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Performance and Emission Studies of a Diesel Engine Fuelled with Different Jatropha Biodiesel Blends

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Abstract:

The ever increasing number of automobiles has led to increasing in demand for petroleum fuels. The environment degradation and depletion of fossil fuels are another reason to search the replacement of this fossil fuel. Biodiesel can become an attractive choice because it is renewable, non-toxic, environmental friendly. The objective of the present research work is to investigate the use of Jatropha biodiesel (JB) and fuel derived from pyrolysis of waste tires (WTDL) in diesel engine as a replacement of diesel in certain amount. The JB and WTDL were blended with diesel (5, 10, 15 and 20% by volume) and experiments have been conducted in a single cylinder, four stroke, air cooled diesel engine. The brake thermal efficiency of the blend was found to be lower than diesel. However, hydrocarbon emission and smoke opacity were found to be lower with blend (up to 10%) than diesel operation. The nitric oxide emissions of blend were higher than diesel. In view of comparable engine performance and reduction in most of the engine emissions, it can be concluded that blend which contained 10% JB, 10% WTDL and 80% diesel can be be used as a potential fuel for diesel engine operation without any engine modification.

Keywords: Biodiesel; Diesel Engine; Waste to Energy; Efficiency

1. Introduction

Clean fuel for transportation and power generation is the worldwide requirement for environment protection and sustainable development. The transportation sector mainly depends on petroleum fuels resulting to economic and environmental consequences. Global climate changes due to carbon dioxide (CO_2) emission which motivates a vigorous policy debate on alternative source of energy for the light duty vehicle transportation sector. With the increase in use and the depletion of fossil fuels will create a big problem in front of whole world in the coming decade. The numerous biomass based feed stocks can be used to generate alternate energy which may act as extender or a complete replacement of fossil fuels. This will help very significantly in agricultural, industrial and transport sector in the energy crisis situation. The importance of diesel fuel in these sectors cannot be neglected because of its ever increasing use. In fact, agricultural and transport sectors mainly depend on diesel. The different alternative fuel options which may replace diesel partially or 100 % are mainly biogas, producer gas, ethanol, methanol vegetable oils, and biodiesel etc.

Use of petroleum based fuels is extensively considered as unsustainable due to their finite resources and enhanced pollution load on the ambient environment. On the other hand, need of energy is increasing continuously with rapid increase in urbanization and industrialization. In India forest and plant based non edible oils are considered as main source of bio-diesel production. Non edible oils can be obtained from plant species such as Jatropha curcas, Pongamia pinnata, Linseed, Madhuca indica, Rapseed, Cotton seed and Rubber seed etc [1-3]. In India, the prohibitive cost of edible oil prevents the use of bio-diesel preparation, but non-edible oils are affordable for biodiesel production. Among the non-edible oils, Jatropha seeds are easily available and being renewable offer potential opportunities for the production of biodiesel as it is considered carbon neutral fuel. At the same time not much attempt has been made to use of esters of non-edible oils as a substitute for diesel expect Jatropha. On the other hand the vegetable oil esters are feasible substitute for diesel fuel and there is still a lot of work that could be done to make a biodiesel commercially viable in diesel engine.

Among the non-edible seeds produced in India, Jatropha is the most preferred because of its high oil content and biodiesel yield [4]. The research works related to the use of biodiesel obtained from Jatropha oil in diesel engines established different results. However, the biodiesel production from Jatropha has a limited scope, due to its lesser availability and collection of oil seeds, as of today. The government of India has already launched a biodiesel programme in the year 2003, to increase biodiesel production. As the availability of Jatropha oil and oil seeds is found to be less at this point of time, a certain percentage of biodiesel can be replaced by some other second generation biofuels [5-7].

In the current study fuel derived by pyrolysis of waste tire and Jatropha biodiesel are used for the replacement of diesel fuel by some percentage. The experiments were carried out in a naturally aspirated, single cylinder, four stroke, air cooled, direct injection (DI) diesel engine with a rated power of 4.4 kW at a constant speed by using different fuel blends. The results were analyzed in terms of performance parameter such as brake thermal efficiency and emissions of hydrocarbon, carbon monoxide, oxides of nitrogen, smoke etc. and compared with those of diesel operated engine.

2. MATERIALS AND METHODS

The Jatropha biodiesel (JB) was produced by the tranesterification process which is known as the most efficient process of converting oil into biodiesel. Tranesterification process is also known as alcoholysis and this process is used worldwide for reducing the viscosity of vegetable oils. The transesterification reaction using heterogeneous catalyst potassium impregnated zinc oxide (60K/ZnO) was conducted in this study for conversion of Jatropha curcas oil into biodiesel. The designated amount of catalyst was dispersed into methanol at 35-40 ºC for 15 min using the same experimental set up.

