Experimental investigations on performance and emission characteristics of diesel engine using bio-diesel as an alternative fuel

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Abstract

In India petro-diesel is a crucial fuel to drive many sectors such as Transportation, Agriculture, Power generation etc. Ever since the invention of IC Engine in particular CI Engine many improvements have taken place in engine design by varying both designs and operating parameters. This scarcity of conventional fuels and their pollutants generated by combustion have become serious concern about the alternate fuels. From the previous researchers it is learnt that the solo bio-diesels have given fruitful results which are closure to conventional fuels such as diesel. In this work the composites blends are used by considering the properties of Bio-diesel jatropha and animal Tallow. The experimental investigation are carried out on a single cylinder 4-strokes CI diesel Engine, water cooled, Coupled with loading device of eddy current dynamometer. From the experiments conducted, both biodiesels and their blend are similar to that of diesel in terms of performance without any modifications of engine. The highest Mechanical efficiency is for diesel is 72.3% at full load condition at injection pressure of 180bar. The maximum heat input is 15.42% for animal tallow biodiesel at full load condition of 180bar. The emission of CO and HC of Biodiesels and their blends is less than diesel. But the NOx emission of biodiesel and their blends are high when compared with diesel, this is due to the large amount of inherent oxygen in biodiesel.

Keywords

Biodiesel; Performance; Combustion; Emissions; Jatropha; Animal Tallow; Dual fuel.

1. Introduction

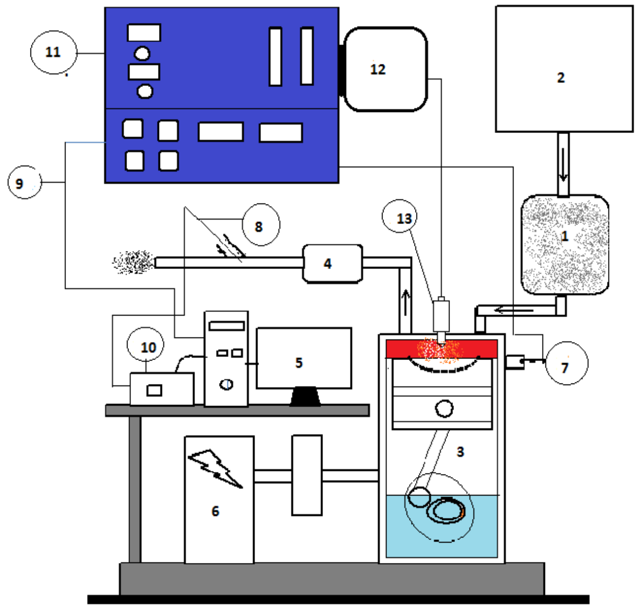
In one of the most historical controversies on biodiesel, some of the researchers claim that Rudolph Diesel fuelled one of his early engines with peanut oil at the Paris Exhibition in 1900. In 2005 b Knothe, prepared a comprehensive review of the literature available from the Diesel era. His work concluded that Diesel did not actually use peanut oil himself but was describing a test conducted by another company. In any case, the vegetable Oil experiment was considered to be a success and offered the potential for remote colonies to be self-sufficient in fuel. Knothe (2005 b), Quick (1980 a), and others report that in a1912 Rudolf Diesel, in one of his speech said "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time." From the data available on his work on vegetable oils it is difficult to determine what extent Diesel believed that his engines could be run by vegetable oil. In 1912, the thought of using 33 billion gallons (125 billion litres) of diesel annually in the United States would have been staggering. It would have been impossible for Rudolph Diesel to foresee the massive usage of diesel and other fossil fuels as we know it is today. It was known from Diesel's time that vegetable oil in the raw form was sufficient to start and Power a diesel engine. Since then, we have learned that raw oils cause engine deterioration when the use is continued for an extended period of time and that better success is observed when the oils are first converted to methyl or ethyl esters, which have come to be known as biodiesel. The first step towards vegetable oil fuels was made in the late 1970s during the OPEC oil embargo. This conference documented the studies of the late 1970s was held in August 1982, held by the American Society of Mechanical Engineers. The conference was held in Fargo, North Dakota, and was entitled simply "Vegetable Oil Fuels". Contributions were made by leading researchers from around the world. The majority of the papers dealt with the potential of raw oils as fuel, several papers discussed the production of esters and the use of the esters as engine fuels that showed more promise than did the raw oils. The transesterification process is well known and useful for purposes other than diesel fuel well before the time of this 1982 conference. What was occurring in 1982 was an adaptation of the transesterification process to produce fuel. Goering in his paper on "Study on Properties of Vegetable Oil," reported that the properties of different vegetable oils and modified fuels for automotive applications have acceptable cetane numbers (60-65), high viscosity (50 Cst), high flash points (220-285 0C) and high pour points (-6 to 12 0C) and appreciable heating values (about 90 % of diesel) and low sulfur content (< 0.02%).The first known report of using esters of vegetable oils as a motor fuel was described in a Belgian patent granted to G. Chavanne of the University of Brussels on 31 August 1937. The first report on use of esters in the U.S. was evidently by Fort et al. (1982), reported in an SAE paper titled, "Evaluation of Cottonseed Oils as Diesel Fuel." This study was closely followed by two other important studies on using ester fuels, Geyer et al. (1984) and Wagner. These early studies concluded that a significant factor that slowed development of vegetable oil esters was cost. In the 1980s vegetable oils were considerably more expensive than diesel and it was mentioned that the additional processing would only drive the cost higher. The overall theme and outcome of the 1982 ASME conference was that raw vegetable oils, while showed promise had a issues related to injector coking, polymerization in the piston ring belt area resulting in stuck or broken piston rings, and a tendency to thicken of lubricating oil leading to sudden and catastrophic failure of the rod or crankshaft bearings. It was learnt that transertification process helps in reducing the viscosity of vegetable oil and also its tendency of polymerization. In 1984, Ziejwski fueled engine with sunflower derived biodiesel. In 1984, Shrinivasan and Gopal Krishnan used Karanja based bio-diesel. Schumacher was the first of the many researchers to report the ability of Biodiesel to reduce smoke density, in the year 1992. During 1977, Christopher Daniel of Chicago conducted two tests using biodiesel as fuel. The test results proved that the biodiesel could be used as a feasible alternative fuel.In the works carried out by the researchers, M. Senthil Kumar, T. Ganapathy and P.Ravi Kumar has proved that methyl ester of Jatropha oil could be considered as fuel and showed that transesterfication reaction improved the properties of the ester. In the experiments conducted by Masjuki and Prasad using esterifed Palm oil to conduct experiments on diesel engine has proved that Torque, Brake Power, Specific Fuel Consumption and Brake Thermal Efficiency were found comparable to that of diesel fueled engine.

