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Performance, Emission and Combustion characteristics of a single cylinder diesel engine operating on simarouba biodiesel and diesel fuel

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Abstract

Biodiesel is a fatty acid alkyl ester which is renewable, biodegradable and non toxic fuel which can be derived from any vegetable oil by Transesterification process. Biodiesel has become a key source as a substitution fuel and is making its place as a key future renewable energy source. Biodiesel derived from vegetable oils are quite promising alternative fuels for diesel engines. Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their high viscosity. The performance of vegetable oils can be improved by modifying them through the Transesterification process. In the present work, the performance of single cylinder direct injection diesel engine using simarouba biodiesel (SOME) as fuel was evaluated for its performance, emission and combustion characteristics. The properties of SOME thus obtained are comparable with ASTM biodiesel standards. The produced SOME is blended with diesel (Simarouba-S20, S40, S60, S80 and S100) were tested for their use as a substitute fuel for diesel engine. Tests have been conducted at different blends of biodiesel with standard diesel, at an engine speed of 1500 rpm, fixed compression ratio 16.5:1, fixed injection pressure of 200bar and varying brake power. The performance parameters evaluated includes brake thermal efficiency, specific fuel consumption, exhaust gas temperature, Break mean effective pressure, Air fuel ratio, Mechanical efficiency, Volumetric efficiency and also combustion and emission characteristics against varying Brake Power(BP).

Key words: Simarouba biodiesel, diesel engine, Transesterification, performance, combustion and emission characteristics

1. INTRODUCTION

The most harmful effect of our present day civilization is global warming and environmental pollution. With rapid industrialization and urbanization we are also making our planet unsafe for us and for the generations to come. The vehicle population throughout the world is increasing rapidly; in India the growth rate of automotive industry is one of the largest in the world. It is quite evident that the problem cannot be solved with the conventional fossil fuels, however stringent the emission control norms may be. The consumption of diesel fuels in India was 28.30

million tonnes which was 43.2% of the consumption of petroleum products. This requirement was met by importing crude petroleum as well as petroleum products. The import bill on these items was 17,838 crores. With the expected growth rate of diesel consumption of more than 14% per annum, shrinking crude oil reserves and limited refining capacity, India will be heavily dependent on imports of crude petroleum and petroleum products. From the standpoint of preserving the global environment and to sustain from the large imports of crude petroleum & petroleum products from Gulf countries, alternate diesel fuel is the need of the hour. As world reserves of fossil fuels and raw materials are limited, it has stimulated active research interest in nonpetroleum, renewable, and nonpolluting fuels. With this scenario the need for an alternate fuel arises to maintain the economy of the country. The world has been confronted with energy crisis due to the decrease of fossil fuel resources and the increase of environmental restrictions. Therefore attention has been focused on developing the renewable or alternate fuels to replace the petroleum based fuels for transport vehicles. There are several alternative sources of fuel like vegetable oils, biogas, biomass, primary alcohols which are all renewable in nature. Among these fuels, vegetable oils appear to have an exceptional importance as they are renewable and widely available, biodegradable and non-toxic, and environmental friendly. In a country like India it is observed that biodiesel can be a viable alternative automotive fuel. Biodiesel is a fastest growing alternative fuel and India has better resources for its production.

The vegetables oils cannot be used directly in diesel engines as alternative fuel because of high viscosity of vegetable oils leads to problem in pumping and spray characteristics. The inefficient mixing of vegetable oils with air contributes to incomplete combustion. The best way to use vegetable oils as fuel in diesel engines is to convert it into biodiesel. It is a fact that biodiesel is a safer, more economical and infinitely more environmentally friendly than the conventional petroleum diesel that the majority of people currently use. Biodiesel is a vegetable oil-based fuel that can be used to replace diesel oil. The main argument for its usage in internal combustion engines as it causes less pollution than diesel.

2. MATERIALS AND METHOD

Based on the availability of biodiesel, the properties like calorific value, kinematic viscosity, flash point and fire point, Simarouba biodiesel and diesel fuel is estimated in the table-1 selected for bio-fuel preparation and experimental analysis.

Table-1 Preparations of flue samples of multi-blend biodiesel along with diesel

Characteristics	**SOME**	**Diesel**
Kinematic Viscosity at 400 ^{0}C (mm^2/s)	4.7	3
Specific Gravity	0.865	0.82
Flash point (°C)	160	54
Density (kg/m^3)	865	820
Calorific Value (kJ/kg)	37933	43500

3. EXPERIMENTATION

A. ENGINE COMPONENTS:

The various components of experimental set up are described below. Fig.1 shows line diagram of the experimental set up. The important components of the system are

(i) The engine

(ii) Dynamometer

Fig-1 Experimental Setup

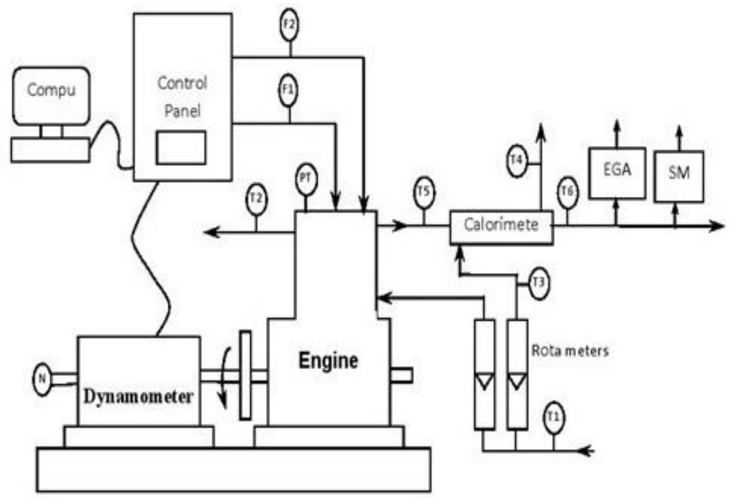

Table-2 Engine Specifications

Manufacturer	Kirloskar oil engines
Ltd, India	
Model	TV-SR, naturally
aspirated	
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
C.R.	16.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	four stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle
Resolution of 1 deg	360 deg with a
resolution of 1deg	

