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Research Paper

OPTIMIZATION OF INJECTION PRESSURE FOR A COMPRESSION IGNITION ENGINE WITH METHYL ESTER OF CORN OIL AS AN ALTERNATE FUEL

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The major problem associated with the direct use of vegetable oils as fuel in the compression ignition engines due to their higher viscosity. The use of vegetable oil in the compression ignition interferes the fuel injection and atomization and contributes to incomplete combustion, nozzle clogging, excessive engine deposits, ring sticking, producing thick smoke, etc. The problem of higher viscosity of vegetable oils can be resolved by various techniques, such as heating of fuel lines, trans-esterification, modification of injection system, etc. In the present investigation, tests were conducted with the use of transesterified corn oil in a single cylinder, four stroke, and direct injection diesel engine. Tests were conducted with methyl ester of corn oil and diesel. To improve the combustion characteristics of methyl ester of corn oil in an unmodified engine, effect of increase in injection pressure was studied. The injection pressure was increased from 180 bar to 220 bar. The investigation revealed that the optimum pressure at 200 bar and comparison of the performance of the engine was studied in terms of brake specific fuel consumption, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency and exhaust emissions.

Keywords: Injection pressure, Raw corn oil, Methyl ester of corn oil, Compression Ignition Engines, Performance and Combustion

INTRODUCTION

Biodiesel has received much attention in the past decade due to its ability to replace fossil fuels, which are likely to run out within a century. Especially, the environmental issues concerned with the exhaust gases emission by the usage of fossil fuels also encourage the usage of biodiesel, which has proved to be eco-friendly far more than fossil fuels (K Srinivasa Rao *et al*., 2012).

Bio-fuels made from agricultural products (oxygenated by nature) reduce the dependence on oil imports, support local agricultural industries and enhance farming

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incomes, generate local employment, moreover, offer benefits in terms of reduced emissions. Among those, vegetable oils, their derived bio-diesels (methyl or ethyl esters) and bio-alcohols are considered as very promising fuels. Experimental work on the use of bio-ethanol in diesel engines have been reported. Bio-fuel production is a rapidly growing industry in many parts of the world. Bio-ethanol is the primary alternative at present to gasoline for spark-ignition engines, and vegetable oils, their derived bio-diesels and bio-ethanol mixed with diesel fuel for compression ignition (diesel) engines.

The main disadvantages of vegetable oils, as diesel fuels, are associated with the highly increased viscosity, 10-20 times more than the normal diesel fuel. Thus, although tests using neat vegetable oils showed promising results, problems appeared after the engine had been operated for longer periods. To solve the problem of the very high viscosity of neat vegetable oils, the following usual methods are adopted: blending in small blend ratios with diesel fuel, micro-emulsification with methanol or ethanol, cracking, and conversion into bio-diesels mainly through the trans esterification process.

The advantages of bio-diesels as diesel fuel are the minimal sulfur and aromatic content, and higher flash point, lubricity, cetane number, bio-degradability and nontoxicity. On the other hand, their disadvantages include the higher viscosity and pour point, and the lower calorific value and volatility. Furthermore, their oxidation stability is lower, they are hygroscopic, and as solvents may cause corrosion in various engine components. For all the above reasons, it is generally accepted that blends of diesel fuel, with up to 20% bio-diesels and vegetable oils, can be used in existing diesel engines without modifications.

THE BIODIESEL PRODUCTION AND CHARACTERIZATION

A. Biodiesel Production Procedure

The biodiesel fuel used in this study was produced from the transesterification of raw corn oil with methanol (CH_3OH) catalyzed by potassium hydroxide (KOH). A titration was performed to determine the amount of KOH needed to neutralize the free fatty acids in raw corn oil. A 12 gram of of KOH needed as catalyst for every liter of raw corn oil. For transesterification, 200 mililitre of CH_3OH plus the required amount of KOH were added for every liter of raw corn oil, and the reactions were carried out at 55°C for the period of one hour. The water wash process was performed by using a sprinkler which slowly sprinkled water into the biodiesel container until there was an equal amount of water and biodiesel in the container. The water biodiesel mixture was then agitated gently for 20 minutes, allowing the water to settle out of the biodiesel. After the mixture had settled, the water was drained out.

