Experimental Study of Performance and Emissions for different Biodiesels Fuelled on Diesel Engine

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Abstract - *The rapid diminishing of fossil fuel resources, limited in nature and concerns of environment were the reasons for exploring the biodiesel use as petroleum based fuel substitute. Hence biodiesel produced from cheap feedstock Pongamia and Simarouba oils could be used for biodiesel production to fulfill energy demand and alternative to petroleum diesel. In line with the framed objective, the effect of performance, and emission characteristics of alternate fuels is observed by engaging a direct injection (DI) single-cylinder four-stroke variable load multi-fuel engine. The present work is focused on performance and emission tests by using Pongamia and Simarouba oil biodiesel. owever slightly lower performance was obtained with Pongamia and Simarouba biodiesels compared to petroleum diesel. Slightly lower NOX and HC & CO emissions were obtained with Both Biodiesels when conducting engine test.*

***Key Words*: Fuel substitute, Pongamia and Simarouba biodiesels, Performance, Emissions, Four stroke, Variable load.**

1.INTRODUCTION

In the recent past, intensive studies on internal combustion engines has emerged with a view to obtaining higher rate of production of fuels from alternative sources. The increase in alternative fuel investigations is caused by two main factors; a rapid decrease in world petroleum reserves and important environmental concerns originating from exhaust emissions. Fast depletion of fossil fuels is demanding an urgent need to carry out research work to find out the viable alternative fuels. Diesel fuel is largely consumed by the transportation sector. Thermodynamic tests based on the engine performance evaluations have established the feasibility of using vegetable oils. It has been found that vegetable oils hold special promise in this regard, because they can be produced from the plants grown in rural areas. Vegetable oils from crops such as soyabean, peanut, sunflower, rape, palm, coconut, karanja, neem, cotton, mustard, jatropha, linseed and coster have been evaluated in many parts of the world in comparison with other non-edible oils. To solve energy and environmental concerns, the renewable energy with lower environmental pollution impact should be necessary. Hence, it is imperative to look for alternative fuels, which can be produced from the resources that are available within the country Today, most of the energy demand in India is met by fossil fuels. As India is an agricultural country, there is a wide scope for the production of vegetable oils (both edible and non-edible) from different sources.

Performance tests are necessary to carry out for an engine to assess the fuel and thermal efficiencies. Further, it is also required to study the effect of different parameter on the engine performance, i.e. incomplete combustion of heterogeneous mixture, and droplet combustion. Compression ignition engines, because of their varied applications, are manufactured in a large range of sizes, speed and power inputs.

1.1 Emissions

Automobile is a major contribution to air pollution in most of the industrialized nations according to the survey conducted in the present atmosphere. The air we breathe is proven to be unhealthy, the various emission from the automobile exhaust like CO, HC, NOX, particulate matters, SOOT etc., are highly harmful for human health, apart from that, animals and plants are also facing a negative impact by emission caused by automobiles. Automobile exhaust emission has also actively participation in increasing global warming.

1.2 Alternative Fuels

Alternative fuel is any material or substance, other than petroleum, which is consumed to provide energy to power an engine. Alternative fuels are bio-diesel, ethanol, chemically stored electricity, hydrogen, methanol, Natural gas, wood and vegetable oil. The increase in industrialization and materialization of the world led to step rise in the demand of petroleum products. Petroleum based fuels are extracted from earth crust and hence their reserve is limited and are irreplaceable. With our present known reserves and the growing rate of fuel consumption, it is feared that they will be exhausted soon. The fuels used in C.I. Engines primarily are diesel, which is a petroleum fraction, which lies between kerosene and lubricating oil. Cetane rating is very important factor diesel fuel as it is the measure of auto ignition of the fuel that is supposed to auto ignites inside the combustion chamber due to temperature rise with the compression of air in C.I. engine.

Some of the alternate fuels that can be used in C.I Engines are:

1. Hydrogen
2. Biogas
3. Vegetable Oils
4. Alcohols
5. CNG
6. Synthetic Hydrocarbons

2. BIODIESEL

Biodiesel is the name of a clean burning alternative fuel produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression ignition (diesel) engines with no major modifications.