Table-3 Notations

PT	Pressure transducer
N	Rotary encoder
Wt	Weight
F1	Fuel flow
F2	Air flow
F3	Jacket water flow
F4	Calorimeter water flow
T1	Jacket water inlet temperature
T2	Jacket water outlet temperature
T3	Calorimeter water inlet temperature = T1
T4	Calorimeter water outlet temperature
T5	Exhaust gas to calorimeter temperature
T6	Exhaust gas from calorimeter temperature

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4. RESULTS AND DISCUSSIONS

A. Performance characteristics

1) Break power v/s break thermal efficiency

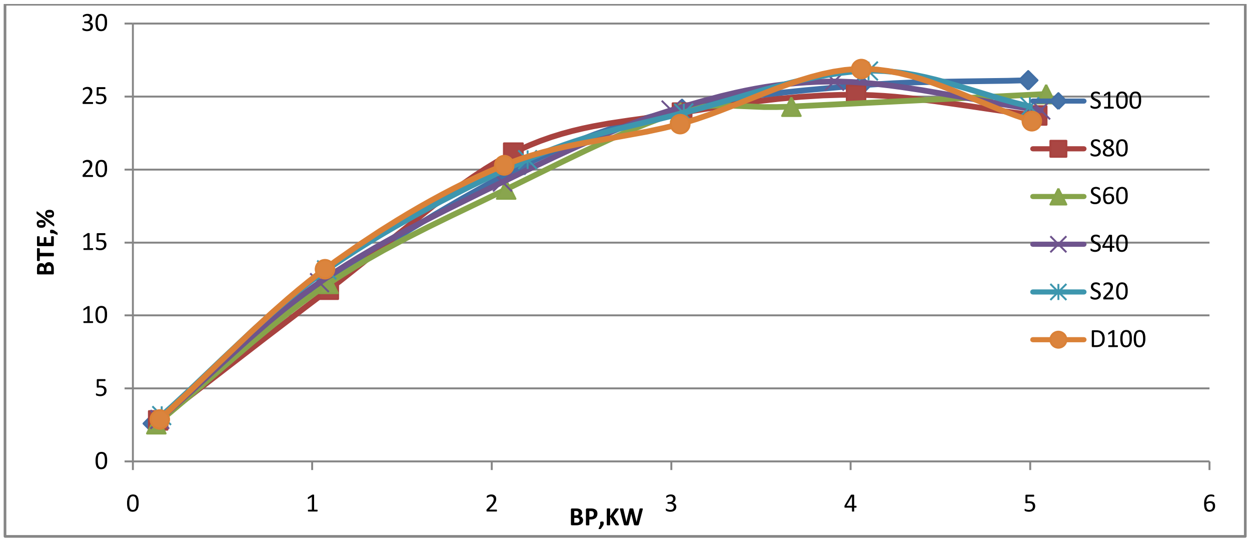
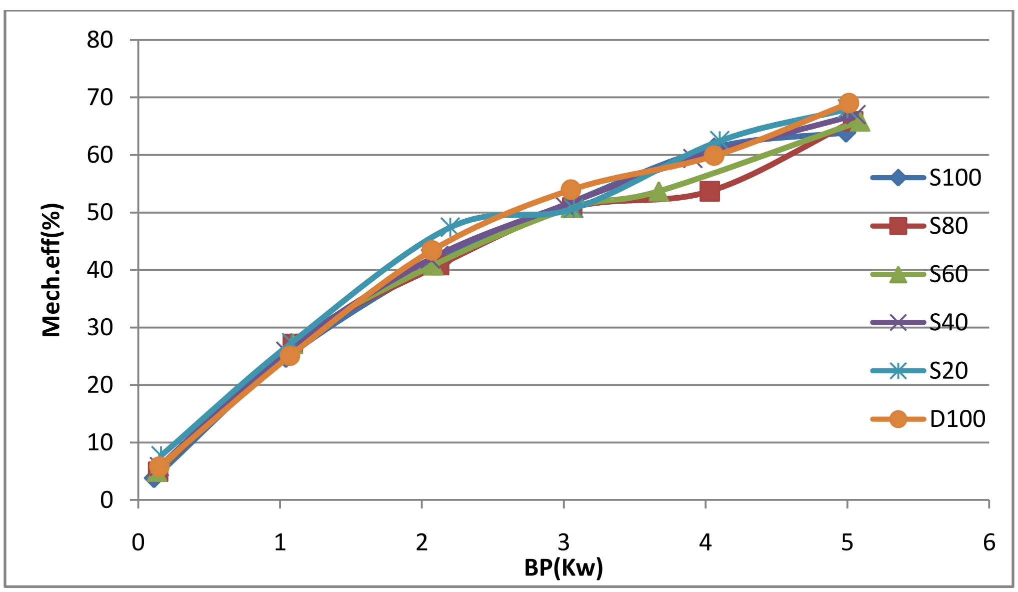