In 2003, Lin and Wang of China used Emulations as fuel for diesel engines, because of their ability to reduce smoke and NOx emissions. In the same year, G. Amba The similar conclusion was given by Lin Y in 2008, in the usage of waste oil biodiesel as the alternative.

The exhaust emission characteristics of diesel engines operated with biodiesels have been studied by many researchers, across the globe. A review of research papers of Quick, Baric and Lhumke revealed that with the use of biodiesel the harmful exhaust emission particularly CO and sulphur compounds are reduced as compared to mineral diesel operation. Prasad and R. Mohan have studied the effect of super charging using biodiesel of Cotton Seed Oil on diesel engine. In the year 2007, M.A. Rahman has concluded that Mahua based biodiesel can be safely blended up to 20% with mineral diesel and could be a used as alternative fuel. In contrast, several researchers (Rahman, Phadtare 2004, K. Agarwal 2001, Md. NorunNubi 2006, He Bao and Hamelinck) have observed that the exhaust emissions are affected by the use of biodiesel. It is known that biodiesel generally causes on increase in NOx emission and decrease in unburned hydrocarbon (HC), CO and particulate matter, emission when compared with diesel emissions. There are reports related to study of performance and emissions characteristics of diesel engine fuelled on blends Karanja biodiesel and Neem biodiesel optimizing the relevant working parameters.

2. Experimental setup and procedure

The details of the experiment setup, specifications of test engine, loading and instrumentation are described in this chapter. Experiments are conducted on a Kirloskar AV-1 stationary diesel engine of the IC Engines laboratory of Mechanical Engineering Department of LIET, Hyderabad. The specifications of test engine are given in the below table.



1.Mixing chamber 2.Air tank 3.Engine 4.Exhaust gas calorimeter 5.PC 6.Dynamometer 7.Pysoelectric sensor 8.Exhaust gas sensor 9.Sensor to PC 10.Exhaust analyzer 11.Control panel 12.Fuel tank 13.Fuel injector.

Fig.2 Engine setup and Instrumentation.

