Performance and Emission Characteristics of Compression Ignition Engine Operated with Biodiesel Blends Derived from Waste Material

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Abstract: Every country has special features of energy sources and demand of energy varies country to country. These parameters depend upon lifestyles and livelihood of the native of that country. Some of the energy resources are coal, fossil fuels, natural gas, wind energy etc. India is a developing country and population is growing fast. Due to fast growing population need for energy is also increasing. In this regard it is very much essential that we need to find other renewable sources of energy which could be replacement of petroleum fuels. In the present study biodiesel produced from sewage slug is used as replacement of petroleum fuels. This biodiesel is blended with mineral diesel in different proportions and tested in a diesel engine. The results obtained were compared with those of base fuel and analyzed. The different parameters such as BTE, EGT, CO and HC emissions were found out.

Index Terms - Alternative fuel; Fossil fuels; Diesel Engine; Performance.

I. Introduction

Public concern towards maintaining a clean environment has motivated extensive research into the sources of pollution and ways to reduce it. Internal combustion engines are the major polluting contributors. Experimental works aimed at good fuel economy and lower tailpipe emissions involves frequent changes in the operating parameters concerned, which will be a time and money consuming module. Alternatively, in this computers era, simulation of engine combustion with a mathematical model can be done easily by considering the effects of design and changes in the operating parameters in short period of time. Various engine combustion models such as zero dimensional, quasi-dimensional and multi-dimensional models have been developed by many researchers to solve the complex heterogeneous combustion process of diesel engines [1-5].

Biodiesel is one of the prominent alternative fuels for many applications. In India many researchers have tried with different kind of vegetable oils for biodiesel production [6]. The details about different feedstock for biodiesel production are given in Figure 1. Among those Jatropha and Karanja has got more attention due to its availability and high oil contents.

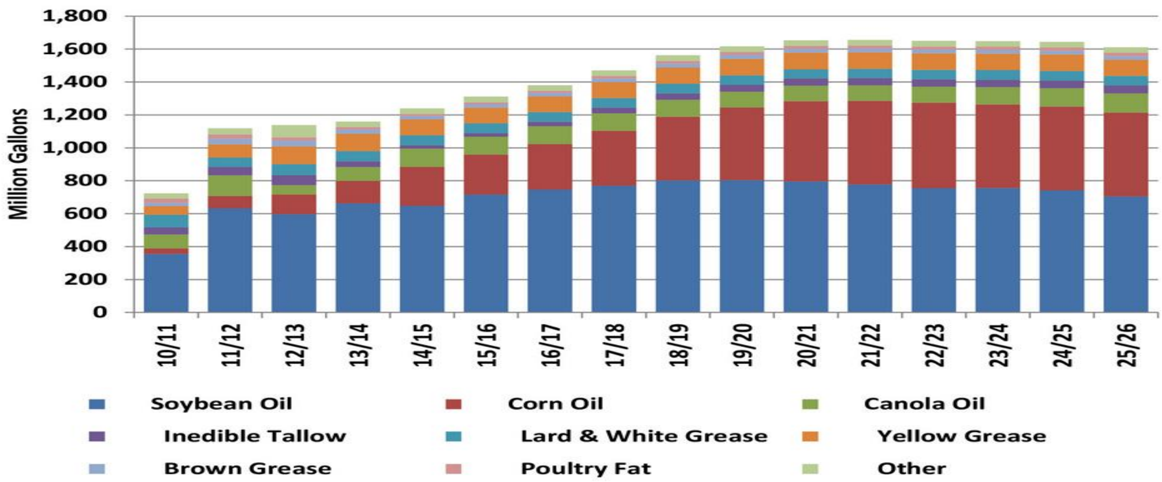

Fig.1 Different Feedstock for Biodiesel Production

Also many investigations have been done with waste material as a source for biodiesel production. The biodiesel production from waste material has motivated us and we got idea for the present study. In this research study biodiesel was produced from a sewage slug and used in diesel engine by blending with diesel. The name used for different types of fuels used is given in below.