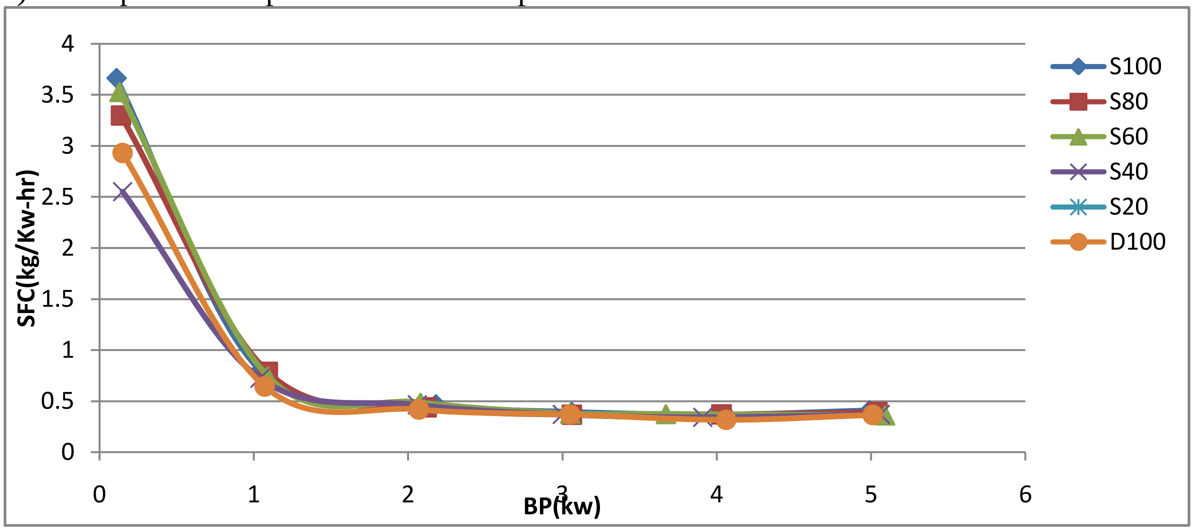
Figure (1) shows that the variation of brake thermal efficiency (BTE) with Brake power for different blends. Brake thermal efficiency is defined as the ratio between the brake power output and the energy of the fuel combustion. Graph shows as the Brake power increases the brake thermal efficiency increases to an extent and then decreases slightly at the end. The brake thermal efficiency reduces due to heat loss and increase in power developed with increase in brake power. The decrease in brake thermal efficiency for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption.The curve S80 is running nearer to the Diesel curve, which shows S80 blend can be a favourable to existing diesel engine.

2) Break power v/s Mechanical efficiency



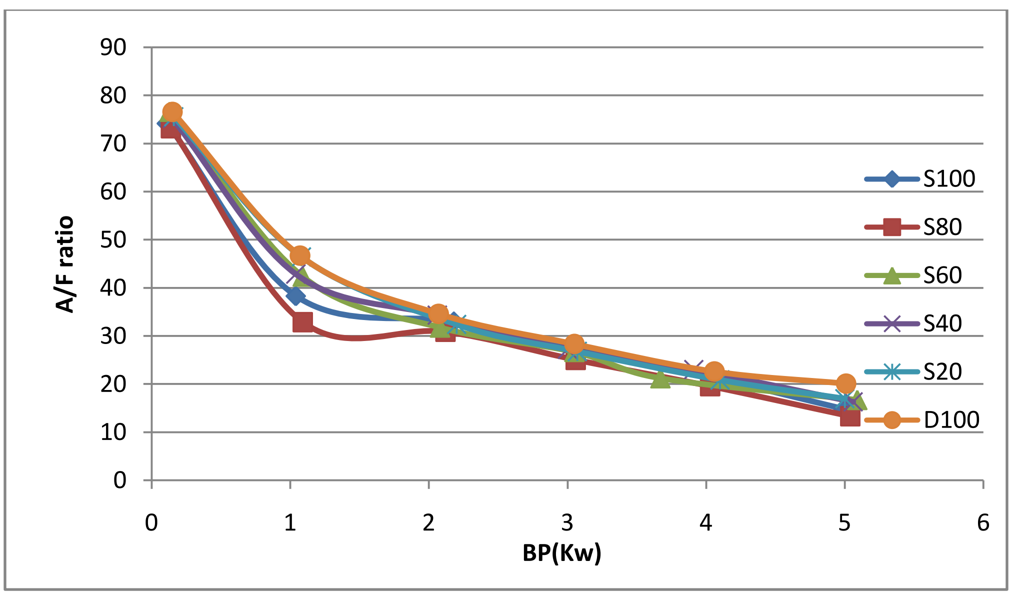
The variation of mechanical efficiency with brake power, for diesel and Simarouba biodiesel blends are as shown in figure (2). The mechanical efficiency of diesel is slightly higher than the Simarouba biodiesel. From the graph it is evident that with increase in the concentration of Simarouba biodiesel in neat diesel decreases the mechanical efficiency. Mechanical efficiency of both diesel and biodiesel are equal at 20% of blend.

