EXPERIMENTAL STUDY OF THE EFFECT OF FUEL INJECTION PRESSURE ON DIESEL ENGINE PERFORMANCE AND EMISSION

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ABSTRACT

Diesel engines are the primary source of power for the heavy duty vehicles. The advantages of diesel engines are high fuel efficiency, reliability and durability. The performance and emission characteristics of diesel engine depend on many parameters. One of the important factors which influence the performance and emission of diesel engine is fuel injection pressure. An experimental study was performed on a light duty direct injection diesel engine at 150 bar, 200 bar and 250 bar injection pressure to study its effect on performance and emission. The injection pressure was changed by adjusting the fuel injector spring tension. The performance and emission characteristics were presented graphically and concluded that they were found better at the fuel injection pressure 200 bar for the light duty engine.

Keywords: diesel engine, fuel injection pressure, BSFC, NOx emission.

1. INTRODUCTION

Diesel engines are the primary power plant of vehicles used in heavy duty applications. This includes buses, large trucks, and off-highway construction and mining equipments. Furthermore, diesel engines are winning an increasing share of the light duty applications worldwide. The popularity of the diesel engine revolves around its fuel efficiency, reliability, and durability. 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 [6]. 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 [1].

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 [2].

In this work the effects of fuel injection pressure are experimentally studied on performance and emission characteristics of single cylinder light duty direct injection diesel engine.

2. EXPERIMENTAL SETUP AND PROCEDURE

The experiments were conducted on a single cylinder Kirloskar make direct injection four stroke cycle diesel engine. The general specifications of the engine are given in Table-1. Water cooled eddy current dynamometer was used for the tests. The engine is equipped with crank angle sensor, piezo-type cylinder pressure sensor, thermocouples to measure the temperature of water, air and gas, Rotameter to measure the water flow rate and manometer to measure air flow and fuel flow.

Table-1. Engine specifications.

Item	Specification
Engine power	5.2 kW
Cylinder bore	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Engine speed	1500 rpm
Compression ratio	17.5
Swept volume	661 cc

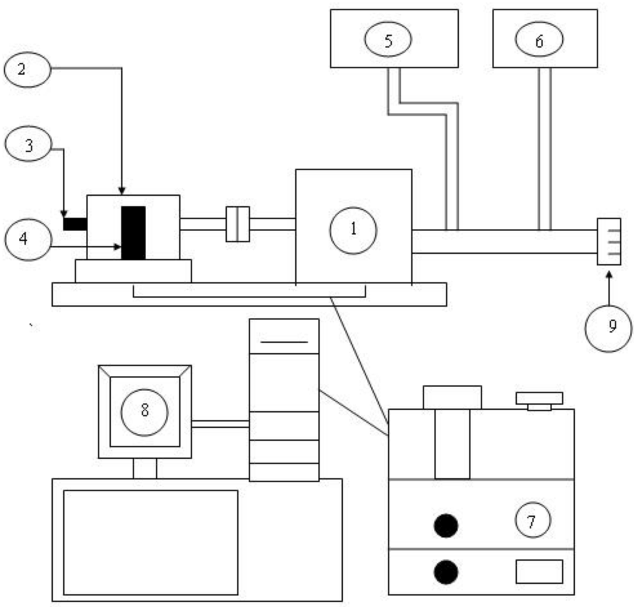
An exhaust gas analyzer Model QRO 402 is used to measure CO, HC, CO_2, O_2, and NOx. The measuring range and resolution are given in the Table-2.

A smoke meter, Model OPA-391/HD, is used to measure the smoke opacity in the range 0 to 0.99 m^{-1} and 0 to 99.9 %. The smoke meter works on the light absorption principle. When light in the visible range from a source is transmitted through a certain path length of the exhaust gas, smoke opacity is the fraction of light that is prevented from reaching the observer or the light detector of smoke meter.

Table-2. Exhaust gas analyzer specification.

Measuring item	Measuring method	Measuring range	Resolution
CO	NDIR	0 - 9.99 %	0.01%
HC	NDIR	0 - 5000 ppm	1 ppm
CO_2	NDIR	0 - 20 %	0.10%
O_2	Electro chemical	0 - 25 %	0.01%
NOx	Electro chemical	0 - 5000 ppm	1 ppm

The schematic diagram of the experimental setup is shown in Figure-1.



1. Engine; 2. Dynamometer; 3. Crank angle encoder; 4. Load cell; 5. Exhaust gas analyzer; 6. Smoke meter; 7. Control panel; 8. Computer; 9. Silencer.

Figure-1. Schematic diagram of experimental setup.

The experiments were performed at constant speed of 1500 rpm. The engine was loaded by eddy current dynamometer and the load was measured using a strain gauge. The fuel injection pressure was set to 150 bar, 200 bar and 250 bar. Injection pressure was changed by means of adjusting the injector spring tension. The air consumption was measured with an air manometer surge tank set which has orifice diameter of 20 mm.