For the present investigation, waste tire derived liquid (WTDL) was bought from a tire recycling plant located in Rourkela, India. The plant's one batch capacity is 10 Ton. High temperature required for Pyrolysis is obtained by burning of biomass at combustion chamber. Air required for burning was supplied through external blower from bottom of combustion chamber. Flue gases escaping out from combustion chamber are made to circulate outside the pyrolytic chamber and finally released to atmosphere through chimney. Firstly the biomass is burnt to produce desired temperature of 400-700 °C at the surface of combustion chamber. When steady temperatures are attained waste tire is made to fall through the outside surface of combustion chamber with the help of pusher mechanism. Waste tire coming in contact with hot surface melts on outside surface of combustion chamber, cracking occurs and vapors escape to the top of pyrolytic chamber.

The present study is focused to analysis the effect of fuel derived by pyrolysis of waste tire (WTDL) blended with JB and diesel in four different percentages as test fuels, on the performance and emission characteristics of a direct injection (DI) diesel engine. The WTDL and JB at low percentages (5-20% at regular intervals of 5% on a volume basis), was blended with diesel, to get the fuel blends for the investigation. The designations of the test fuels and their compositions used in this study are given below.

Fuel	**JB (by volume)**	**WTDL (by volume)**	**Diesel (by volume)**
diesel	-	-	100%
JB	100%	-	-
B5	5%	5%	90%
B10	10%	10%	80%
B15	15%	15%	70%
B20	20%	20%	60%

3. Experimentation

The test was carried out on a single cylinder, four stroke, naturally aspirated, air cooled, DI diesel engine which has a maximum power out of 4.4 kW. The test engine specifications are provided in Table 1. For loading on the test engine an eddy current dynamometer is coupled to engine with the help of load cell. The engine is interfaced to a control panel, which is connected to a computer. The inputs obtained from different instruments are interfaced to a computer through an analog and digital converter card PCI-1050 which is mounted on the motherboard. A data acquisition system (DAS) integrated with a computer received data from different instruments which is then processed and displayed on the monitor.

Table 1 Engine specifications

Manufacturer	Kirloskar
Model	TAF 1
Engine type	Single cylinder, four stroke, constant speed, air cooled, direct injection, CI engine
Rated power (kW)	4.4
Speed (rpm)	1500 (constant)
Bore (mm)	87.5
Stroke (mm)	110
Piston type	Bowl-in-piston
Displacement volume (cm^3)	661
Compression ratio	17.5
Nozzle Opening pressure (bar)	200
Start of fuel injection	23 ˚CA bTDC (for diesel)
Start of fuel injection	24.5 ˚CA bTDC (for JMETPO20)
Dynamometer	Eddy current
Injection type	Pump-line-nozzle injection system
Nozzle type	Multi hole
No. of holes	3

4. Results and Discussion

This section discusses the results of the performance and emission parameters obtained from the test engine run on diesel, JB and different diesel-JB-WTDL blends.

4.1 Brake Thermal Efficiency

The brake thermal efficiency gives information regarding how efficient the energy in the fuel was converted in to power output [8]. Figure 1 presents the power performance of the diesel and different test fuel blends derived engine under different loading conditions. It can be seen that under the same load, the greater efficiency is for diesel operated engine. In addition, the engine power increased linearly with the load for all the test fuels. As the load increases the heat generated in the cylinder increases, and hence, the brake thermal efficiency increases. At full load the diesel gave highest brake thermal efficiency compared to all the test fuels used in the present study. This can be pertained to the higher calorific value of the diesel fuel compared among all test fuel used.