In this work biodiesel refers to the fuel produced from renewable sources that meets ASTM International D6751, the standard for biodiesel. A number following the "B" indicates the percentage of biodiesel in a gallon of fuel. Pure biodiesel is also known as B100. Biodiesel is most commonly used as a blend with petroleum diesel. Biodiesel, a renewable fuel, is produced from vegetable oils and animal fats by a process called transesterification. And the properties of the fuels are noted in following Table-1.

Table -1: Properties of Fuels used

Properties	Pongamia Biodiesel	Simarouba Biodiesel	Diesel
Sp. Gravityat (at 25^0C)	0.899	0.875	0.834
Calorific Value (kJ/kg)	38119	38233	42707

2.1 Blending Of Fuel

The produced bio diesel is blended with the regular in different percentages as shown in Fig 1 and 2. Below are the notations for different fuel samples which are blended.

1. The blending process was carried out with the help of a measuring jar and beaker. The appropriate percentages of diesel and biodiesel were added to the beaker and then transferred to bottle. The bottles were shaking well and were allowed to stay upside down to ensure proper mixing of fuels.
2. The bottles were stored in dry place and kept still for the next 24 hour. Blends were checked for every 6 hrs. time intervals for any layer formation. All the blends were stable and passed the 24 hrs. Stability test and were ready to be used on engine. Both biodiesels blends are shown bellow Fig-1 and Fig-2.

Fig -1: Pongamia Biodiesel Blends

Fig -2: Simarouba Biodiesel Blends

3.Experimental Setup

The fuel is supplied to the engine through the separate fuel tank through fuel line. The burette is used to measure the amount of fuel flow. The engine is connected to the eddy current dynamometer. The dynamometer is connected to the electric current supply to apply load on the engine.

The engine is loaded by applying the opposite current to the eddy current dynamometer, this current causes the electromagnetic force applied in opposite of the rotation direction. The engine speed is constant for all loads. The time taken to consume quantity of fuel is noted. At the same time torque applied is also noted.

When fuel tank knob is opened, the fuel comes to the engine through the burette. The amount of fuel sent can be measured from the burette. Then by cranking the engine, the engine gets started. The output of the engine is connected to the eddy current dynamometer.

The engine can be loaded by applying the opposite current to the dynamometer. When a current is applied to the dynamometer, the electromagnetic force will generate opposite to rotation of shaft. This increases load on the engine. The sensor is provided to measure the torque applied on engine. Experimental setup is shown below in Fig-3. And the Table-2 shows the specifications of engine.

Fig -3: Engine Setup

Table -2: Engine Specifications

Engine	Four Stroke Single Cylinder vertical water cooled engine
Company	Kirloskar
Capacity	3.7 kW
Compression Ratio	16.5:1
Cylinder Bore	80 mm
Stroke	110 mm
Cylinder Capacity	553 cc
Cooling	Water cooled
Rated speed	1500 rpm

3.1 Testing Procedures

Performance test on single cylinder diesel engine, the procedure for conducting a performance test on the engine specified above is as follows,

- Calculate the full load capacity of the engine.
- Check up all the connections and check the fuel and water.
- Press the decompression lever and crank the engine, when the specific speed is reached, release the lever.
- Firstly on no load the following readings are taken.

  - ✓ Speed of the engine (constant),
  - ✓ Time taken to consume 10 cc of fuel using stop valve
  - ✓ Mass flow rate of air,
  - ✓ Exhaust temperature

Then load the engine by applying the opposite current to the dynamometer by rotating the knob gradually. The time taken to consume 10cc of fuel and toque on the engine is noted. Repeat the experiment for different loads (0,5, 10, 15 & 20Nm) and note down the corresponding readings. This procedure same for different blends of different biodiesels.

The AVL DIGAS 444 smoke meter had shown in Fig 4, which measures the opacity of polluted air in particular, diesel engine exhaust gases. The opacity is extension of light between light source and receiver. The temperature of the gas should be between 70degree Celsius and 130 degree Celsius at each point in the measurement chamber. The equipment has a microprocessor controlled program sequence to check the measurement process and to store the value such as pressure, temperature, opacity and adsorption. This Exhaust Gas Analyzer measures the Exhaust gases values based on the volume. This AVL DIGAS444 shown in Fig-4, will help us to get the emission volumes of different emission gases like Monoxide(CO), Unburnt Hydrocarbons(HC), Corbon di-Oxide(CO_2), Oxygen(O_2), Nitrogen Oxide(NO).