Table.1 Specification of test engine

Sl. No	**Specifications**	**Kirloskar**
	Number of cylinders	One
	Bore× Stroke(mm)	87.5 × 110
	Cylinder Diameter(mm)	87.5
	Stroke Length(mm)	110
	Compression Ratio	17.5 : 1
	Orifice Diameter(mm)	20
	Connecting rod length(mm)	238
	Rated Power(kW)	5.2 @1500 rpm
	Swept Volume(cc)	661
	Clearance Volume(cc)	38.35
	Type of combustion Chamber	Hemispherical open combustion chamber

2.1 Methodology

The biodiesel of Jatropha is supplied by the Online Southern Biodiesel, Bangalore. The biodiesel of Animal Tallow is supplied by the Online Southern Biodiesel, Hyderabad. The engine is first started by using Diesel as a fuel at injection pressure of 180 bar and the operating characteristics and emissions such as Carbon Monoxide (CO), Hydrocarbons (HC) and Nitrous Oxide (NOx) of the engine from the exhaust gas are noted down. The obtained results of diesel are standard parameters and are used for comparison of performance and emissions of biodiesels and their blend. The engine is then runned by Jatropha biodiesel at an injection pressure of 180 bar. The engine after starting is allowed to run for 10-15 minutes to reach steady state conditions before noting the readings. After the steady state conditions are achieved the observations are made for incremental loads ranging from no load to full load.
For each loading the inlet air flow rate, the time for 10 cc of fuel consumption, the ambient temperature, the exhaust gas temperature, the outlet cooling water flow rate, the temperature readings and the five emissions such as CO, HC and NOx from the gas analyzer are noted and experiments are repeated for injection pressures of 200,220 and 240 bar respectively at each load. The fuel tank which contained Jatropha

biodiesel is emptied and then is filled with Animal tallow biodiesel. The engine is started at an injection pressure of 180 bar and allowed to run for 10-15 minutes in order to obtain steady state conditions.
Then the readings of the inlet air flow rate, the time for 10 cc of fuel consumption, the ambient temperature, the exhaust gas temperature, the outlet cooling water flow rate, the temperature readings and the five emissions such as CO, HC and NOx from the gas analyzer are noted are down. The experiments are carried out by following the same steps at injection pressures of 200, 220 and 240 bar respectively and the readings are tabulated. The biodiesels of jatropha and animal tallow have densities close to each other and hence they are directly mixed. The blend is prepared just before test to ensure mixture homogeneity on volume basis from 0% to 100% volume of biodiesel at room temperature. The blend is prepared by adding two litres of jatropha biodiesel to two litres of animal tallow biodiesel. The blend prepared is then supplied to the fuel tank after ensuring the tank is empty and clean.
Then engine is started at 180 bar and is kept ideal at zero load, till the steady state conditions are reached. The above mentioned observations are recorded at injection pressures of 200, 220 and 240 bar respectively at each load.

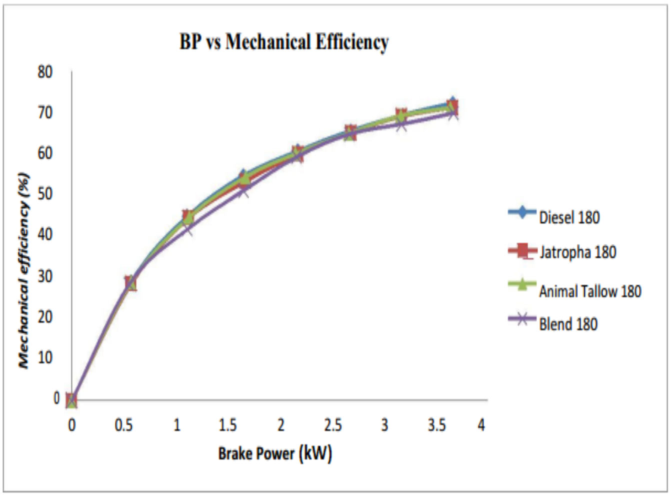
3.Results and Discussion

The results obtained from the experiments of Jatropha biodiesel, Animal Tallow biodiesel and their blends at injection pressures of 180, 200, 220 and 240 bar are compared and discussed with respect to the results when the engine is fuelled with diesel at injection pressure of 180 bar. The reason for taking the results of diesel at 180 bar is that these results are considered to be standard for CI diesel engines throughout the globe.