Table 1 Test Fuel Proportion

Fuel	SSB (by volume)	Diesel (by volume)
D100	-	100%
S100	100%	-
S10	10%	90%
S30	30%	70%
S50	50%	50%

II MATERIALS AND METHODS

Biodiesel Production

For the present investigation SSB was collected from a piolet biodiesel plant that produces the methyl ester through the transesterification process. This method is most popular method for the biodiesel production. The cost associated with this process is very low [6-8].

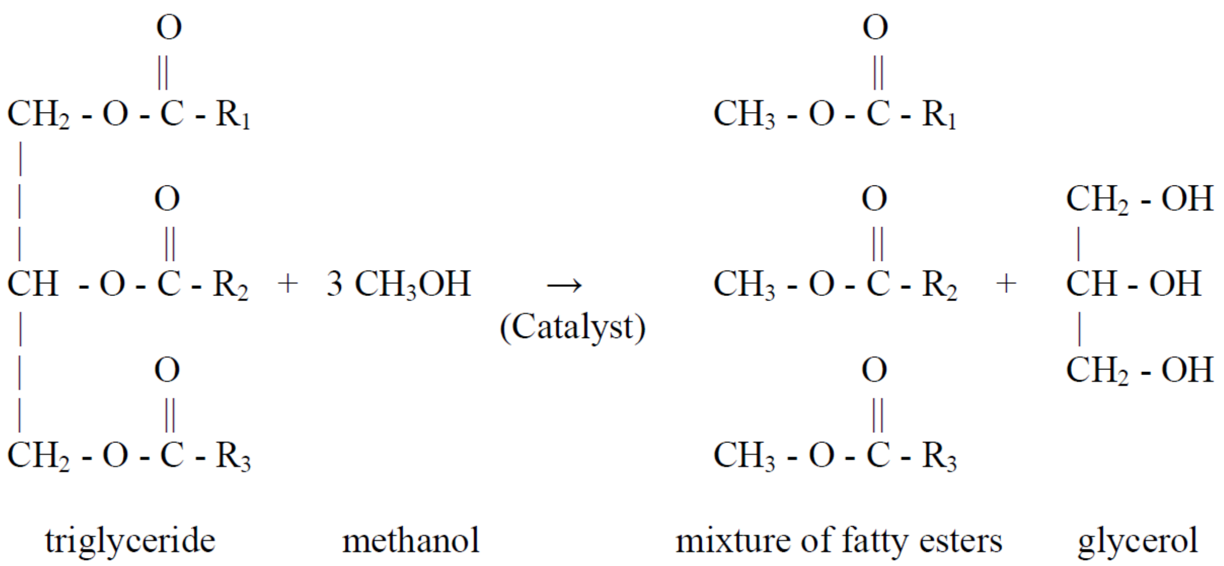

Figure 1 Inputs and outputs of the transesterification unit process

Comparison of Fuel Properties

The physical properties of SSB are compared with diesel and given in Table 2.

Table 2- Properties of diesel and SSB

Properties	Diesel	SSB	SSB30
Density, Kg/m^3	820-830	880	846
Viscosity, cSt	2.5-3.2	4.55	3.7
Calorific Value, MJ/kg	42-45	39-42	43.25
Flash point, ^0C	50	178	68
Iodine value, g I_2 per 100 g	-	85-93	-
Saturated fatty acid, %	-	30-40	-

III EXPERIMENTAL SETUP

Tests have been conducted in a diesel engine to test different types of fuels. The specifications of test engines are given in Table 3. Figure 2 shows the schematic diagram of the experimental set up.

Table 3 - Engine specifications

Type	Kirloskar TAF1 Vertical diesel engine
No. of cylinder	1
Type of injection	Direct
Rated power at 1500 rpm, kW	4.41
Bore, mm	87.5
Stroke, mm	110
Compression ratio	17.5
Displacement volume, litres	0.662
Fuel injection timing bTDC, °CA	23
Number of injector nozzle holes	3
Nozzle-hole diameter, mm	0.25
Inlet valve opening bTDC, °CA	4.5
Inlet valve closing aBDC, °CA	35.5
Exhaust valve opening bBDC, °CA	35.5
Exhaust valve closing aTDC, °CA	4.5
Type of fuel injection	Pump-line-nozzle injection system
Connecting rod length, mm	220

The emissions were measured by the help of AVL437 and AVL444 instruments. Initially tests were done with diesel to find base reading. Further tests were conducted with different fuels. Different sensors were used for recording different parameters.

