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Effect of injection pressure on diesel engine performance with Sea lemon oil

V.S. Hariharan[1] and K. Vijayakumar Reddy[2]

[1]*Dept. of Mechanical Engineering, Balaji Institute of Engineering & Sciences, Narsampet, Warangal-506 331, India*
[2]*Department of Mechanical Engineering, JNTU College of Engineering, Hyderabad-500 085, India*.
vsh1968@gmail.com; kvijayakumarreddy@gmail.com

Abstract

Due to the increasing demand for fossil fuels and environmental threat, a number of renewable sources of energy have been studied worldwide. An attempt is made to assess the suitability of vegetable oil for diesel engine operation, without any modifications in its existing construction. One of the important factors which influence the performance and emission of diesel engine is fuel injection pressure. In the present investigation a vegetable oil, Sea lemon oil has been investigated in a constant speed, DI diesel engine with varied fuel injection pressures (170, 190,210 and 230 bar). The main objective of this study is to investigate the effect of injection pressures on performance and emissions characteristics of the engine. The injection pressure was changed by adjusting the fuel injector spring tension. The performance and emission characteristics were presented graphically and concluded that increase in injector opening pressure increases the brake thermal efficiency and reduces unburned hydrocarbon and smoke emissions significantly.

Keywords: Diesel engine; vegetable oil; sea lemon seed oil, fuel.

Introduction

Diesel engine has gained the name and fame in serving the society in many ways. Its main attractions are ruggedness in construction, simplicity in operation and ease of maintenance. But due to the shortage of fossil fuel, we may not be able to avail its services for long time. Hence efforts are being made all over the world, to bring out non-conventional fuels for use in diesel engines. The performance and emission characteristics of diesel engines depends on various factors like fuel quantity injected, fuel injection timing, fuel injection pressure, shape of combustion chamber, position and size of injection nozzle hole, fuel spray pattern, air swirl etc. The fuel injection system in a direct injection diesel engine is to achieve a high degree of atomization for better penetration of fuel in order to utilize the full air charge and to promote the evaporation in a very short time and to achieve higher combustion efficiency. The fuel injection pressure in a standard diesel engine is in the range of 200 to 1700 atm depending on the engine size and type of combustion system employed (John B Heywood, 1988). The fuel penetration distance become longer and the mixture formation of the fuel and air was improved when the combustion duration became shorter as the injection pressure became higher (Seang-wock Lee *et al*.,2002). When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation leads to inefficient combustion in the engine and causes the increase in NOx, CO emissions. When the injection pressure is increased fuel particle diameters will become small. The mixing of fuel and air becomes better during ignition delay period which causes low smoke level and CO emission. But, if the injection pressure is too high ignition delay become shorter. So, possibilities of homogeneous mixing decrease and combustion efficiency falls down. Therefore, smoke is formed at exhaust of engine (Rosli Abu Bakar *et al*., 2008; Venkanna *et al*.,2009).

In this work, the effects of fuel injection pressure are experimentally studied on performance and emission characteristics of single cylinder direct injection diesel engine using sea lemon oil as a fuel. The Table 1 compares some of the important properties of different vegetable oils, which are used as fuels in diesel engines.

Table 1. Properties of vegetable oils

Properties	Diesel	Sea lemon oil	Jatropha oil	Cotton seed oil	Tobacco seed oil
Density (kg/m^3)	840	927	918	874	920
Calorific value (kJ/kg)	42390	39650	39774	39648	39400
Cetane number	45-55	--	45	45	38
Viscosity (cst)	4.59	49.7	49.9	50	27.7
Flash point (^{0}C)	75	158	240	210	220
Carbon residue (%)	0.1	0.46	0.44	0.55	0.57

Table 2. Technical specifications of the engine

Manufacturer	Kirloskar engines Ltd, Pune, India
Engine type	Four stroke, single cylinder, constant speed, compression ignition engine
Rated power	3.68 kW at 1500 rpm
Bore & stroke	80 & 110 mm
BHP of engine	5
Swept volume	562cc
Compression ratio	16.5:1
Mode of injection	Direct Injection
Cooling system	Water
Dynamometer	Eddy current dynamometer

Materials and methods

The specification of the selected diesel engine is shown in Table 2. A single cylinder four-stroke water-

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Fig.1. Experimental setup

cooled diesel engine developing 3.68 kW at a speed of 1500 rpm was used for this work. This engine was coupled to a eddy current dynamometer with a control system. The engine is equipped with crank angle sensor, piezo-type cylinder pressure sensor, thermocouples to measure the temperature of water, air and gas, Exhaust gas analysis was performed using multi gas exhaust analyser. A Bosch smoke pump attached to the exhaust pipe was used for measuring smoke levels. The variable load tests are conducted using sea lemon oil as a fuel at the rated speed of 1500 rev/min. At each load, air flow rate, fuel flow rate, exhaust gas temperature, HC, nitric oxide and smoke emissions are recorded. The total experimental setup is shown in Fig.1.