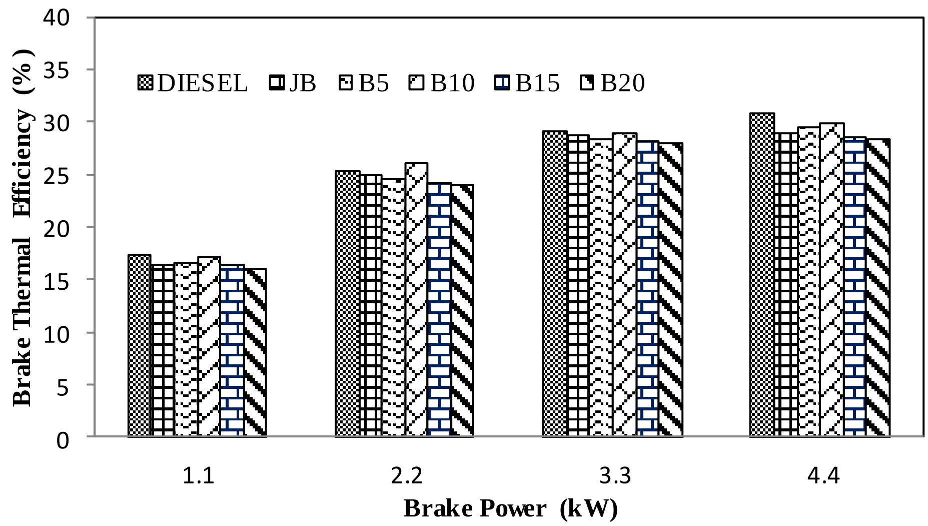

Fig.1 Variation of brake thermal efficiency with brake power

The poor atomization of test fuels due to the higher viscosity may also be one of the causes for lower brake thermal efficiency than that of diesel. Among blends B20 produces highest brake thermal efficiency.

4.2 Carbon Monoxide Emission

The carbon monoxide (CO) emission characteristics of the engine run on diesel and different test fuel blends is presented in Fig. 2. It is known that the rate of CO emission is a function of the unburned fuel availability and mixture temperature, which controls the rate of fuel decomposition and oxidation. In the presence of sufficient oxygen, the CO emission is converted into carbon dioxide emission [9]. The value of CO emission at full load for the diesel, JB, B5, B10, B15 and B20 blend was found to be 0.044, 0.035, 0.037, 0.04, 0.046 and 0.052%. The CO emission for the JB, B5 and B10 is marginally lower than those of diesel fuel. This could be due to the fact that JB contains excess oxygen which helps for better combustion. When the percentage of tire derived fuel increases beyond 10%, the CO emission increases drastically. This may be due presence of aromatic content which results in incomplete combustion, and may lead to higher CO emission [10].