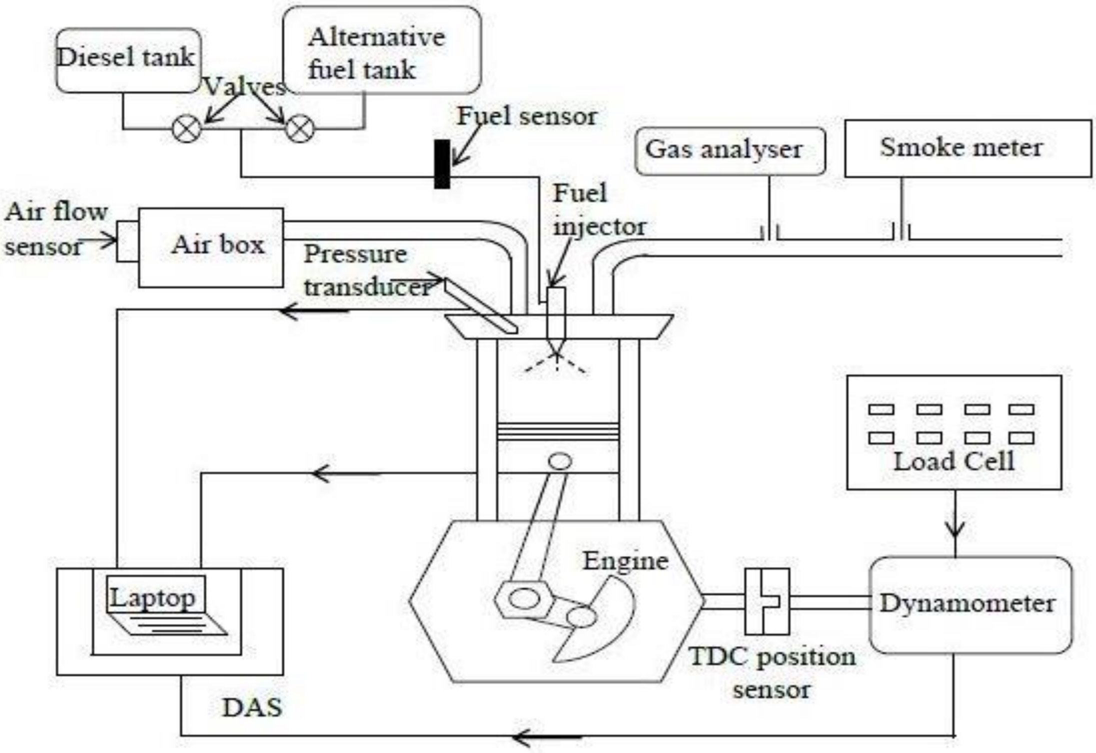

Figure 2 Schematic diagram of experimental setup

IV PERFORMANCE PARAMETERS

The engine behavior was evaluated by the terms such as BTE, BSEC and EGT. The results were compared with diesel operations.

Brake Thermal Efficiency

Figure 3 portrays the variation of brake thermal efficiency with brake power for diesel and SSB blends. The brake thermal efficiency of the engine increases with increase in brake power for diesel and SSB-diesel blends as expected. The brake thermal efficiency for diesel at full load is found to be 29.89%. The brake thermal efficiency for S100, S10, S30 and S50 is 29.40, 29.87, 29.88 and 29.88% respectively at full load.