Fig -4: AVL DIGAS 444 Exhaust analyzer

The Procedure AVL DIGAS 444 Exhaust analyzer:

- Switch on the AVL DIGAS 444 smoke meter.
- Press the CAL button and wait till the reading display becomes zero.
- Check the temperature if it is less than 75 degree Celsius. Then switch on the heater till it becomes 75 degree Celsius.
- Place the smoke tube inside the exhaust pipe of the engine at constant idling speed.
- Repeat the experiment for different loads of diesel engine.
- This procedure also same for different blends of Biodiesels.

4.Results and Discussions

The tests were conducted on a direct injection diesel engine for different blended of Pongamia and Simarouba Biodisels with diesel. Analysis of performance parameters and emission characteristics such as brake power, brake specific fuel consumption brake thermal efficiency, exhaust gas temperature, hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen etc are determined.

4.1 Performance characteristics

Performance of the engine defined as degree of success of the engine in the assigned work, in the conversion of Heat energy into Mechanical work. So many parameters are responsible to measure the performance of the engine. Some important parameters are discussed below. And they are discussed with the independent variable Brake power.

Blends details

B20PBD-20% of Pongamia Biodiesel
B20SBD-20% of Simarouba Biodiesel
B40PBD-40% of Pongamia Biodiesel
B40SBD-40% of Simarouba Biodiesel

4.1.1 Brake thermal efficiency

In Chart-1, the brake thermal efficiency is plotted against brake power for diesel, Pongamia and Simarouba Biodiesels and their blends and neat diesel at constant speed of the engine. It was observed that with the increase of the load brake thermal efficiency increase in all cases. Simarouba biodiesel's B20 blend giving higher Brake thermal efficiency among all blends of both biodiesels. B20 Pongamia biodiesel is near to neat diesel with some 5% variation.

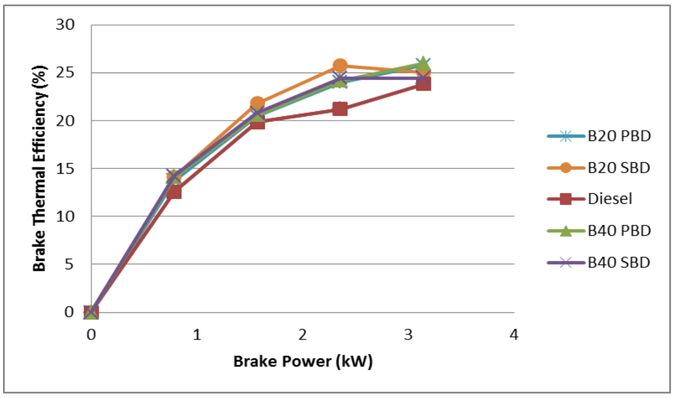

Chart -1: Variation Of Brake Thermal Efficiency With Brake Power

4.1.2 Fuel consumption

The variation of fuel consumption with brake power for different blends of biodiesel and neat diesel are shown in Chart-2 at constant speed. It was observed that consumption of fuel increases with the increase of brake power. The diesel fuel consumption was less in all load conditions due to the high calorific value of diesel than the biodiesel blends. For B20 pongamia biodiesel blend fuel consumption was slightly approaching neat diesel fuel.