B. Biodiesel Properties

The fuels were characterised by determining their density, viscosity, flash point, fire point and lower calorific value. The important fuel properties of Petroleum Diesel and Corn Biodiesel and ASTM standard specification for biodiesel (M Y E Selim *et al*., 2013) are given in Table 1.

Table 1: Properties of Fuels

I	Properties	Unit	Conventional Diesel fuel	Corn Bio-diesel	ASTM Standard
II	Density	gm/cc	0.831	0.87	0.87-0.890
III	Kinematic Viscosity @ 40°C	Cst	2.58	4.26	1.9 - 6.0
IV	Calorific Value	KJ/kg	42500	40500	37500
V	Flash Point	°C	50	158	130 min
VI	Fire Point	°C	56	163	--
VII	Cetane number	----	48	----	48 - 70

Table 2: Technical Specifications of the Engine

Manufacture	Kirloskar Oil Engine
Engine	Single Cylinder D I Compression Ignition
Admission of air	Naturally aspirated
Bore	80 mm
Stroke	110 mm
Compression ratio	17:5
Maximum power	7.4 KW (10 BHP)
Rated speed	1500 rpm
Dynamometer	Eddy Current Dynamometer
Method of cooling	Water cooled
Type of starting	Manual cranking
Governor	Mechanical governing (Centrifugal type)
Type of pressure sensor	Piezo-electric type
Pressure sensor resolution	0.1 bar for cylinder pressure, 1.0 bar inj. Pressure
Crank angle sensor resolution	degree

It is shown that the viscosity of biodiesel is evidently higher than that of diesel fuel. The density of the biodiesel is slightly higher than that of diesel fuel. The heating value of biodiesel is more than that of diesel fuel. Therefore, it is necessary to increase the fuel amount to be injected into the combustion chamber to produce same amount of power. Fuels with flash point above 52°C are regarded as safe. Thus, biodiesel is an extremely safe fuel to handle compared to diesel fuel. Even 20% biodiesel blend has a flash point much above that of diesel fuel, making biodiesel a preferable choice as far as safety is concerned.

EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup used in the investigation is shown in Figure 1. It consist of a single cylinder 4-Stroke, Direct Injection-Compression Ignition engine, an eddy current dynamometer to measure the brake power or load torque, data acquisitation system, display panel, computer, pressure and temperature sensors are used. The detailed technical specifications of engine are described in Table 2. The cooling waterflow rate and temperature is maintained constant throughout the test. The engine was tested with corn oil biodiesel, pre-heated and baseline petroleum diesel to investigate the effect of injection pressure on performance, and combustion characteristics. The engine was allowed to warm up until all temperature reaches steady state in each test. Engine was maintained at constant speed of 1500 rpm

Figure 1: Schematic diagram of experimental setup

with fuel injection pump. To vary the engine load and to measure brake power, an eddy current dynamometer was used.

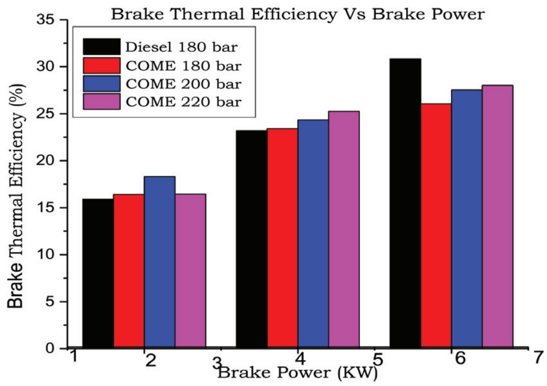
RESULTS AND DISCUSSION

A. Variation of Brake Thermal Efficiency with Brake Power:

Brake power is the power output of the drive shaft of an engine without the power loss caused by gears, transmission, friction, etc. It's called also pure power, useful power, true power or wheel power as well as other terms. Due to increase in fuel temperature, brake thermal efficiency has increased substantially. It is due to the reduction in the viscosity, improved atomization and better combustion.

Figures 2 shows the brake thermal efficiency with brake power for different injection pressures for the torque ranges from 0-30 N-m and the speed 1000 rpm. Brake thermal efficiency increases as the injection pressure increases from 180 bar to 220 bar, and then slightly decreases as the injection pressure is further increased. Brake thermal efficiency increases with the increase in brake power with the blend of 20% corn biodiesel mixed with the conventional diesel fuel.