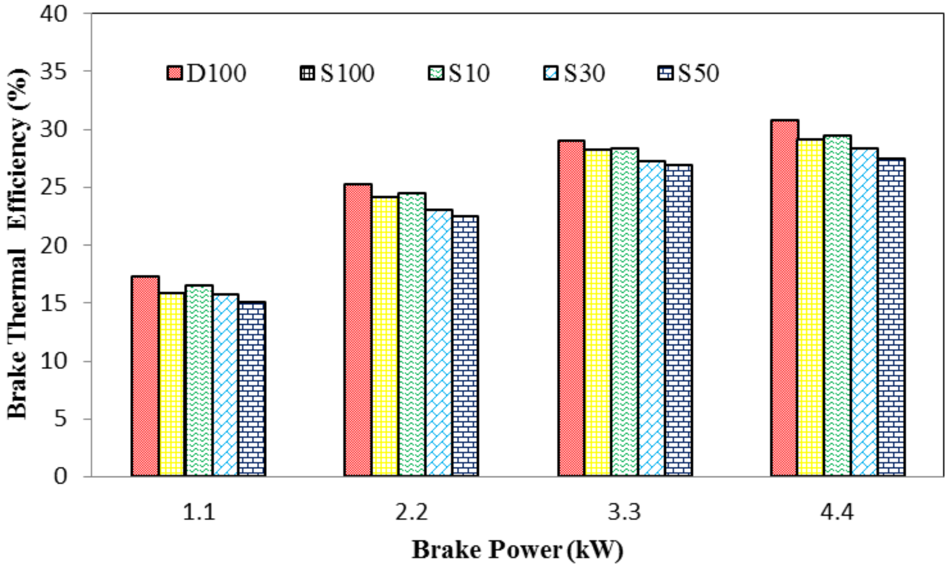

Figure 3 Variation brake thermal efficiency with brake power

However all the SSB blends have thermal efficiency slightly lesser than that of diesel. This may be due to lower calorific value of SSB blends. Poor atomization of blend droplet, as a result of higher viscosity of SSB blends may also be one of the reasons for lower brake thermal efficiency than that of diesel operation [9].

Brake Specific Energy Consumption (BSEC)

The brake specific fuel consumption is not a very reliable factor to compare the two fuels as the calorific value and the density of blends are different from that of diesel fuel [10]. Figure 4 shows the variation of BSEC for diesel and SSB-DIESEL blends. The BSEC for diesel is 11.86 MJ/kWh at full load. As the blends contain SSB and diesel as a constituent, this reduces the net calorific value and hence BSEC also varies accordingly. All the SSB-DIESEL blends exhibit higher BSEC than that of diesel as a result of lower calorific value. The values of BSEC for S100, SSB10, S30 and S50 are found to be 12.24, 12.67, 11.92 and 12.67 MJ/kWh respectively at full load.

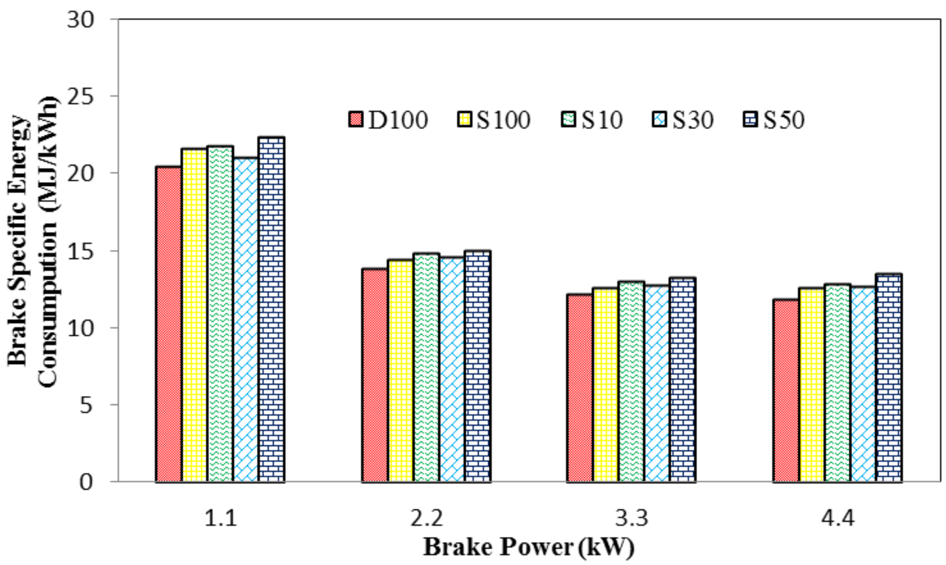

Figure 4 Variation of BSEC with brake power

Exhaust Gas Temperature (EGT)

Figure 5 shows the variation of exhaust gas temperature with respect to brake power. It shows that the EGT increased with increase in brake power for all the fuels tested in this study. For diesel, at full load condition EGT was 303 ^{o}C. For full load, the values for EGT were 318, 297, 330 and 325 ^{o}C for S100, S10, S30 and S50 respectively. The EGT values are higher for SSB blends. Poor volatility and high viscosity are the reasons for the higher exhaust gas temperature for the SSB blends [11].

