Influence of Fuel Injection Parameters on the Performance and Emissions of CI Engine with neat Biodiesel

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Abstract:

Use of biodiesel has attracted over the year as a viable alternative fuel due to its properties being very close to petro-diesel. The major problem encountered with the use of neat biodiesel was high NOx emissions. In the present work an attempt is made to mitigate levels of NOx emissions when engine is operated with neat biodiesel produced from jatropha curcas oil. In this regard, systematic experimental investigations were done on a typical water cooled single cylinder CI engine to study the effect of fuel injection parameters. Fuel injection parameters such as fuel injection pressure, size of fuel injection nozzle hole and fuel injection timing, for each of these parameters three different values were selected. Engine performance was evaluated in terms of brake specific fuel consumption (BSFC), hydrocarbon (HC), oxides of nitrogen (NOx) and Smoke density It was observed that modest increase in fuel injection pressure, smaller nozzle hole size and retarded fuel injection timing yielded satisfactory performance and lower HC , Smoke density and NOx emissions with neat biodiesel operation.

Introduction:

The nature of diesel engine combustion process is unsteady, turbulent, diffusion and heterogeneous [3]. The combustion process is highly influenced by the way of fuel-air mixing in the engine cylinder. Diesel fuelled engines meet the requirement of prime mover in light, medium and heavy duty applications due to its high fuel conversion efficiency. However, due to extensive use of diesel engines the problems of fuel crisis and pollution related issues are increasing alarmingly. The problems of automotive pollution are being tackled by various researchers by the use of exhaust-gas after-treatment methods or adopting alternate fuels. Vegetable oils are found to be promising alternative to petro-diesel fuel owing to its physico-combustion properties near to petro-diesel fuel [1,4]. However, a little higher viscosity of vegetable oil restricts its direct use in engine, this issue made the researcher to suggest treatment of vegetable oils and subsequent conversion into biodiesel [2,4].

To achieve better fuel-air mixing, one approach is to adopt a good fuel injection system as it plays a crucial role to bring fuel and air in intimate contact with each other. High injection pressures with small nozzles are common in the modern diesel engine as they reduce injection duration and improve combustion efficiency [2-4]. Biodiesel is attractive as it is biodegradable, sulphur-free, non-toxic and can significantly reduce exhaust emissions and low overall life cycle emission of carbon oxides (COx) from the engine when burned as a fuel. Experimental investigations to optimize parameters for effective use of vegetable oil fuels, like the effect of injection system parameters on performance and emission characteristics of a twin-cylinder CIDI engine fuelled with pongamia biodiesel–diesel blend using response surface methodology [5]; the effect of supercharging and fuel injection pressure on the performance of a diesel engine with cotton seed oil [6,9] and the influence of compression ratio and injection pressure by adopting karanja methyl ester were studied [10]. Studies were done researchers to make use of ethanol,di-methyl ether or di-ethyl ether but concluded that the production cost of these fuels is cost intensive [11,12].Life cycle analysis of biodiesel fuel were established that such fuels are safe and environment friendly[7].

It is observed from the literature that there were efforts to make use of biodiesel as blends with methanol or ethanol and to further make it feasible and effective[6,13,14]. In the present experimental study, an attempt is made to improve the performance of biodiesel run engine by varying the fuel injection parameters such as fuel injection pressures, size of fuel injector nozzle hole and fuel injection timing.

Materials and Methods.