3) Break power v/s specific fuel consumption



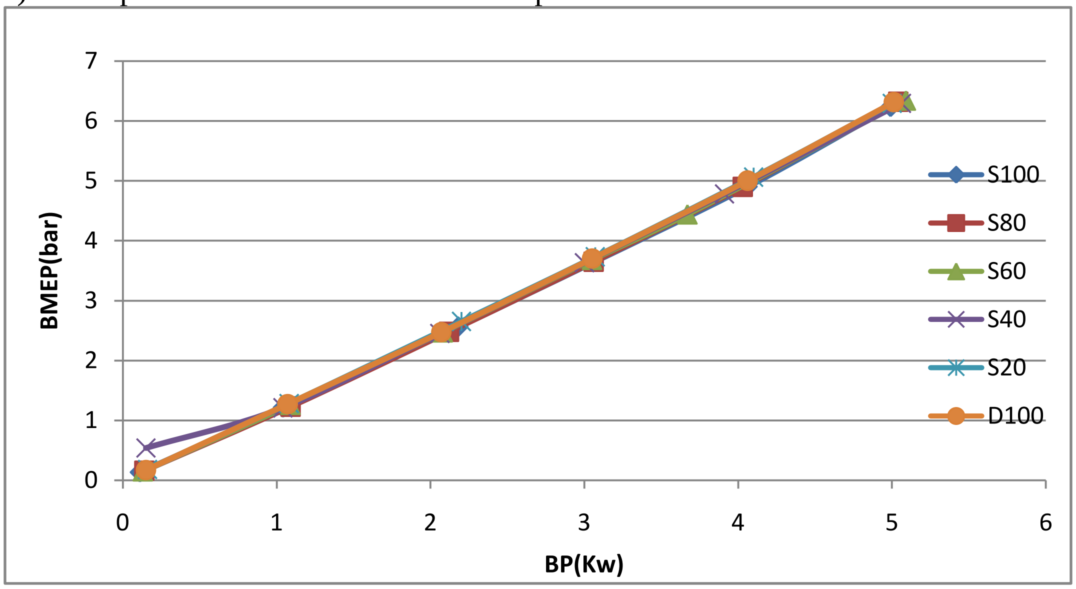
The variation of specific fuel consumption with respect to brake power is presented in Figure(3) for different blends & diesel. In diesel engine due to less temperature initial combustion takes with maximum fuel consumption. At higher brake power the SFC decreases. This may be due to fuel density, viscosity and heating value of the fuels. The curve S80 is almost tracing the path of diesel curve & this indicates blend S80 can be a favorable to existing diesel engine.

4) Break power v/s Air-fuel ratio



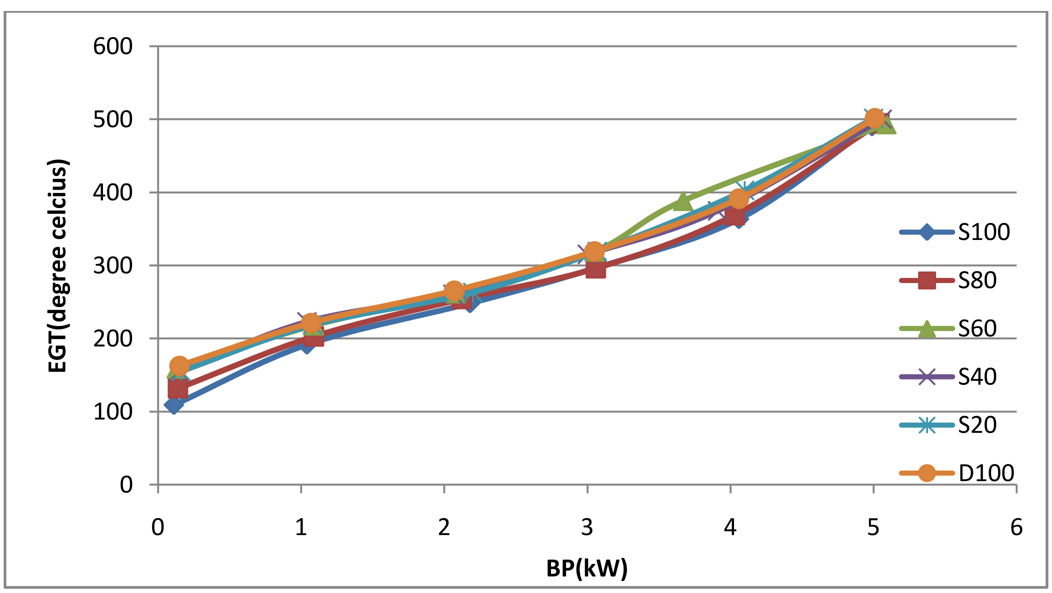
The variation of air fuel ratio with brake power for diesel and simarouba biodiesel blends are shown in figure (4). It can be observed that air fuel ratio of pure diesel is slightly higher than other Simarouba biodiesel and its blends, and we can also see that the air fuel ratio decreases as the load increases. The airfuel ratio for diesel and biodiesel are equal at 20% blend. The air-fuel ratio for diesel is 20.1 at full load and at 25% blend of biodiesel is 16.99 at full load.