Results and discussion

Increased injector opening pressure has a significant effect on the performance and emissions of diesel engines. An increase in injection pressure is found to enhance the atomisation at the nozzle outlet, resulting in a more distributed vapour, hence better mixing. The nozzle opening pressure was set by adjusting the spring of the injector and values were 170,190,210 and 230 bar.

Performance parameters

The effect of injector opening pressure (IOP) at the static injection timing of 27°bTDC is presented in the following graphs. At different IOPs the variation of brake thermal efficiency is shown in Fig.2. It is clear that increasing the injector opening pressure from 170bar (manufacture's specification for diesel) to 190 bar significantly increases the brake thermal efficiency. This is because higher injection pressures lead to better spray and combustion. Significant reduction in HC and smoke level were also observed with this change in the IOP.

Amongst all the IOPs tested, the highest brake efficiency occurred at 190 bar. The brake thermal efficiency increases from 27.3% to 29.1% when the IOP is raised from 170 to 190 bar at full output. As mentioned earlier, high IOP means that the injection always takes place at a high pressure and hence atomization is better and mixing with air is good. This will enhance combustion and in turn

Fig.2. Variation of brake thermal efficiency with BMEP for different injection pressures.

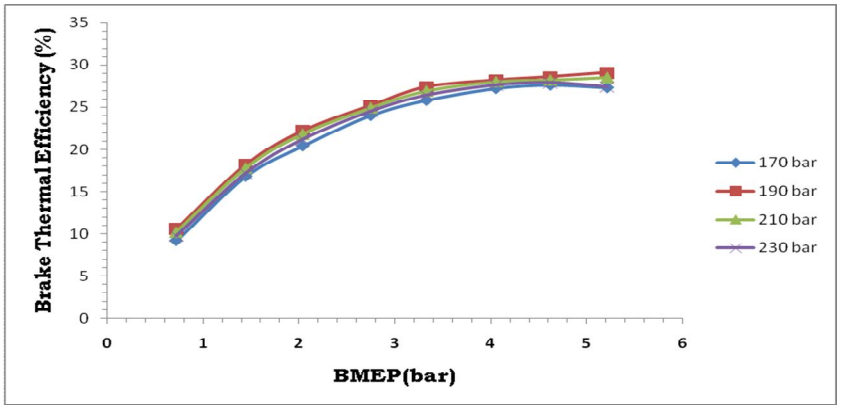


Fig.3. Variation of exhaust temperature with BMEP for different injection pressures