A single cylinder naturally aspirated CI engine is selected for the purpose of present study. The specifications of the engine are given in Table-I. The dimensions of various nozzles employed in the present studies are given in Table-II. For this purpose methyl esters of Jatropha Curcas oil, popularly called as biodiesel, [obtained from non-edible oil, Jatropha oil] as fuel is considered. To begin with sufficient amount of laboratory samples of methyl esters of Jatropha oil were prepared following the procedure well laid out [1,6]. The properties of fuel prepared and comparison with petro-diesel are given in Table-III. Firstly to obtain baseline data, performance tests with petro-diesel, by varying fuel injection pressure, nozzle hole size and number of holes maintaining injection timing unaltered were conducted and performance and emission tests on DI type diesel engine with biodiesel [B100] were conducted. All the tests were carried out at the rated speed of the engine. The jacket water temperature was maintained at about 70°C. The rated injection pressure of the engine was 190bar. To investigate the effect of fuel injection pressure, three different pressures were selected, viz: 190, 210 and 230 bar, for the experimentation. Further, for a fixed fuel injection pressure, effect of three nozzle hole sizes were studied and for a given injector nozzle hole size the effect of injection pressure was investigated [5]. These tests were aimed at arriving at the optimum nozzle hole size and optimum fuel injection pressure. The parameters such as load, time for fuel consumption, exhaust gas temperature; smoke density and exhaust emissions were noted down. Fig.1 represents schematic of the experimental set-up employed.

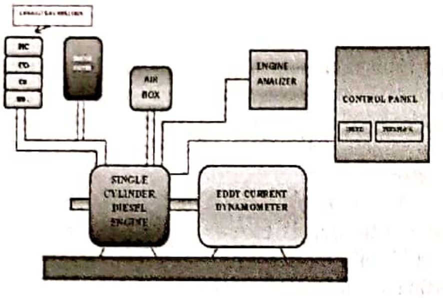

Figure.1.Schematic layout of experimental set-up

Table I - Specifications of Engine

Engine model	Kirloskar, AV1, Water cooled engine, Naturally aspirated engine
Rated Power	5hp @ 1500 rpm
Bore X Stroke	80mm X 110mm
Cubic capacity	0.553 lit (553 cu.cm)
Compression ratio	16.5 : 1
Fuel injection timing	23o btdc
Injection pressure	190 bar

Table II- Specification fuel injection parameters

Fuel	Specific gravity	LHV, MJ/kg
Petro-Diesel	0.832	42.9
B100	0.87	39.2

Table III- Typical Properties of methyl esters of jatropha oil petro-diesel

No. of holes and Diameter of each hole	Injection pressures, bar
NH1- 4, 0.32mm	190,210 and 230
NH2- 4, 0.29mm	190,210 and 230
NH3- 3, 0.28mm	190,210 and 230

Results and Discussion:

Performance Studies: Fig.2 illustrates the variation of BSFC with BP for different fuel injection pressure with petro-diesel as fuel, for the rated nozzle size and at rated injection timing. From the figure, BSFC values are observed to be lower for the fuel injection pressure 210 bar. This can be due to the fact that higher injection pressures would produce smaller droplets facilitating near complete combustion and hence the injection pressure of 210 bar was maintained in further studies. Fig.3 depicts the variation of BSFC with BP for different fuel injection nozzle hole sizes with petro-diesel as fuel. The results are in good agreement with the literature[8-11].

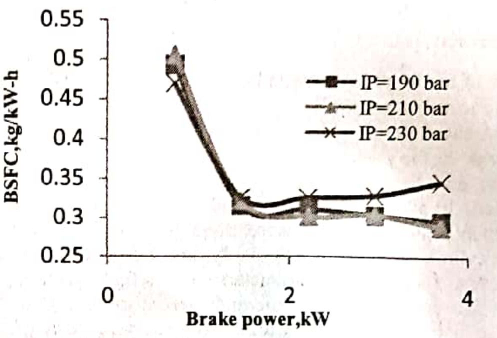

Figure 2. Variation of BSFC with brake power-Diesel-NH3

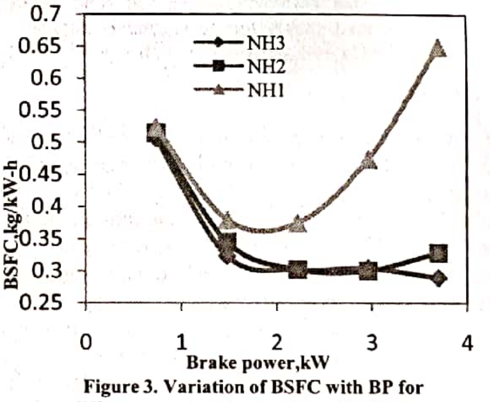

Figure 3. Variation of BSFC with BP for different nozzle hole sizes-Diesel-IP:210bar