Figure 2: Variation of Brake Thermal Efficiency with Brake Power



From the figure, it was observed that the blend of B20 is found to have the maximum thermal efficiency of 27.50% at a brake power of 6.10 kW while for diesel it was 32.5% at a brake power of 5.20 kw. It was observed that as the proportion of corn oil in the blends increases, the brake thermal efficiency decreases. The decrease in brake thermal efficiency with increase in corn oil concentration is due to the poor atomization of the blends due to their higher viscosity.

B. Variation of Brake Specific fuel consum-ption with Brake power:

Figure 3. shows the variation of brake specific fuel consumption with brake power for different injection pressures for the torque ranges from 0-30 N-m for the speed 1000 rpm. It was found that the brake specific fuel consumption of corn biodiesel for the blend of 20% at 200 bar injection pressure is approximately close to diesel fuel. Higher proportions of corn biodiesel in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

The BSFC, in general, is found to increase with the increasing proportion of fuel blends with diesel, where as it decreases with increase in speed for all fuels. The reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. The higher densities of biodiesel blends cause higher mass injection for the same volume at the same injection pressure.

C. Variation of Mechanical Efficiency with Brake Power:

Figure 3: Variation of Brake Specific Fuel Consumption with Brake Power

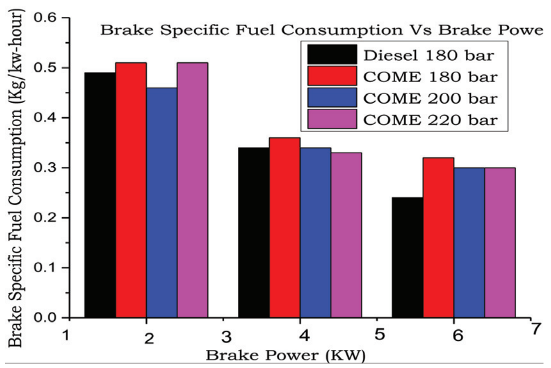
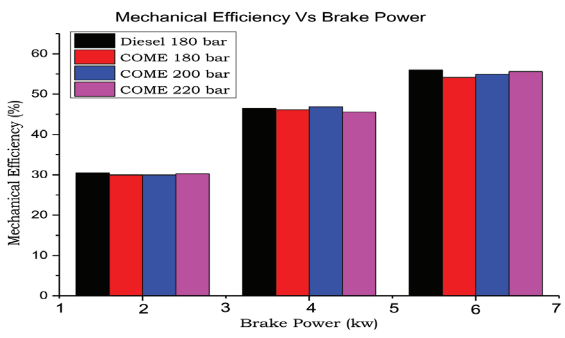


Figure 4 shows the variation of mechanical efficiency with brake power for the biodiesel blend of 20%, speed of 1000 rpm and at the torques of 10 N-m, 20 N-m, and 30 N-m respectively. Mechanical efficiency increases with increasing injection pressures. The mechanical efficiency increases with the blend of the biodiesel as compared with the diesel fuel.

D Variation of Brake Specific Fuel Consum-ption with Speed:

Figures 5. shows the variation of brake specific fuel consumption with the different

Figure 4: Variation of Mechanical Efficiency with Brake Power



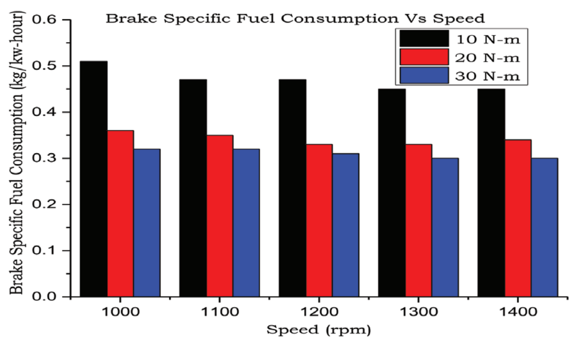
speeds of the engine running on the blend of 20% corn biodiesel.

From the figure, it was observed that the brake specific fuel consumption is based on the torque delivered by the engine in respect to the fuel mass flow. Brake specific fuel consumption is measured after all parasitic engine losses.

Brake specific fuel consumption has been seem to be higher (0.5 kg/kw-hour) for all the speeds and at the torque of 10 N-m. Brake specific fuel consumption decreases with increasing in engine speed and torque.