5) Brake power v/s Break mean effective pressure



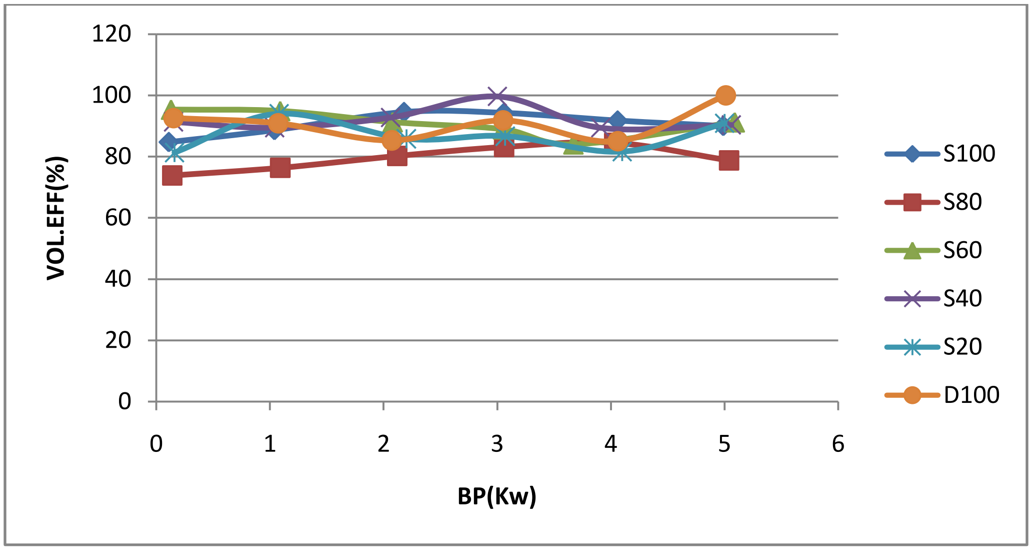
The variations of break mean effective pressure with brake power for diesel and Simarouba biodiesel blends are shown in figure(5). The break mean effective pressure increases with increase in concentration of Simarouba in diesel fuel this is because of volatility and calorific value of SOME.

6) Brake power v/s Exhaust gas temperature



The variation of Exhaust gas temperature with respect to brake power is presented in Figure(6) for different blends & diesel. The engine starts running with low temperature at low load. As the load increases the temperature inside the engine increases exponentially till it reaches full load. This rise of temperature is because of continuous flow of exhaust gas through outlet port.

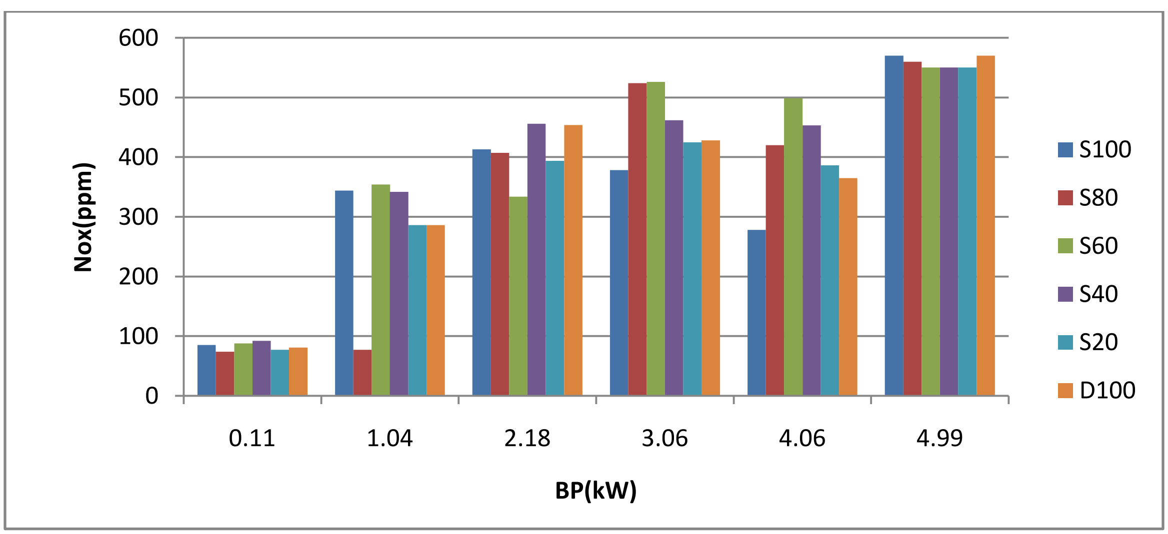
7) Brake power v/s volumetric efficiency



The variation of Volumetric efficiency with respect to brake power is shown in figure(7) for different blends of Simarouba biodiesel and diesel. From the it is observed that diesel is having almost higher volumetric efficiency than that of other simarouba blends but from the start to end the lines of different simarouba biodiesel blends are in zig-zag in nature it is only because of breathing ability of engine for the respect to the particular combinations ie ratio of the air actually induced at ambient conditions to the the swept volume of the engine.