3. RESULTS AND DISCUSSIONS

The engine cylinder pressure was measured by piezo-type transducer. The pressure during combustion did not vary much when the injection pressure was increased in the order 150-200-250 bar at different load conditions. The indicated power was found decreasing when the injection pressure was increased at all loads. The decrease in indicated power was 1.3% and 2.9% when the injection pressure was increased from 150 bar to 200 bar and 200 bar to 250 bar, respectively.

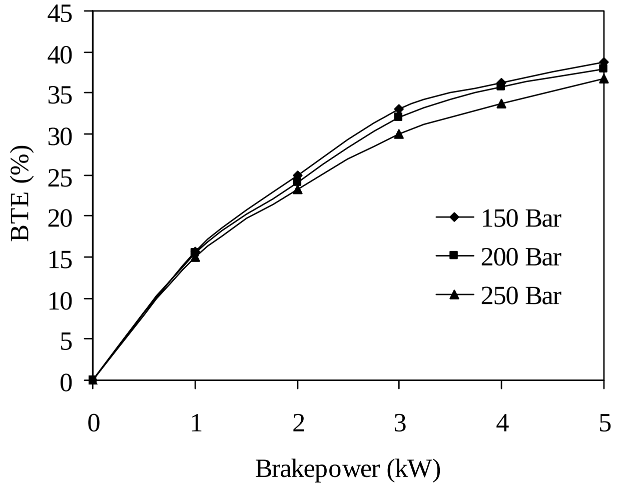


Figure-2. Effect on brake thermal efficiency.

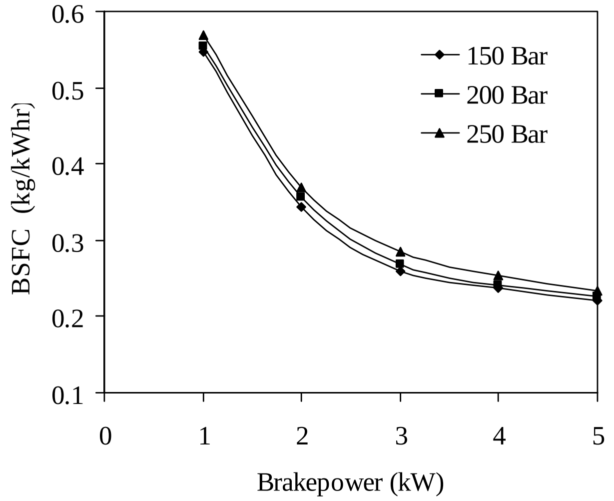


Figure-3. Effect on brake specific fuel consumption.

The highest brake thermal efficiency was found at 150 bar and it decreases for higher pressure at 5 kW load. The quantity of fuel injected increased due to the higher injection pressure and the brake thermal efficiency is decreasing. The variation of brake thermal efficiency at all loads at injection pressure 150, 200 and 250 bar are shown in Figure-2 The brake specific fuel consumption at different loads at injection pressure 150, 200, and 250 bar are shown in Figure-3. At the load 5 kW the brake specific fuel consumption was found increasing with injection pressure in the order 150-200-250 bar. The BSFC increases and BTE decreases when the fuel injection pressure is increased. Can Cinar *et al.*, [3] reported that the specific fuel consumption found deteriorating with increasing injection pressure for a heavy duty direct injection diesel engine. Rosli Abu Baker *et al.*, [4] also reported that the brake specific fuel consumption found increasing with injection pressure both in fixed load-

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variable engine speed and fixed engine speed-variable load tests.

At the fuel injection pressure 250 bar, the percentage of CO_2 in the exhaust gas was found to be the lowest as shown in Figure-4 at all loads. The decrease in the percentage of CO_2 is in the order of 200-150-250 bar fuel injection pressure.

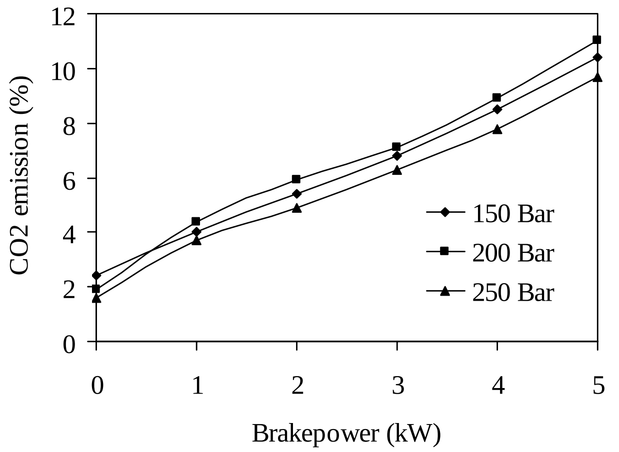

Figure-4. Effect on CO_2 emissions.