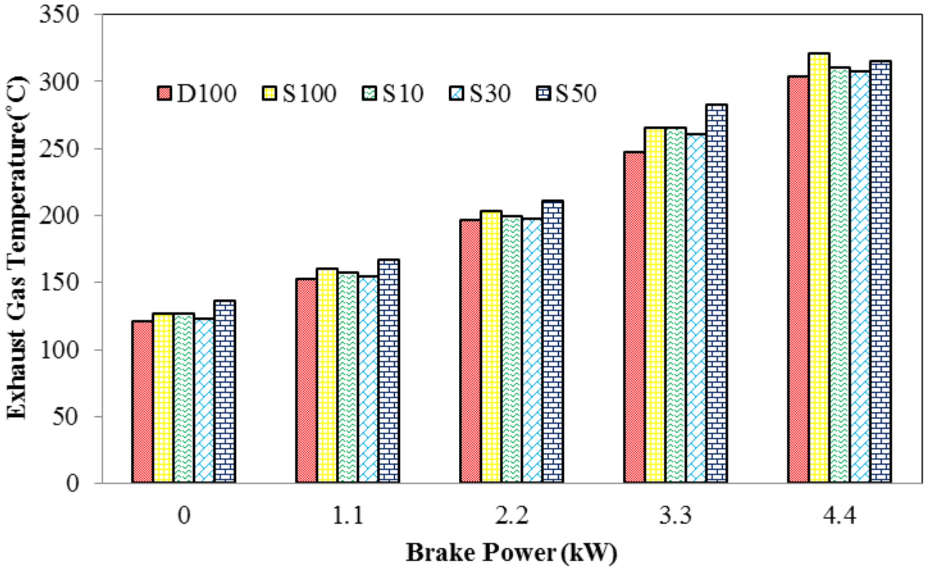

Figure 5 Variation of exhaust gas temperature with brake power

EMISSION PARAMETERS

Emissions such as carbon monoxide, unburnt hydrocarbon, nitric oxide and smoke for diesel and SSB blends are discussed in the subsequent sections.

Carbon Monoxide (CO) Emission

Figure 6 illustrates the CO emission for diesel and SSB blends with respect to brake power. CO emission in a CI engine is due to less oxygen availability and poor mixture formation, as CI engine is operated with lean mixture. It is apparent from figure that CO emission from SSB blends is lower than diesel. The excess oxygen present in the SSB is helpful for the complete combustion and hence amount of CO emission is less [12].