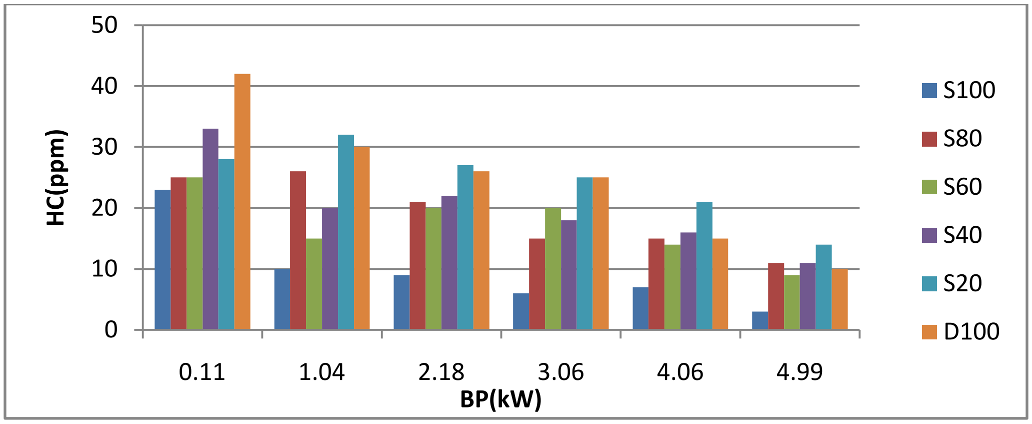
B. Emission characteristics

1) Break power v/s NOx emission.



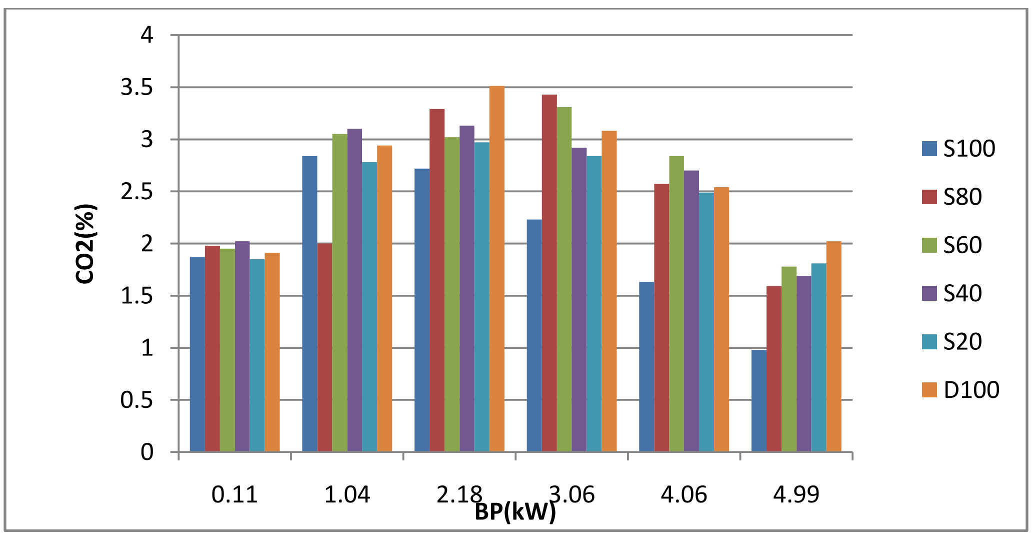
Figure(1) shows the variation of NOx emissions with brake power for different blends & diesel. The NOx emission for biodiesel and its blends is higher than that of standard diesel except S80 at lower loads. It is well known that the biodiesel contains a small amount of nitrogen. From the figure(1), it is observed that at full load S100 and D100 are same. And at the third stage it is observed that emission from diesel is larger than that of the simarouba blends. The reason for higher NOx emission for blends is due to the higher peak temperature.

2) Break power v/s Hydrocarbons



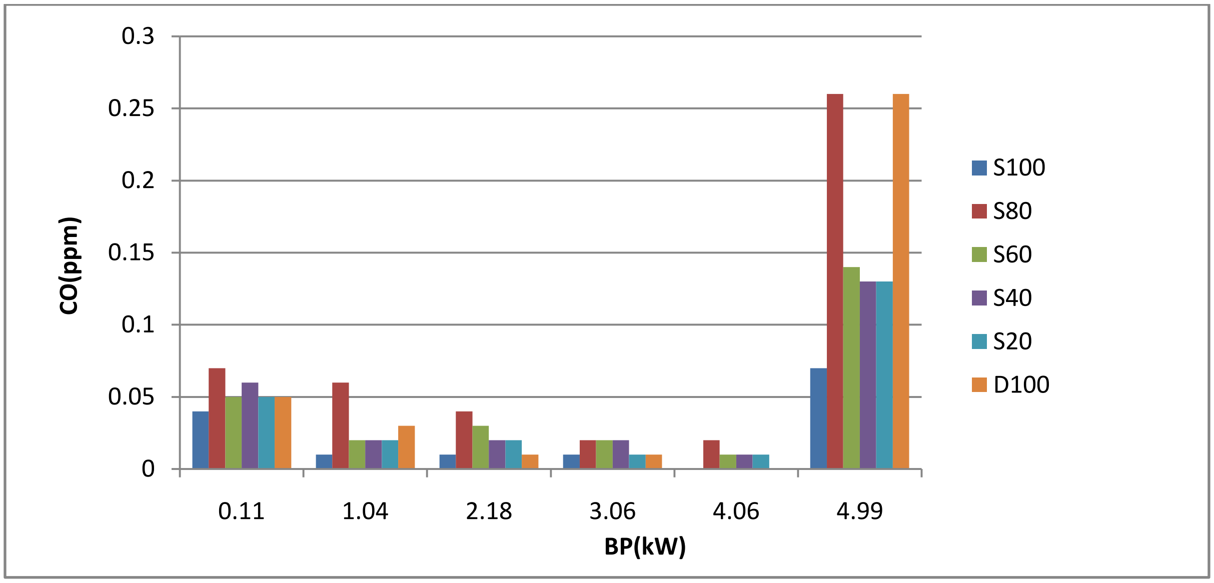
The figure(2) shows the variation of break power vs hydrocarbon emission. It is observed from the figure that for all biodiesel blends the emission of HC is less than that of the diesel except at the full load. Unburnt hydro carbons emission is the direct result of incomplete combustion. A reason for the reduction of HC emissions with biodiesel is the oxygen content in the biodiesel molecule, which leads to more complete and cleaner combustion.

