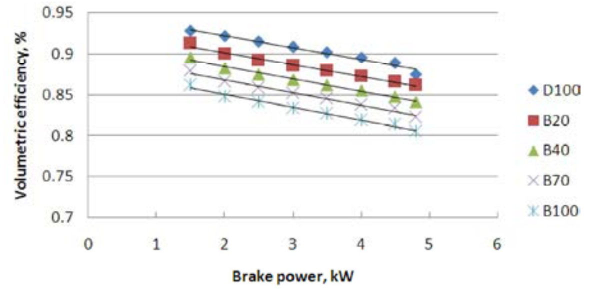

Fig. 5: Variation of volumetric efficiency with brake power for diesel-biodiesel blends.

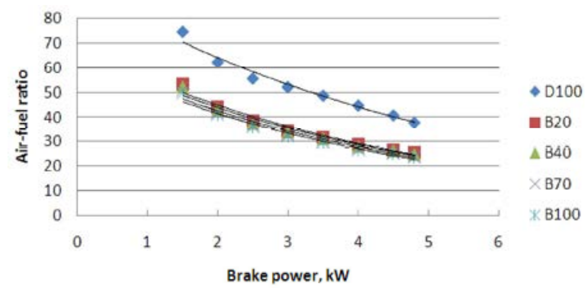

Fig. 6: Variation of air-fuel ratio with brake power for diesel-biodiesel blends.

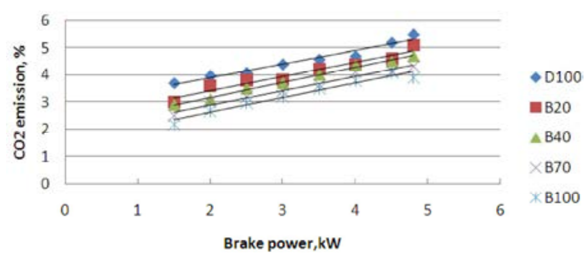

Fig. 7: Variation of CO_2 emission with brake power for diesel-biodiesel blends.

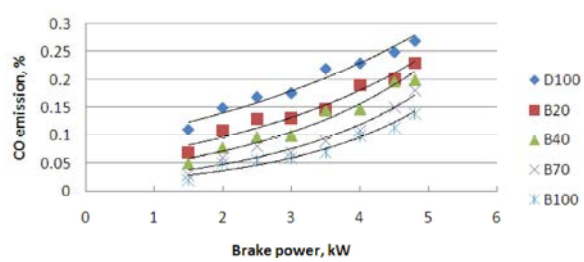

Fig. 8: Variation of CO emission with brake power for diesel-biodiesel blends.

emissions with brake power for biodiesel blends are shown in Fig. 9. NO_x emissions increased with increasing engine load due mainly to the higher combustion temperature. The formation of No_x is significantly

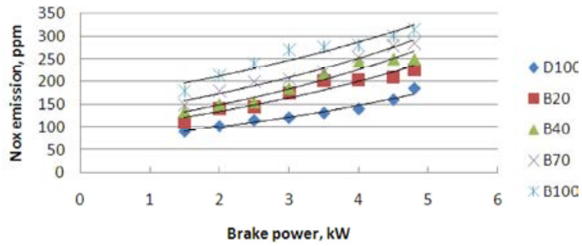

Fig. 9: Variation of NO_x emission with brake power for diesel-biodiesel blends.

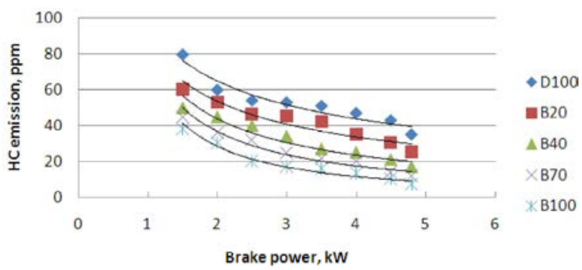

Fig. 10: Variation of HC emission with brake power for diesel-biodiesel blends.

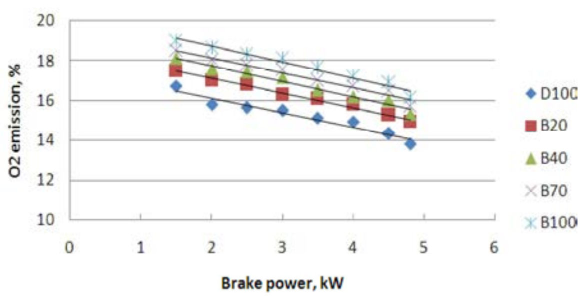

Fig. 11: Variation of O_2 emission with brake power for diesel-biodiesel blends.

influenced by the cylinder gas temperature, the availability of oxygen during combustion and the residence time. It is observed that the increase in NO_x emission for the biodiesel may be due to more oxygen content present in the biodiesel and the increase in cylinder gas and exhaust gas temperatures.

The variations of HC emissions for diesel and biodiesel are given in Fig.10. HC emissions for biodiesel blends are lower than that of diesel fuel. The increase in higher cetane number and exhaust gas temperature are responsible for the decrease in HC emission for diesel-biodiesel blends. Higher temperature of the burned gases prevented condensation of the heaviest hydrocarbons in the sampling line, suggesting proper conditions for HC emission. The higher cetane number of biodiesel causes a decrease in HC emissions due to the decrease in ignition delay. HC emissions decreases with increasing biodiesel percentage in the blend and reaches minimum value when pure biodiesel was used as a fuel. This decrease may be explained in terms of high oxygen content in biodiesel which resulted in improving the combustion efficiency.

The observed decrease in O_2 content in the exhaust with increase in load may be due to richer mixture being burnt in the engine cylinder as shown in Fig.11. The higher cylinder temperature leads to produce a larger portion of oxygen which reacts with nitrogen and carbon to form CO, NO_x and CO_2 at higher loads. Hence less O_2 is released to the atmosphere. It can also be observed that the oxygen emissions increase with increase in biodiesel percentage in diesel- biodiesel blends. Further, the increase in O_2 emission with increase in blend proportion may be due to the inherent oxygen present in biodiesel. It can be noted that the percentage of oxygen in the exhaust is maximum for pure biodiesel and it decreases for other blends in the order B70, B40, B20 and diesel oil.

CONCLUSION

Biodiesel- diesel blends fuels show increase in fuel consumption is often encountered due to the lower calorific value of the 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. 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. Diesel engines should be modified to run with biodiesel and diesel- biodiesel blends, ignition delay and injection pressure should be optimized to achieve the optimum performance and exhaust emissions reduction. One of the aims to use biodiesel as an alternative fuel is due to the depletion of petroleum diesel.

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