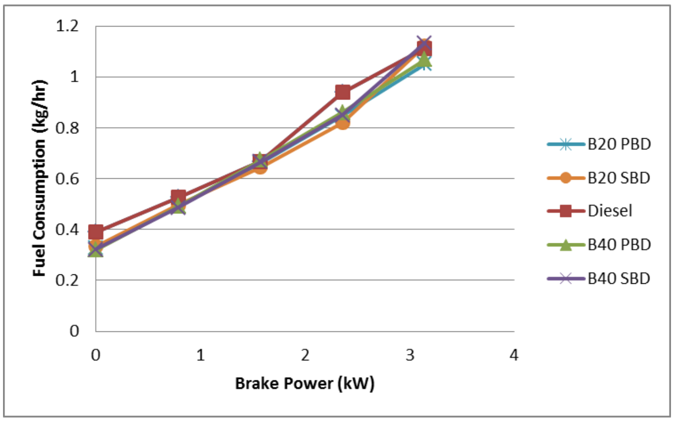

Chart -2: Variation Of Fuel Consumption With Brake Power

4.1.3 Brake Specific Fuel Consumptiion

The variation of specific fuel consumption with brake power for different blends of biodiesels and neat diesel are shown in Chart-3 at constant speed. From graph it is observed that the specific fuel consumptions decreased with the increase of brake power. The specific fuel consumption of biodiesel blends is higher than the neat diesel in all load conditions due to high viscosity of the biodiesel blends. The specific fuel consumption for B40 Simarouba Biodiesel blend is closer to the neat diesel fuel.

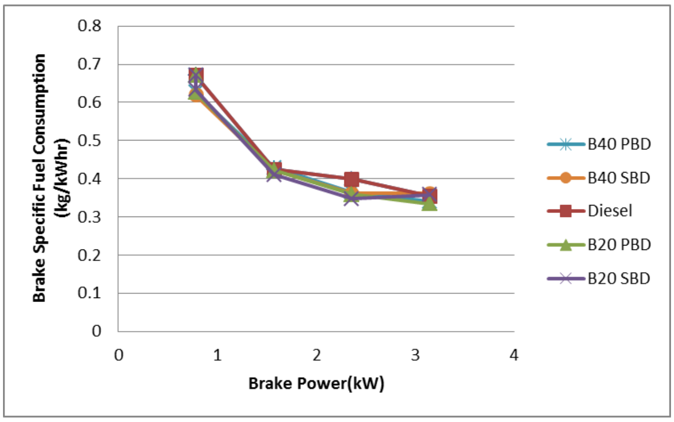

Chart -3: Variation Of Specific Fuel Consumption With Brake Power

4.1.4 Exhaust Gas Temperature (EGT)

The variation of exhaust gas temperature with brake power for different blends of biodiesel and neat diesel are shown in Chart-4. From the graph it is observed that the exhaust gas temperature increases with the increase of the brake power. The exhaust gas temperature of the biodiesel blends in all load condition is higher than the neat diesel fuel due to high flash point temperature and high viscosity of the biodiesel blends. The exhaust gas temperature of biodiesels B20 is 30°C higher than diesel fuel.

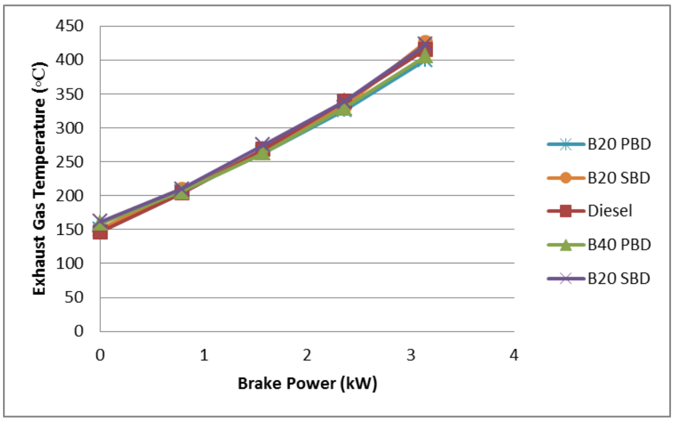

Chart -4: Variation Of Exhaust Gas Temperature With Brake Power

4.2 Emissions characteristics

4.2.1 Carbon monoxide emissions

These lower CO emissions of biodiesel blends may be due to their more oxidation as compared to diesel. Some of the CO produced during combustion of biodiesel might have converted into CO_2 by taking up the extra oxygen molecules present in the biodiesel chain and thus reduced CO formation. It can be observed from Chart6. that the CO initially decreased with load and later increased sharply up to full load. This trend was observed in all the fuel blend tests.

These lower CO emissions of biodiesel blends may be due to their more oxidation as compared to diesel. Some of the CO produced during combustion of biodiesel might have converted into CO2 by taking up the extra oxygen molecules present in the biodiesel chain and thus reduced CO formation. This shown in Chart-5.