3) Break power v/s carbon dioxide



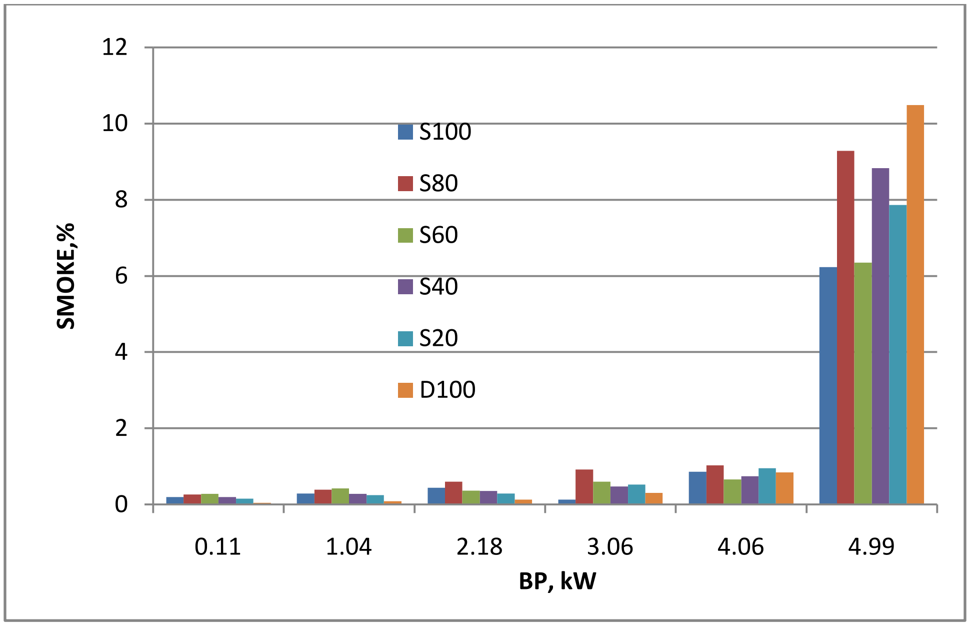
The figure(3) shows that variation of brake power with CO2. It is observed that the emission for different blends of Simarouba increases initially and then it decreases. And also observed that at full load condition emission of simarouba blends is lower than that of the diesel.

4) Break power v/s carbon monoxide



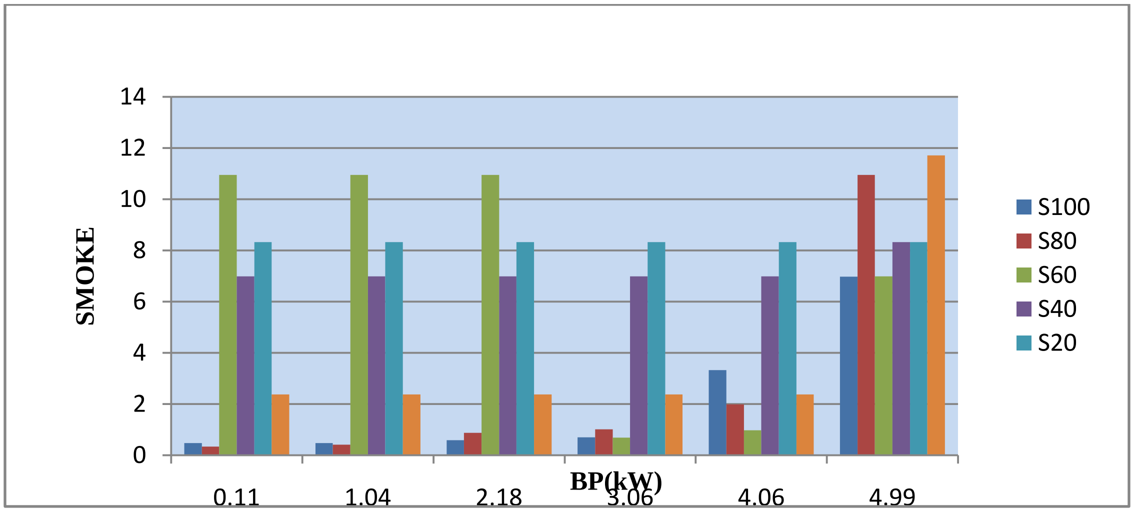
The figure(2), shows the variations of break power with CO, From the figure it is observed the co emission for different blends of simarouba decreases slowly and then increases exponentially at full load condition.

5) Break power v/s Smoke



The figure(5) shows that variations of the emission of smoke from the different blends of simarouba . It is observed that for both pure diesel and blends of simarouba the smoke emission is going to increases slowly but at the full load condition the smoke emission is going to increase exponentially and it is also observed that at full load condition the emission of diesel is higher than that of the blends of simarouba.