3.1 Performance

3.1.1Mechanical Efficiency

The mechanical efficiency of different fuels is shown as function of brake Power. The mechanical efficiency of all the fuels is seen to increase with increase in brake Power.
From the below figures the mechanical efficiency of biodiesels and the blend are lower than diesel at four injection pressures showing the poor performance characteristics due to high viscosity and poor volatility of biodiesels.



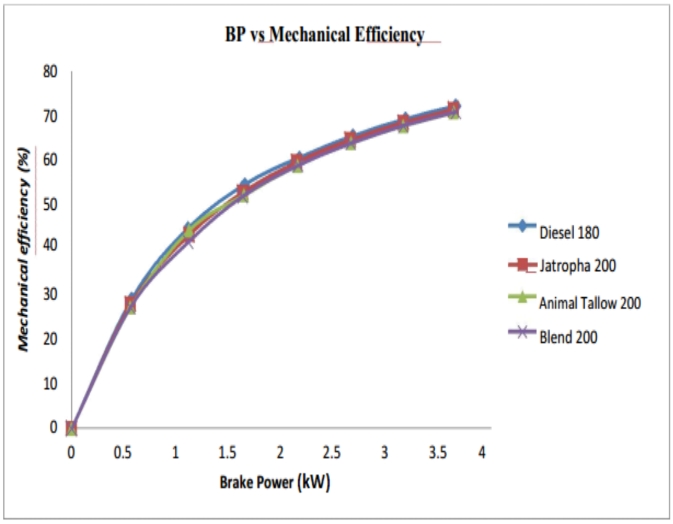
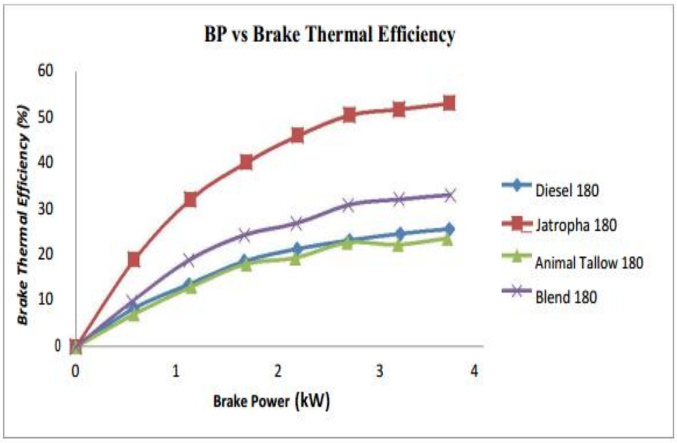


Fig 3.1.1 Brake Power vs Mechanical Efficiency at fuel injection pressure of 180, 200, 220 & 240 bar respectively.

3.1.2Brake Thermal Efficiency

From the below figures it is observed that brake thermal efficiency of Jatropha biodiesel and the blend is higher than brake thermal efficiency of diesel at all injection pressures.
The brake thermal efficiency of Animal Tallow biodiesel is lower when compared with that of diesel.



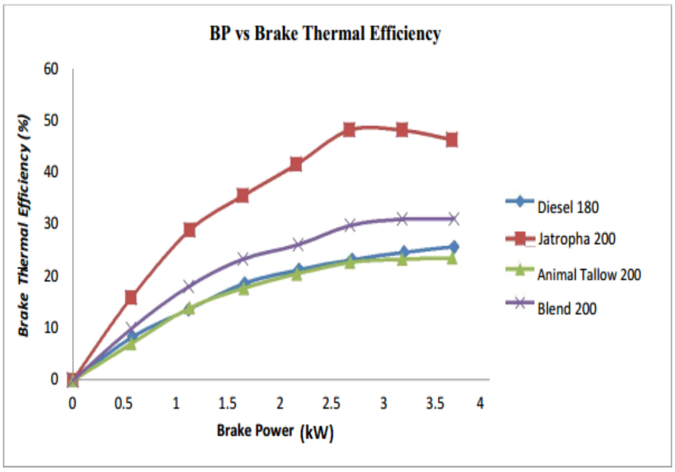
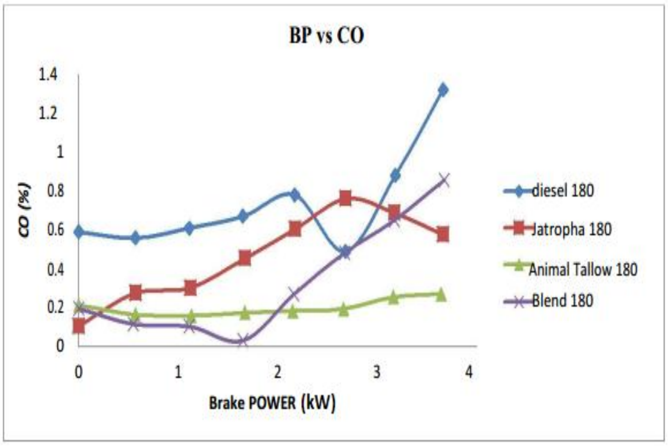


Fig 3.1.2. Brake Power vs Brake Thermal Efficiency at fuel injection pressure of 180, 200, 220 & 240 bar respectively.