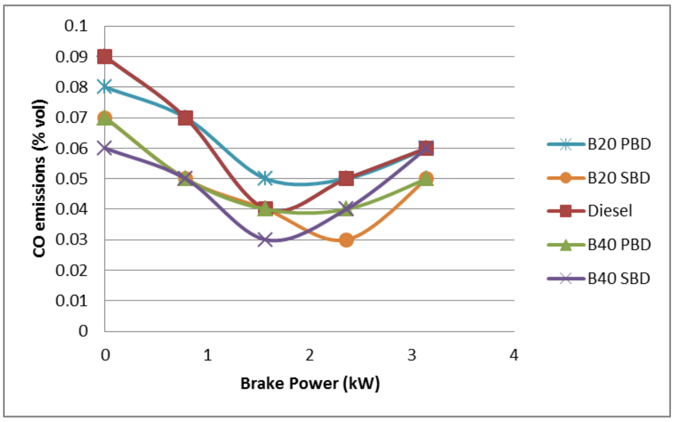

Chart -5: Variation Of Carbon Monoxide Emission With Brake Power

4.2.2 Hydrocarbon emission (HC)

The variation of hydrocarbon emission with brake power for different blends of biodiesel and neat diesel are shown in Chart-6, at constant speed 1500rpm. Form the graph it is observed that the hydrocarbon emission of different blends of biodiesel blends is less than the neat diesel fuel due to the less amount of carbon and hydrogen content of the biodiesel blends. The hydrocarbon emission of Pongamia biodiesel blend B20 is closer to diesel and lowest hydrocarbon emission is observer for B40 Pongamia biodiesel blend.

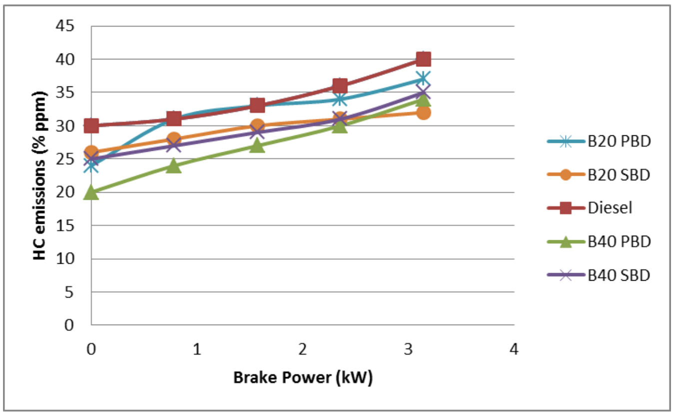

Chart -6: Variation Of Hydrocarbon Emission With Brake Power

4.2.3 Carbon Dioxide emission (CO2)

The variation of carbon dioxide emission with brake power for different blends of biodiesel and neat diesel are shown in chart-7 at constant speed 1500rpm. From the graph it is observed that the carbon dioxide emission increases with the increase of the brake power.

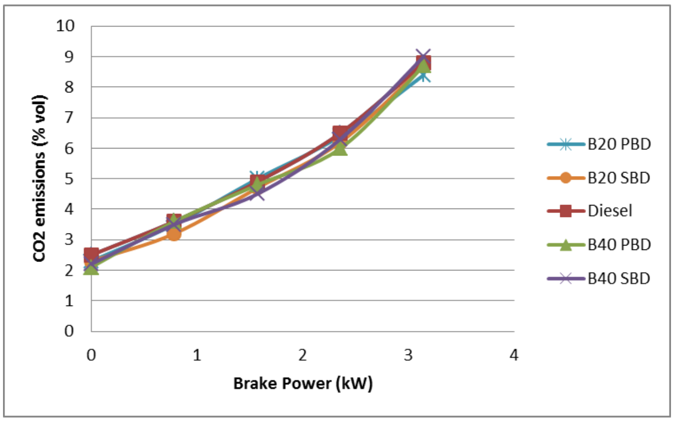

Chart -7: Variation Of Carbon Dioxide Emission With Brake Power

4.2.4 Oxygen (O2)

The variation of oxygen with brake power for different blends of biodiesel and neat diesel are shown in chart-8 at constant speed 1500rpm. From the graph it is observed that the level of oxygen decreases with the increase of brake power.