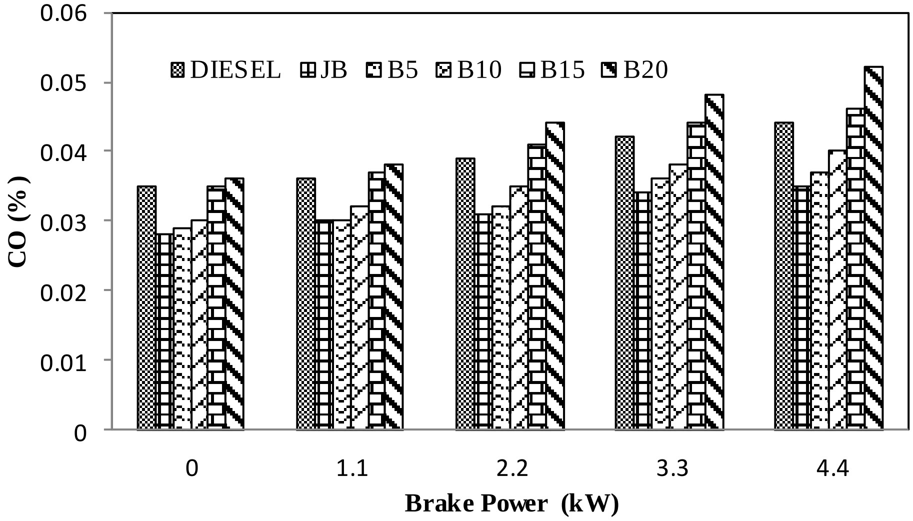

Fig.2 Variation of carbon monoxide emission with brake power

4.3 Hydrocarbon Emission

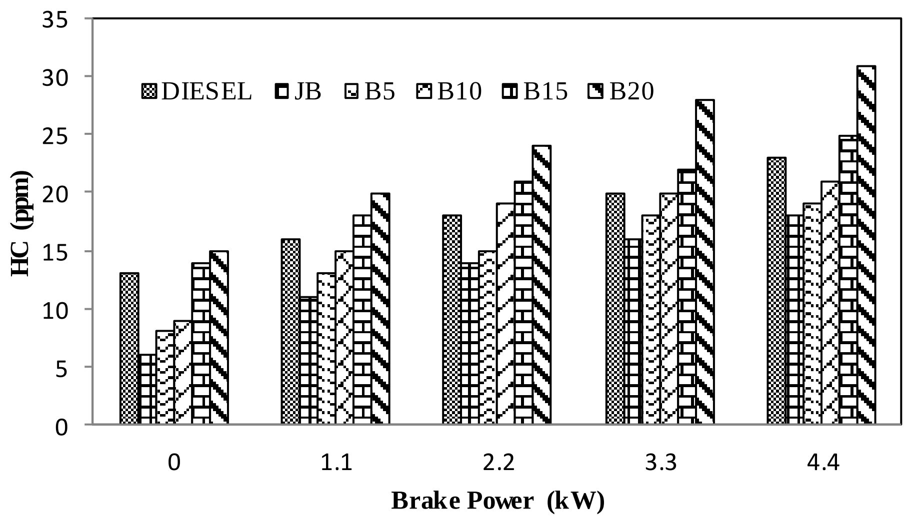

Fig.3 Variation of the unburnt hydrocarbon emission with brake power

The variation of hydrocarbon (HC) emission for diesel, JB and different test fuel blends is shown in Fig. 3. It is observed that hydrocarbon emission increases with the increase in percentage of WTDL in the diesel-JB-WTDL blends. The HC emission is lowest for JB and it was about 18 ppm at full load operation. This can be due to oxygen molecule present in biodiesel [11]. The highest value of HC emission was obtained with B20 blend and was noticed to be 31 ppm.

But the addition of the tire derived liquid percentage results in higher HC emission. This is due to the fact that TPO has higher aromatic content, and hence may result in incomplete combustion and more HC emission for B15 and B20 compared to the other test fuels used in this study. The HC values for diesel, JB, B5, B10, B15 and B20 23, 18, 19, 21,25 and 31 ppm are at full load.

4.4 Nitric Oxide Emission

The nitric oxide (NO) emission characteristics of the diesel and different test fuel blends derived engine at different load conditions are presented in Fig.4. It can be seen that the NO emission concentration increased with the load for all the test fuels.

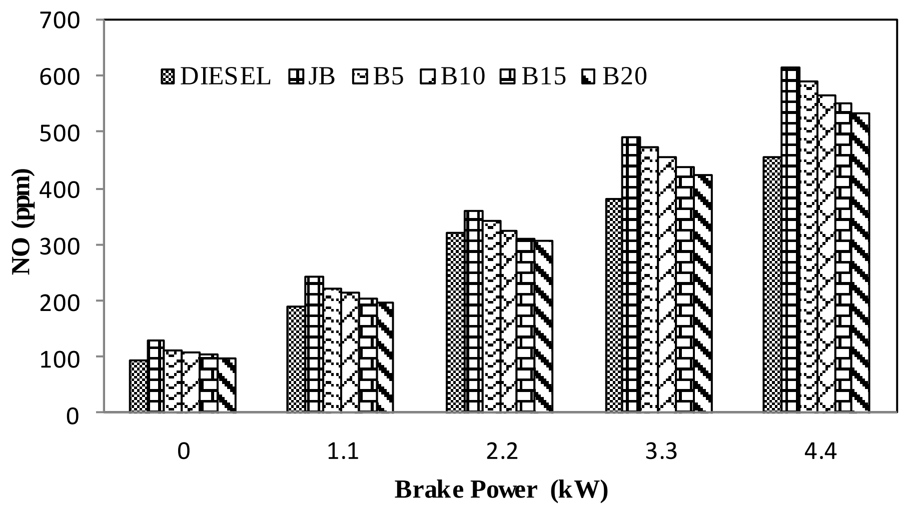

Fig.4 Variation of the nitric oxide emission with brake power

This is due to the fact that, because with increasing load, the temperature prevailing in the combustion chamber increases [12-13]. The NO emission form engine exhaust is highly dependent on oxygen concentration and combustion temperature. The JB has about 11% oxygen molecule which is the major cause of higher NO emission for this fuel compared to all other test fuel used in this study. While increasing the WTDL percentage in the blend, the NO emission decreases, because of lower heat release rates than that of JB. The values of NO emission for diesel, JB, B5, B10, B15, and B20 are by about 452, 614, 589, 564, 549, and 532 ppm respectively, at full load operation.

5 Conclusions

A single cylinder, four stroke, naturally aspirated, air cooled, DI diesel engine was operated successfully using diesel-JB-WTDL blends. The following conclusions are made based on the experimental results.

- The brake thermal efficiency of the engine was highest for the diesel and among different blend B10 gave higher brake thermal efficiency. At full load, the brake thermal efficiency is almost the same, i.e., 29.9% and 30.8% for B10 and diesel respectively, at full load.
- The CO and HC emissions were lower by about 9%, 19% respectively for B10, compared to diesel at full load.
- Nitric oxide emission was higher by about 21% for B10 in comparison with diesel at full load.
- On the whole it is concluded, that the B10 blend can be used as fuel in a diesel engine directly, without any engine modification. The B10 gives the optimum result, compared to the other blends. The results from the experiments prove that B10 blend is good substitute for diesel fuel.

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