3.2 Emissions

3.2.1 CO emissions

The below graph shows the variations of CO emission with brake Power. It is seen that CO emissions are increased with increase in brake Power. It is observed that the CO emissions of biodiesels and their blends are far below the emissions of diesel at all injection pressures. The lower CO emission of biodiesels and their blends are due to high oxygen content of biodiesel which helps in complete oxidation of fuel.



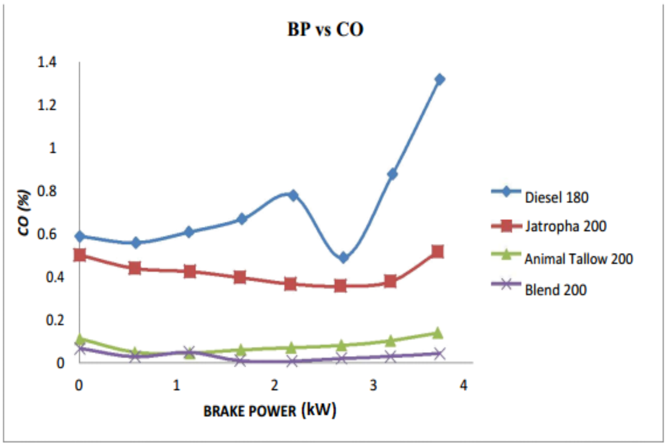


Fig 3.2.1 Brake Power vs CO at fuel injection pressure of 180, 200, 220 & 240 bar respectively.

3.2.2 NOx emissions

The NOx values as parts per million are plotted as function of brake Power. From the figure it is observed that the emissions of biodiesels and their blends are high compared with that of diesel at all injection pressures.
This could be because of high oxygen content and also shorter ignition delay because of high cetane number.

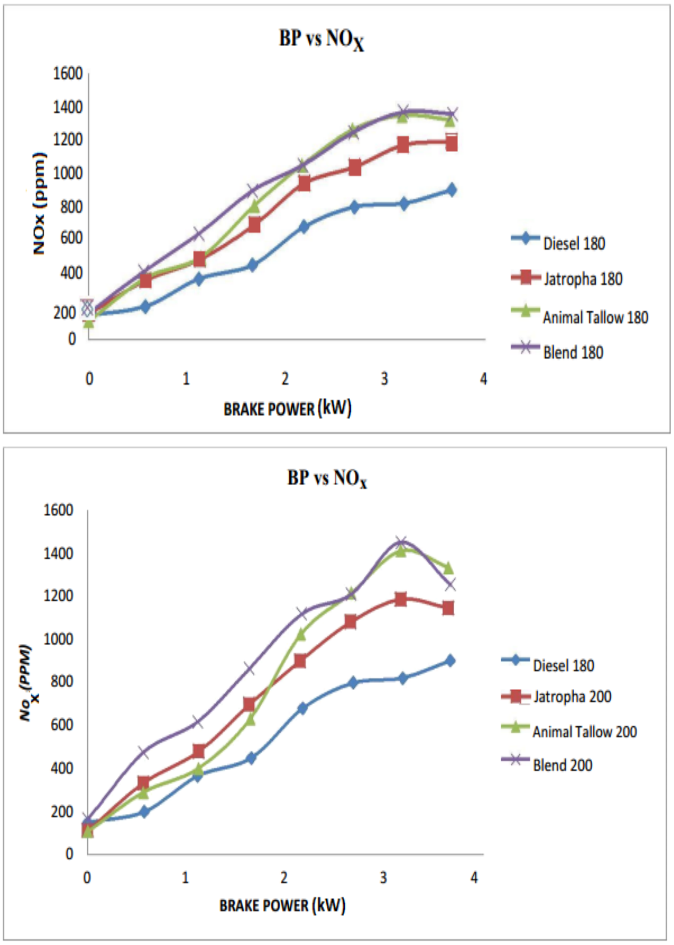


Fig 3.2.2 Brake Power vs NOx at fuel injection pressure of 180, 200, 220 & 240 bar respectively.