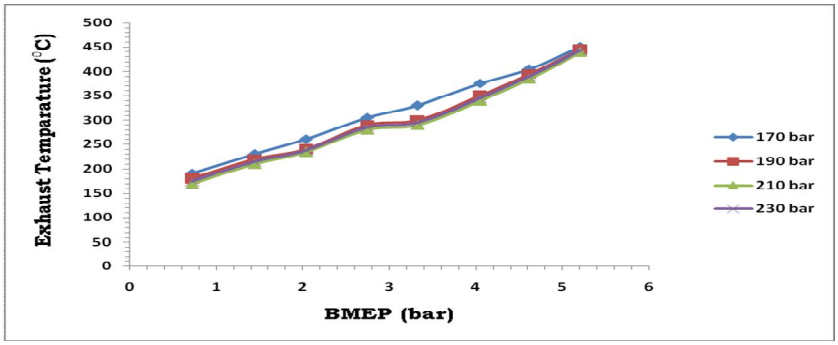


Fig.4. Variation of HC with BMEP for different injection pressures

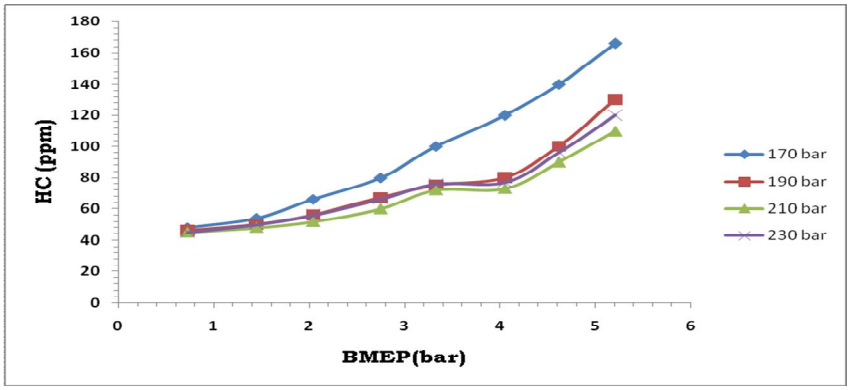
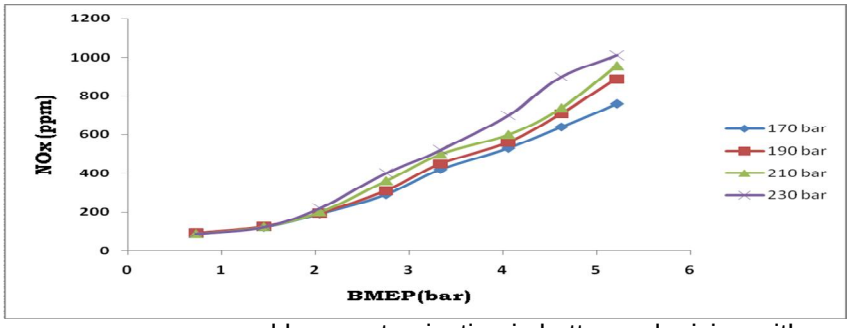


Fig.5. Variation of NOx with BMEP for different injection pressures



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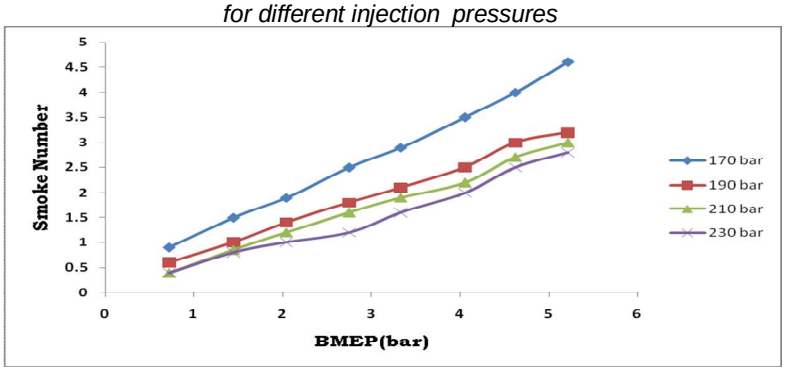
improve efficiency. Too high IOPs will lead to delayed injection. There is a significant variation in exhaust gas temperature, shown in Fig.3. It is highest at 170 bar where the thermal efficiency is lowest, *i.e.* where the highest fuel energy input for a given engine output will occur. Sluggish combustion at lower IOPs will lead to increased exhaust gas temperature.

Emission parameters

Fig.4 shows a significant drop in HC emission as IOP increases because of better combustion. Enhanced atomization also led to a lower ignition delay. This will enhance the performance with vegetable oils, which normally have a high ignition delay on account of their high viscosity. An improvement in the spray, will lead to a lower physical delay. The improved spray also leads to better combustion and thermal efficiency at full load. HC reduced from 166to 130ppm after increasing the IOP from 170 to 190 bar. The highest IOP leads to an increase in the HC level probably because of delayed injection. Also very high injector opening pressures will lead to a considerable portion of the combustion occurring in the diffusion phase on account of the small ignition delay.

As expected NOx level increases with increasing IOP due to faster combustion and higher temperatures reached in the cycle shown in Fig. 5. The Fig.6 indicates that smoke levels steadily fall with increase in the injector opening pressure due to improved mixture formation because of well-atomized spray. At full load the smoke level falls from 4.6BSU to 3.2 BSU when the IOP is increased from 170 to 190 bar. Lowest smoke level is seen with the IOP of 230 bar.

Fig.6. Variation of smoke number with BMEP for different injection pressures



Conclusions

Increasing the injector opening pressure (IOP) from the rated value for the diesel *i.e*. 170 bar to 190 bar resulted in a significant improvement in performance and emissions with Sea lemon oil due to better spray formation. The changes noted at maximum engine output were: 1. Brake thermal efficiency increases from 27.3% to 29.1%, 2. HC reduced from 166 to 130ppm, 3. NOx level increases with increasing IOP due to faster combustion and higher temperatures reached in the cycle and 4. Smoke level reduced from 4.6BSU to 3.2 BSU. Smoke levels steadily fall with increase in the injector opening pressure due to improved mixture formation because of well-atomized spray. On the whole a significant improvement in the performance and emissions can be realized by properly optimizing the injector opening pressure when a diesel engine is to be operated with neat Sea lemon oil.

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