At full load condition the Both biodiesel blends of B20 and B40 have lower oxygen level due to complete combustion of the biodiesel blends. At low load condition oxygen level of both biodiesel the blends B20 is higher than the diesel fuel

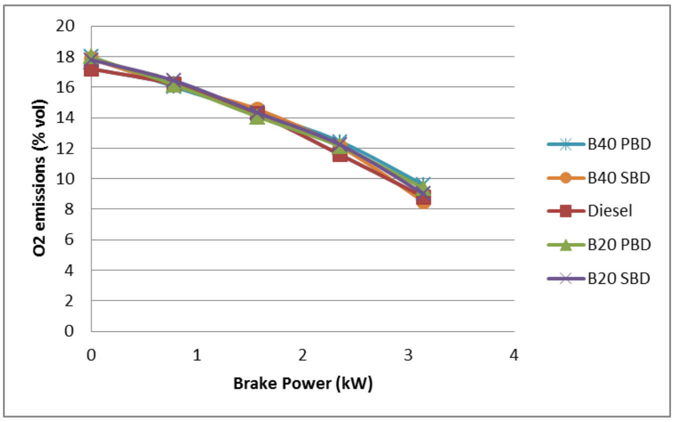

Chart -8: variation of oxygen with brake power

4.2.5 Oxides of Nitrogen emission (NOx)

The variation of oxides of nitrogen (NOx) emission with brake power for different blends of biodiesel and neat diesel are shown in Chart-9 at constant speed 1500rpm. From the graph it is observed that the NOx emission of all the biodiesel blends is higher than the diesel and increases with the increase of the brake power due to the high combustion temperature in the combustion chamber for extra oxygen molecules of biodiesel and high cetane number of the biodiesel blends. At high load condition NOx emission is same of both biodiesels blend B20 and neat diesel.

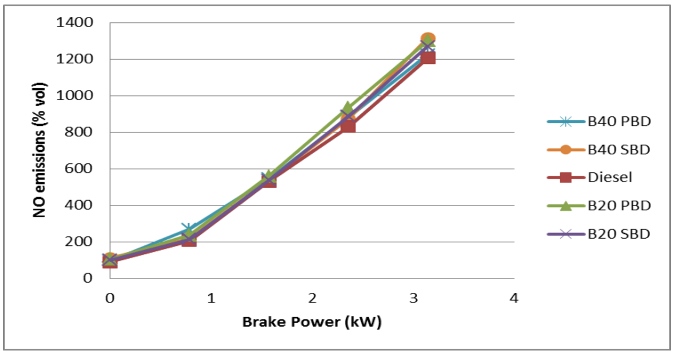

Chart -9: Variation Of Oxides Of Nitrogen With Brake Power

5. Conclusion

A four stroke water cooled single cylinder direct injection diesel engine was run successfully using Pongamia and Simarouba biodiesel blends (B0,B20 and B40) as fuel. The performance and emission characteristics have been analyzed and compared to baseline diesel fuel. The following conclusions are made with respect to the experimental results.

a) At full load condition brake thermal efficiency of the biodiesel blends were marginally lower than the neat diesel fuel.

b) Specific fuel consumption for B20 blend was close to neat diesel fuel at full load condition.

c) Exhaust gas temperature of Both biodiesels blends were higher than neat diesel fuel at all load conditions and EGT of PB40 and SB40 was 30°C higher than diesel fuel at full load condition.

e) There was 20% reduction of hydrocarbon of PB40 and SB40 than neat diesel at full load condition.

f) There was 5% reduction of CO emission of B25 than neat diesel at full load condition.

g) There was 2% reduction of NOx of PB20 and SB20 blends than neat diesel at full load condition.

ACKNOWLEDGEMENT

Firstly, thank to my Project Guide **Sri. C.N. NATARAJ,** and all the staff members of Department of Studies in Mechanical Engineering, **University of B.D.T. College of Engineering Davangere, Karnataka** for their guidance, encouragement and suggestions at every step.

I would like to express my gratitude to **Dr. Sharanappa Godiganur,** Professor and Head of R&D, AND Staff members of **REVA UNIVERSITY BENGALURU** for facilitating in all the way.

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