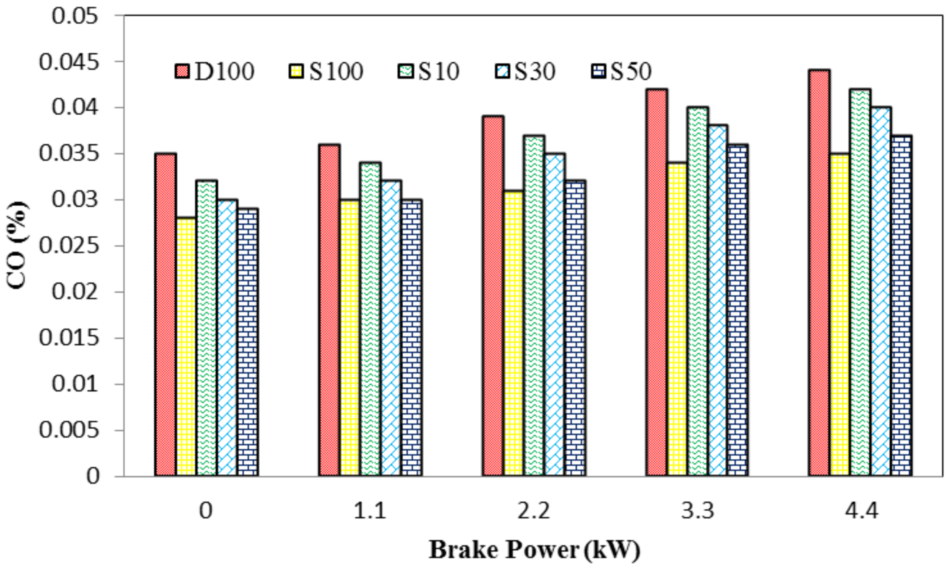

Figure 6 Variation of carbon monoxide with brake power

Hydrocarbon (HC) Emission

The values of HC emission from the engine in case of SSB blends is less than diesel as evident from the Figure 7.

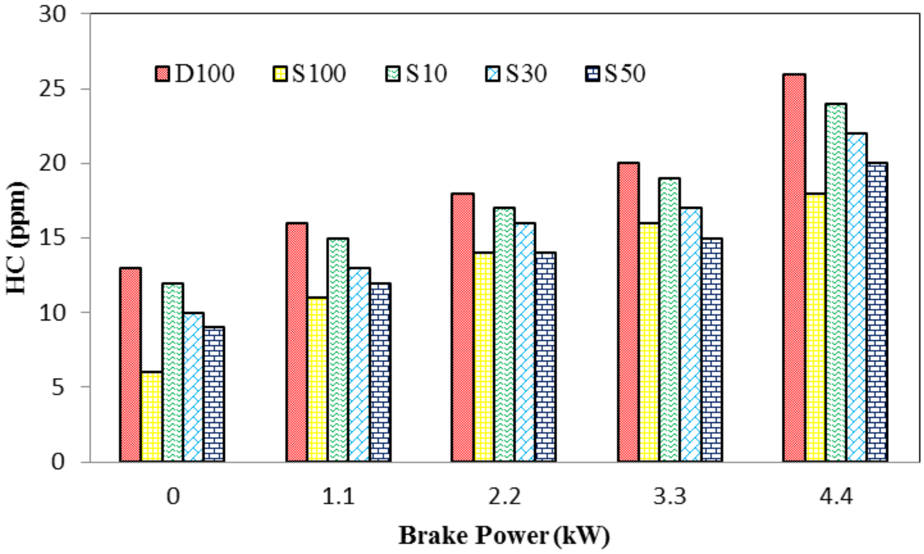

Figure 7 Variation of hydrocarbon with brake power

Hydrocarbon emission is mainly due to incomplete combustion. HC emissions are increasing with increasing load for all the fuels tested. HC emission for diesel at full load was 23 ppm. At full load HC emission are 18 ppm, 19 ppm, 20 ppm and 21 ppm for S100, S10, S30 and S50 respectively. The reduction in HC emission is mainly due to the result of improved combustion with SSB blends, as SSB is oxygenated fuel [13].

Nitric Oxide (NO) Emission

Figure 8 shows the variation of NO emission with brake power for fuels tested. NO emission is highly dependent on temperature and availability of oxygen inside the cylinder [14]. As the load increases the temperature inside the cylinder also increases. At full load NO emissions were 452,612, 589, 574, and 564 for diesel, SSB5, SSB10, SSB15 and S50 respectively. However the NO emission is lower for all the SSB blends compared to diesel. This may be due to lower combustion temperature as a result of inferior combustion, because with increasing SSB percentage volatility decreases.