For a heavy duty indirect injection diesel engine, Ismet Celikten [2] reported that the NOx emission is descending in the order 250-200-100-150 bar at 50% throttle, 250-150-200-100 bar at 75% throttle and maximum value at 250 bar and minimum value at 100 bar at 100% throttle condition. But, in the present study for a light duty direct injection diesel engine the NOx emission was found lowest at 250 bar injection pressure at all loads and found decreasing in the order 200-150-250 bar injection pressure as shown in Figure-5.

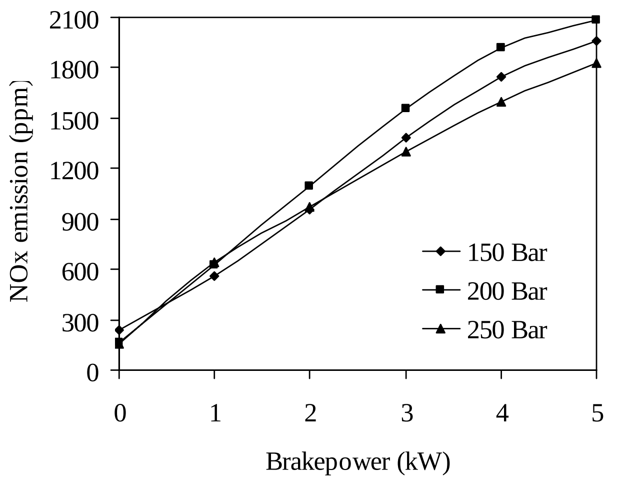

Figure-5. Effect on NOx emissions.

The variation of HC in the exhaust gases at all loads at injection pressure 150,200 and 250 bar are shown in Figure-6. The HC emission found increasing in the order 200-150-250 bar injection pressure.

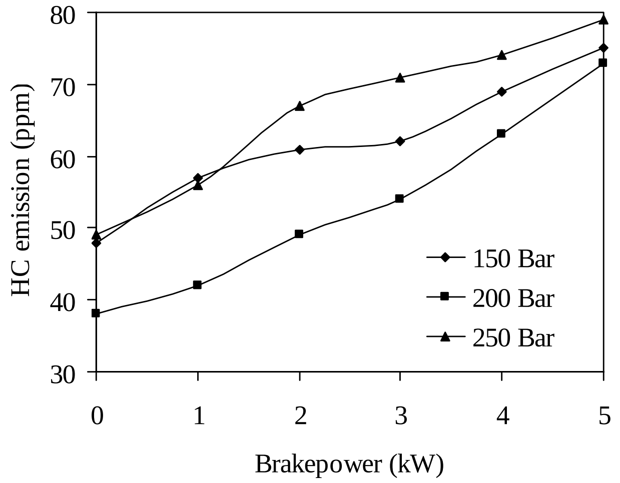

Figure-6. Effect on HC emissions.

For the light duty direct injection diesel engine the smoke level found to be higher at 200 bar injection pressure at all loads as shown in Figure-7 and order of increase of smoke level is 150-250-200 bar.

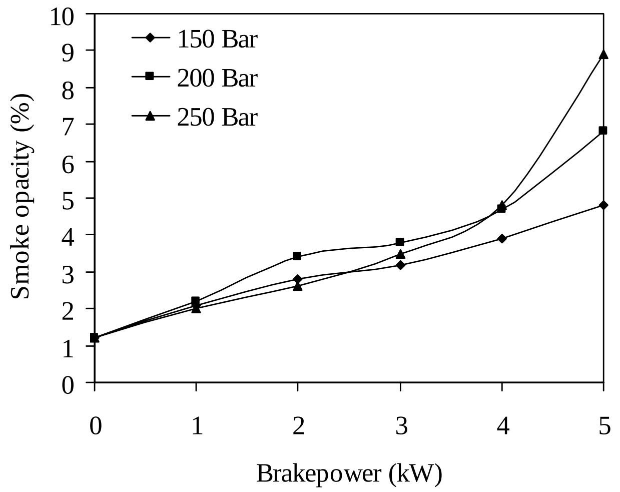

Figure-7. Variation of smoke level.

4. CONCLUSIONS

The light duty diesel engine is normally employed for agricultural water pumping, electrical power generation etc. where the engine mostly operated above 75% load. At 5 kW load, the engine performance parameter brake thermal efficiency found increasing in the order 250-200-150 bar injection pressure and brake specific fuel consumption found decreasing in the order of 250-200-150 bar injection pressure. Though at 150 bar higher brake thermal efficiency and lower brake specific fuel consumption were obtained the percentage of improvement was at the maximum of 1%. So, increasing injection pressure gave insignificant effect on engine performance.

At 5 kW load, CO_2 and NOx emissions were found the lowest at 200 bar and HC emission and smoke level were found lowest at 150 bar. CO_2 is 15% and 24% and NOx is 12% and 20% lower compared with 150 bar and 250 bar respectively. HC emission is 30% and 34% lower and smoke level is 7% and 1% lower compared with 200 bar and 250 bar, respectively.

Fuel economy is important for engine. But environmental protection is more important than fuel economy. So, decreasing emission is the primary concern which demands moderate injection pressure for a light duty diesel engine.

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