3.2.3 HC Emission

The variations of HC emission for diesel, biodiesel and their blends are shown in the below figure. The HC emissions of diesel are higher compared to that of biodiesels and their blends at each load.
This is because of high cetane number and increased gas temperature of biodiesel. The high cetane number decreases the ignition delay and the high temperature helps in preventing condensation of hydrocarbons, thus reducing the HC emissions.

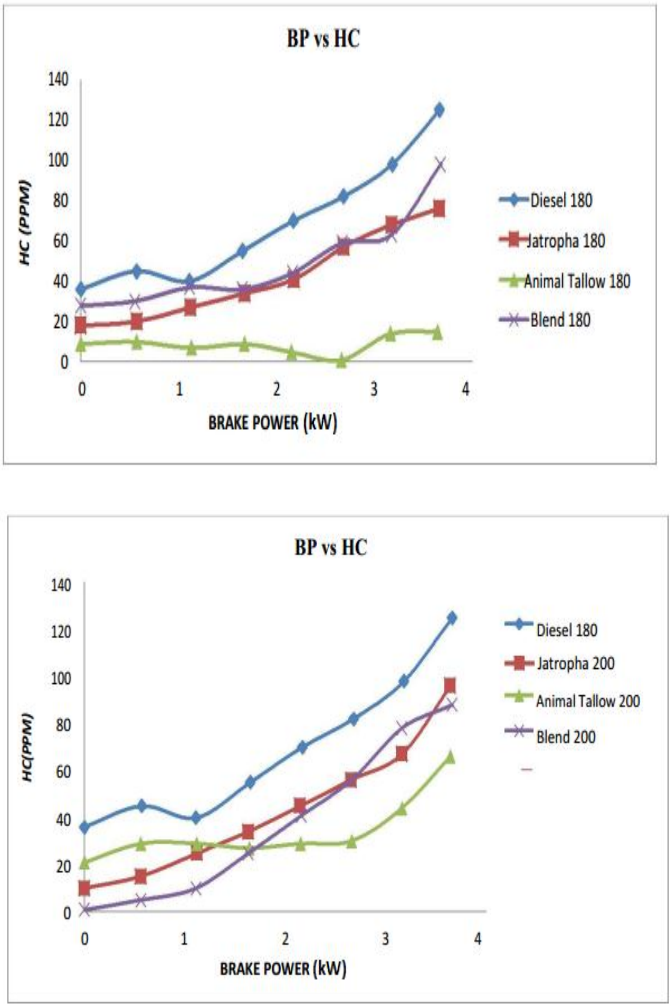


Fig 3.2.3 Brake Power vs HC at fuel injection pressure of 180, 200, 220 & 240 bar respectively.

4. Conclusions

In this work engine is runned by fuelling with Diesel, Jatropha Biodiesel, Animal Tallow Biodiesel and their Blends respectively. The engine performance and the emissions (CO, CO2, NOx, HC, and O2) are obtained at different loads at injection pressures of 180, 200, 220 and 240 bar respectively. From the results obtained the following conclusions are made.
Jatropha and Animal Tallow biodiesels can be directly used for diesel engines without any modification.
The maximum Mechanical Efficiency obtained is 72.33% for Diesel at full load condition, at an injection pressure of 180 bar and the engine speed at 1365 rpm.
The mechanical efficiency for biodiesels and their blends is lower than diesel at all assorted injection pressures, at each load. Moreover the mechanical efficiency increases with increase in brake Power. The

maximum Brake Thermal Efficiency obtained is 53.12% for Jatropha biodiesel at full load condition, at an injection pressure of 180 bar and the engine speed at 1375 rpm. The brake thermal efficiency of jatropha and the blend is more than the brake thermal efficiency of diesel. The brake thermal efficiency of animal tallow is slightly less when compared with diesel at all assorted injection pressures.

The maximum CO and HC emissions are for diesel at full load condition. The CO and HC emissions of biodiesel and the blend are lower than diesel at all injection pressures. The maximum NOx emission is obtained for blend at an injection pressure of 240 bar, at full load condition. These emissions of blend and the two biodiesels are higher than diesel at all injection pressures. The exhaust emissions of CO and HC are reduced when compared with diesel emissions at all injection pressures.

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