It can be seen that among these three nozzle hole sizes, the size is decreasing in the order of NH1, NH2 and NH3, i.e. larger diameter droplets are produced with NH1 and smaller with NH2 and NH3 respectively, with smallest being NH3. Therefore, it can be inferred at this stage that smaller nozzle hole with small droplet size and slightly higher injection pressures appeared to be better to allow thorough mixing of fuel and air to yield near complete combustion and thus resulting in lower BSFC values. The data of BSFC with BP for IP:210 bar and NH3 is taken as baseline test data and used for comparison in further tests.

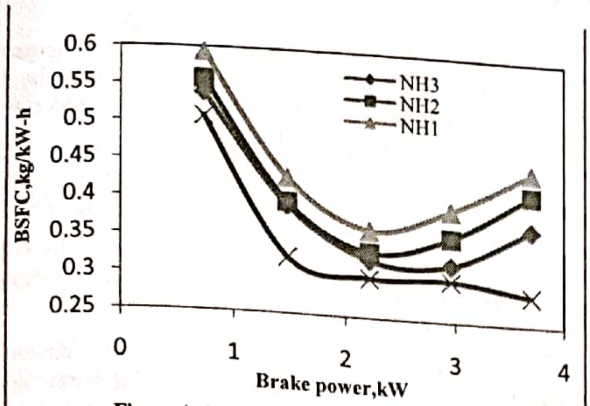

Figure 4. Comparison of BSFCs with BP for different NHs-B100

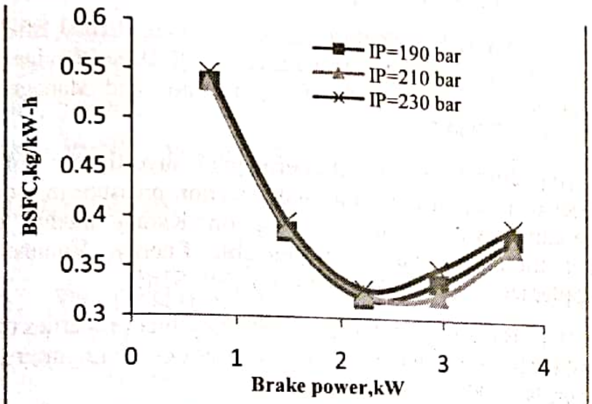

Figure 5.Variation of BSFC with BP-B100-NH3

Fig,4 illustrates the variation of BSFC with BP for an injection pressure of 210 bar and three different nozzle hole sizes. Since the viscosity of B100 is higher than petro-diesel, smaller nozzle size with the injection pressure has resulted in lower values of BSFC. The values are also compared with baseline results in the same figure. The baseline BSFC values are deviating far more in the 50-100% load range of the engine. This can be attributed to the higher viscosity and higher density of B100 compared to petro-diesel. It is interesting to note at this stage that 210 bar and NH3 are observed to be optimum fuel injection pressure and nozzle hole size even for B100 as these parameters resulted in lower BSFC values. The variation of BSFC with BP for optimized IP and nozzle size is shown in Fig.5.

Emission Studies:

The emissions of unburned hydrocarbons, oxides of nitrogen and smoke density are quantified and plotted for the optimized fuel injection pressure and three nozzle hole sizes.

Comparison of emissions for B100 and petro-diesel.

HC, NO_x and smoke emissions obtained under full load condition for optimized nozzle hole size and injection pressure are illustrated in Figure 6, 7 and 8 respectively. It can be noticed that except NOx emissions are higher side where as HC and smoke density values are lower for neat biodiesel operation. This observation is in-line with the already established in the literature. The lower emissions of HC and smoke emissions are due to the near complete combustion of biodiesel fuel under the optimized conditions owing to presence of oxygen in the molecular structure of biodiesel.