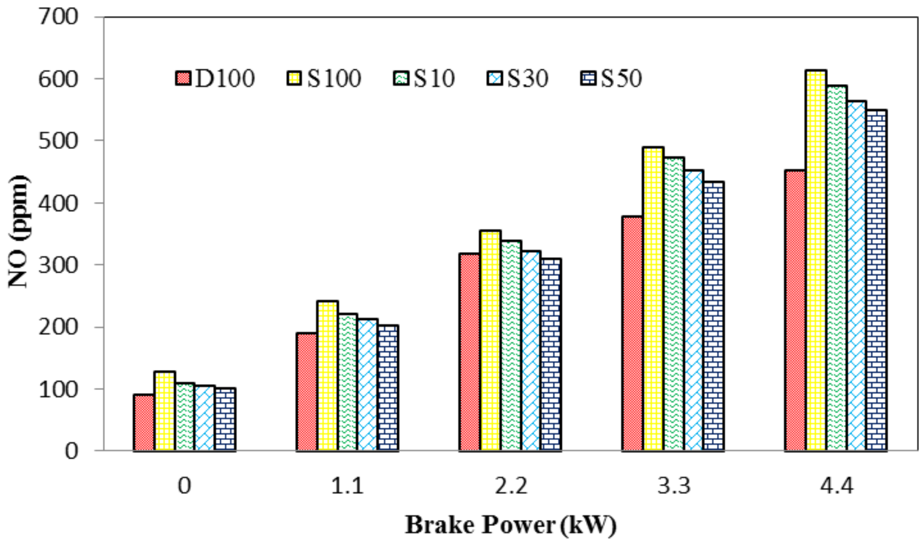

Figure 8 Variation of nitric oxide with brake power

Smoke Emission

Smoke is nothing but solid soot particles suspended in exhaust gas. Figure 9 shows the variation of smoke emission with brake power for different tested fuels. Smoke increases with increase in brake power for all the tested fuels and lower for SSB blends compared to that of diesel. This reduction is due to absence of sulphur and presence of oxygen in SSB, which plays a vital role for complete combustion. But As percentage of the SSB increases in blend, aromatic content and carbon/ hydrogen ratio also increases and results higher smoke with increasing SSB in blends. [15].

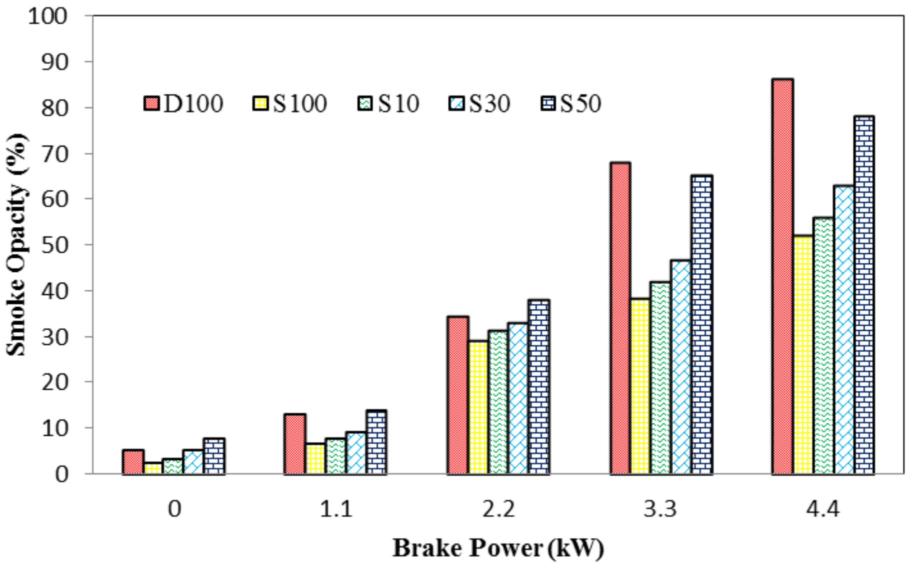

Figure 9 Variation of smoke emission with brake power

Smoke emission for diesel at full load is 86.3%. At full load smoke emissions were 39.5, 56.2, 54.5, and 63.1% for S100, S10, S30 and S50 respectively.

CONCLUSIONS

In this research study tests were conducted in a compression ignition engine by using different SSB-diesel blends and results were compared with diesel operations. The summary of the results are presented below.

- Engine works smoothly with SSB blends and exhibited similar performance and lower HC, CO, smoke emission, but higher NO emission compared to that of diesel. S30 gives optimal result compared to other SSB blends.
- The brake thermal efficiency of S30 is almost same to that of diesel at full load.
- The BSEC for S30 is 11.92MJ/kWh and for diesel 11.86MJ/kWh at full load. BSEC increases by about 0.05% with SSB15.
- The EGT is higher for S30 compared to that of diesel at full load.
- Carbon monoxide is decreased by about 11.36% for S30 compared to that of diesel.
- NO emission is increased by about 19.5% for S30 lower for compared to that of diesel.

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