It was observed that at low speed and torque, heat losses from the combustion

Figure 5: Variation of Brake Specific Fuel Consumption with Speed



chamber walls is proportionately higher and combustion chamber efficiency is poorer, resulting in higher brake fuel consumption for the brake power produced. Brake specific fuel consumption decreases with the increase of the speed and the torque for the 20% blend of corn biodiesel.

E. Variation of Brake Thermal Efficiency with Speed:

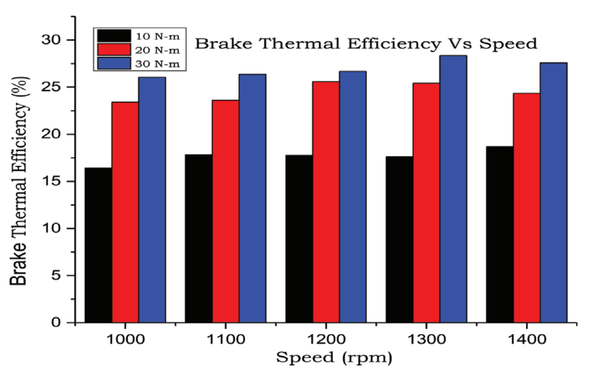
From the **Figure 6**, the following observations were made

i) for the torque of 10 N-m, variation of brake thermal efficiency is between 16% to 20% for all the speeds and for all the injection pressures.

ii) for the torque of 20N-m, brake thermal efficiency is between 22.50% to 25% for all the speeds, and for all the injection pressures.

iii) for the torque of 30 N-m, brake thermal efficiency is between 26 – 27.5% for all the speeds and injection pressures without any appreciable variations.

Figure 6: Variation of Brake Thermal Efficiency with Speed



F. Variation of Mechanical Efficiency with Speed:

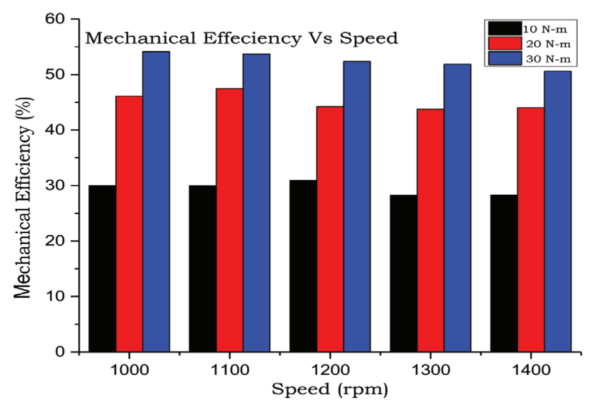
Figure 7. shows the variation of mechanical efficiency with speed for the torque of 10 N-m, 20 N-m, and 30 N-m respectively. From the figure, following observations were made;

i) for the torque of 10 N-m, mechanical efficiency is 30% which is more or less equal to all the speeds.

ii) for the torque of 20 N-m, mechanical efficiency is 40 - 45% which is remains same for all the speeds.

iii) for the torque of 30 N-m, mechanical efficiency is highest (52.5%) at the speed of 1000 rpm – 1300 rpm. At the speed of 1400 rpm, mechanical efficiency is decreases to 50%.

Figure 7: Variation of Mechanical Efficiency with Speed



CONCLUSION

1) It is generally accepted that blends of diesel fuel, with up to 20% bio-diesels and vegetable oils, can be used in existing diesel engines without modifications.

2) Due to increase in fuel temperature, brake thermal efficiency has increased substantially. It is

due to the reduction in the viscosity, improved atomization and better combustion.

3) Higher proportions of corn biodiesel in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.

4) i) Brake thermal efficiency substantially increases with the increase in fuel temperature.

ii) Brake thermal efficiency increases with the increase in injection pressure and slightly decreases with the further increase of injection pressure.

iii) Brake thermal efficiency increases with thea increase in brake power.

iv) In general, brake specific fuel consumption increases with the increasing proportion of fuel blends with the diesel.

v) Brake specific fuel consumption is based on the torque developed by the engine in respect to the fuel mass flow delivered to the engine. Brake specific fuel consumption is measured after all parasitic engine losses.

vi) Brake specific fuel consumption is directly proportional to the engine volume; as the engine volume decreases, brake specific fuel consumption is also decreases. This is due to the heat losses from the end gas to the cylinder walls.

vii) Mechanical efficiency increases with increasing injection pressures. The mechanical efficiency with the blend fuel is slightly lower than the diesel.

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