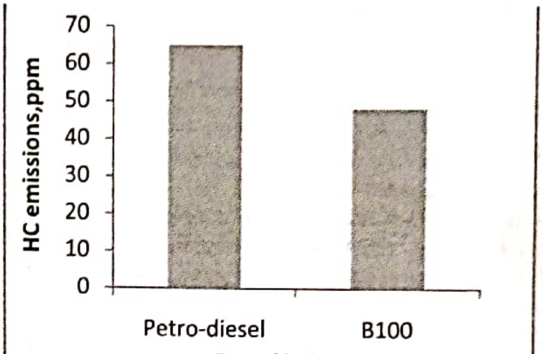

Figure 6. Comparison of HC emissions under full load operation

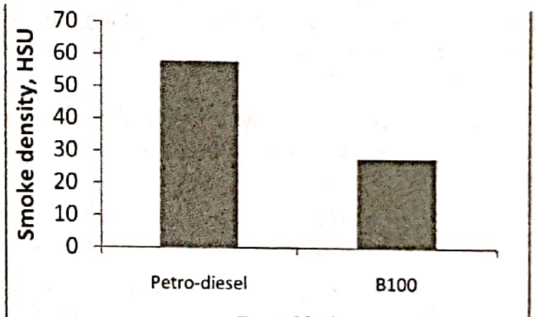

Figure 7. Variation smoke density under full load

Effect of fuel injection timing on NO_x emissions:

The biodiesel operation is advantageous with regards to complete combustion where as high reactive nature of biodiesel fuels leads to higher NOx emissions. Many a studies have established that NO_x emissions could be significantly reduced when engines are operated with retarded fuel injection timings. The rated injection timing for the given engine configuration is 23°bTDC .To investigate the effect of fuel injection timing, timing was varied 3 degrees from the rated injection timing i.e.20°bTDC and 26° bTDC respectively. The effect is shown in Fig.8.

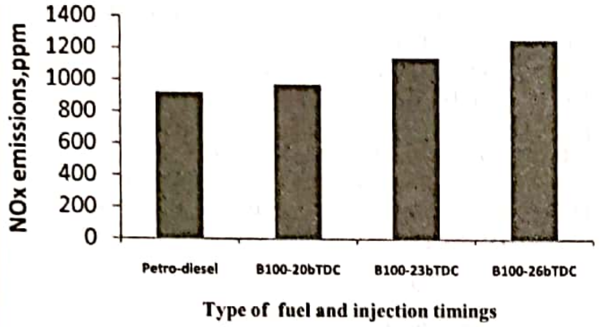

Figure8.Variation of NOx emissions under full load

This can be reasoned out as that injection timing is retarded, fuel will be injected late in the compression stroke and hence fuel and air mixture would not get sufficient time for raising its pressures and temperatures to a high value and before overcoming its ignition delay, the expansion will begin. Thus the temperatures realized were low when compared to rated injection timing and at that temperature, dissociation reactions would not be that prominent to promote thermal prompt reactions for formation of NO_x emissions and hence low oxides of nitrogen were obtained. Where as in case of advanced injection timing , the fuel would be injected far ahead of the compression stroke giving much more conducive environment for mixing, releasing its energy and raising the in-cylinder temperature to very high levels and releasing higher NO_x emissions.

Conclusions: The following conclusions are drawn based on the experimental studies done on a CI with neat biodiesel obtained from jatropha curcas oil.

1. Better yield of methyl esters of jatropha oil is obtained with addition of higher amounts of ethanol.
2. Fuel injection pressure of 210 bar (against rated pressure of 190 bar) and 3-hole nozzle of each 0.28mm yielded lower BSFC values.
3. Retarded fuel injection timings are beneficial to reduce NOx emissions.

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