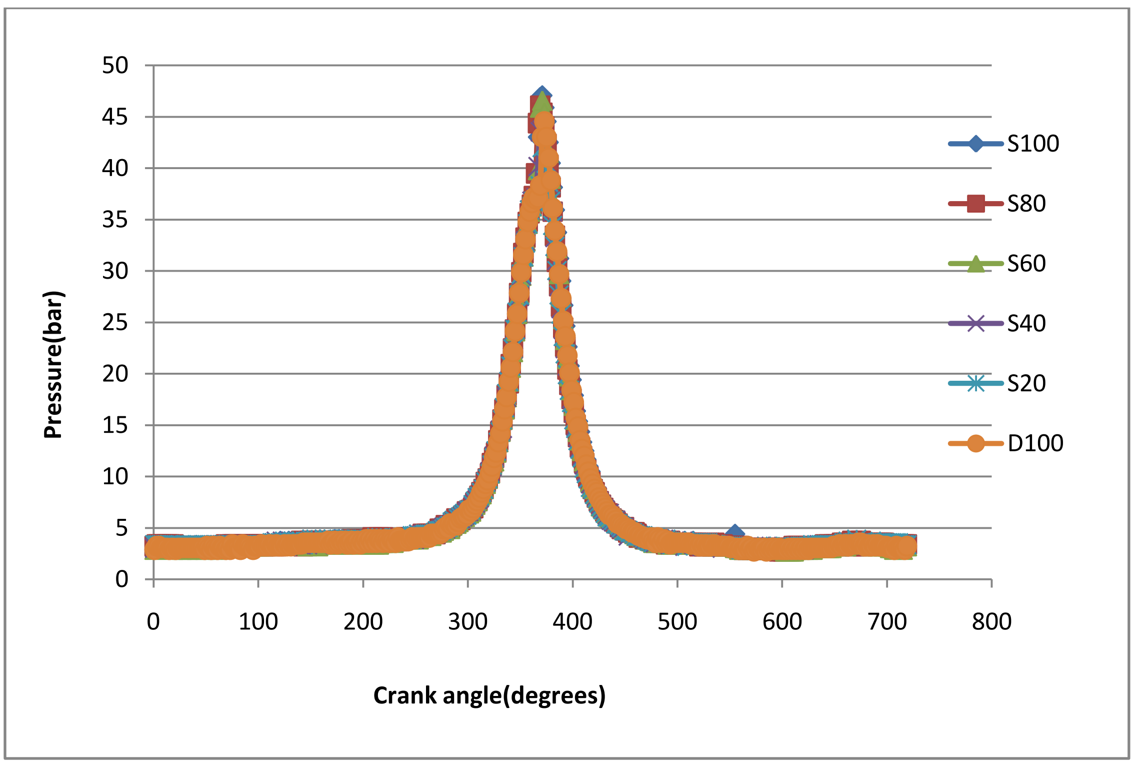
6) Range of smoke



The above figure shows that maximum range smoke which can be obtained in our current work, it is observed that S40 is same up to last load.

C. Combustion characteristics

1) Crank angle v/s pressure



In a CI engine the cylinder pressure is depends on the fuel-burning rate during the premixed burning phase, which in turn leads better combustion and heat release. The variation of cylinder pressure with respect to crank angle for diesel and 40% blend of Simarouba biodiesel are presented in above Figure. Peak pressures of 44.54 bar and 43.69 bar are found for pure diesel and S40 respectively. From the test results it is observed that the peak pressure variations are less Since the properties such as calorific value, viscosity and density are brought closer to diesel after Transesterification of the vegetable oil, no major variation in the pressures are found.

Summary of Results and Discussions

The experiments were conducted on a direct injection compression ignition engine for various brake power and various blends (Simarouba Biodiesel-S20, S40, S60, S80 and S100) of biodiesel. Analysis of performance like specific fuel consumption, brake thermal efficiency, Exhaust gas temperature, air-fuel ratio, break mean effective pressure, mechanical efficiency, volumetric efficiency and emission characteristics like hydrocarbon, oxides of nitrogen, carbon monoxide, carbon dioxide smokes and combustion characteristics like pressure v/s crank angles are evaluated. The biodiesel used is as per ASTM standard, there is no modification in the engine. The experiment is carried out at constant compression ratio of 16.5:1 and constant injection pressure of 200bar by varying brake power.

5. CONCLUSIONS

A single cylinder compression ignition engine was operated successfully using methyl ester of Simarouba oil as the soul fuel. The following conclusions are made based on the experimental results.

1. SOME satisfies the important fuel properties as per ASTM specification of Biodiesel.
2. Engine works smoothly on methyl ester of Simarouba oil with performance comparable to
3. diesel operation.
4. Methyl ester of Simarouba oil (S80) results in a nearly equal in thermal efficiency as compared to that of diesel.
5. The exhaust gas temperature is decreased with the methyl ester of Simarouba oil as compared to diesel.
6. The specific fuel consumption of diesel is almost equal S80 at lower loads but at higher loads the SFC of all simarouba blends is equal to diesel.
7. The break mean effective pressure of all the blends of simarouba oil as well as diesel increases with break power.
8. The air fuel ratio of diesel is observed that higher than that of the other blends of simarouba oil and air fuel ratio of diesel and other blends of simarouba oil decreases as the load inceases.
9. The volumetric efficiency of all the blends of simarouba oil is almost traces the path of diesel.
10. It is concluded that by using blends of simarouba biodiesel NOx, CO, SMOKE increases, this is the draw back and main emissions like CO2, HC decreases.
11. It is concluded that the combustion characteristics of all blends of simarouba oil is almost same as that of diesel along with that S40 is nearer to D100.

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