AN EXPERIMENTAL INVESTIGATION OF DIESEL ENGINES FUEL INJECTION PRESSURE EFFECT ON POWER PERFORMANCE AND FUEL CONSUMPTION

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(Received: February 29, 2008 – Accepted in Revised Form: September 25, 2008)

Abstract The objective of this paper is to investigate the effect of fuel injection pressure on power performance and fuel consumption of diesel engine. In a diesel engine, fuel injection pressure is an important aspect of the engines' power performance in order to obtain combustion treatment. The experiments in this paper are performed on a four-cylinder two-stroke direct injection diesel engine. The diesel engine power performance and fuel consumption values are investigated based on load variation, engine speed and fuel injection pressure. The power performance values such as; indicated pressure, indicated horse power, shaft horse power, brake horse power and break mean effective pressure, is investigated both for various engine speed-fixed load and fixed engine speed-various loads. The fuel injection pressure changed from 180 to 220 bar. According to the experiment results, the best pressure injection performance has been obtained at 220 bar, specific fuel consumption has been obtained at 200 bar for fixed load-various speed and at 180 bar for various loads-fixed speed. The results of the experiment are shown as graphs in this paper. The experiment results show, that the increasing injection pressures increases the engine power and fuel consumption.

Keywords Diesel Engines, Specific Fuel Consumption, Fuel Injection Pressure, Power Performance

چکیده هدف این مقاله بررسی فشار سوخت تزریقی بر عملکرد و میزان مصرف سوخت در موتورهای دیزلی است. فشار سوخت تزریقی جنبهٔ مهمی در مطالعات مربوط به عملکرد موتورهای دیزلی است. در این مطالعه تجربی، یک موتور چهار سیلندر دو زمانه با تزریق مستقیم بررسی شده است. عملکرد و مصرف سوخت بر اساس تغییرات بار، سرعت و فشار سوخت مورد مطالعه قرار گرفت. برای دو حالت موتور با سرعت متغیر و ثابت، عملکرد موتور، توان موتور، توان محور و حداکثر توان مقایسه شده‌اند. فشار سوخت تزریقی از ۱۸۰ تا ۲۲۰ بار تغییر داده شده است. نتایج نشان داده‌اند که بهترین عملکرد موتور در فشار تزریقی ۲۲۰ بار، بهترین مصرف سوخت ویژه در ۲۰۰ بار برای دور موتور متغیر و ۱۸۰ بار برای دور موتور ثابت بدست آمده است. نتایج به صورت نمودار داده شده و معلوم شده است که با افزایش فشار سوخت تزریقی توان موتور و مصرف سوخت افزایش می‌یابد.

1. INTRODUCTION

The diesel engine is a type of internal combustion engine; more specifically, it is a compression ignition engine, in which the fuel is ignited solely by high temperature created by the mixture of air-fuel compression [1]. The engine operates using the diesel cycle. According to Kowalewicz [1] diesel engine is more efficient than petrol engine, since the spark-ignition engine consumes more fuel than compression-ignition engine. The use of diesel engines has become more popular in the last few years, due to their high efficiency and also economic motivations (fuel cost) [3].

In diesel engine the caloric energy from diesel fuel combustion were used to produce 50 % of the power and the rest are lost due to energy loss or heat release [13,14]. Diesel engine heat release definition as shown in Figure 1.

Due to its high efficiency, diesel engine has

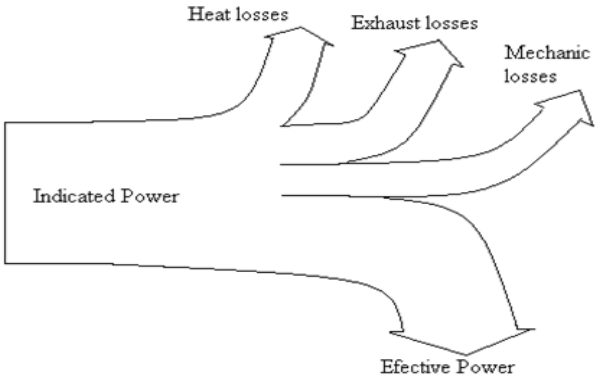

Figure 1. Heat release of diesel engine.

always been the favorite power train for heavy-duty applications, especially in trucks and all non-road applications [15]. Regarding passenger car applications, diesel engine suffered some disadvantages in noise, transient behavior (small low-end torque), and weight, for a long time. During the last decade, the realization of high-pressure direct injection combined with modern turbo-charging techniques has completely revolutionized the diesel engine technology. High power output and high low-end torque combined with excellent fuel economy and a significant reduction of noise are the main reasons for the enormous rise in popularity of the diesel engine passenger car [12].

There are several factors that engine designer vary in order to provide high performance and fuel efficiency. Some of the researched factors were; the shape of the combustion chamber, the location and angle of the fuel nozzle, the injection rate and nozzle spray pattern, injection timing, and camshaft timing [15]. This also had a positive effect on economy and performance. In present diesel engines, fuel injection systems are designed to obtain lower and higher injection pressure than current used. So it is aimed to increase the performance by increasing diesel engines efficiency.

Direct injection diesel engine is a fuel injection system to achieve a high degree of atomization, in order to enable sufficient evaporation in a very short time, and to achieve sufficient spray penetration in order to utilize the full air charge. The fuel injection system must be able to measure the desired amount of fuel, depending on engine speed and load, and to inject that fuel at the correct time and with the desired rate. Further more, depending on a particular combustion chamber, the appropriate spray shape and structure must be produced. Usually a supply pump draws the fuel from the fuel tank and carries it through a filter to a high-pressure injection pump.

Dependent on the area of application and engine size, pressure between 100 and 200 MPa is generated. The high pressure injection pump carries the fuel through high-pressure pipes to the injection nozzles in the cylinder head [12]. Excess fuel is transported back into the fuel tank. The functionality of the so-called unit pump system is practically identical to that of unit injector system, and offers the same advantages and disadvantages. However, the pump and nozzle are not combined into one unit. The high-pressure pump is again driven by a camshaft and thus directly coupled with the engine speed. The injection nozzle is located inside a so-called nozzle holder in the cylinder head and connected via a high-pressure pipe with a pump. An advantage of this system is that, the pump and the nozzle does not have to be installed in the same place. This reduces the size of the components that have to be integrated into the cylinder head and also simplifies the assembly of the injection system.

Injection characteristics of direct injection diesel engines are investigated by many researchers [2-13]. In this study, the parameters concerned with proportion of injection pressures have been calculated. It has been determined that theoretical calculations in the model are similar to engine conditions [2]. In addition, abnormal injection characteristics and appropriate flow analysis have also been performed [3]. The performance of direct injection diesel engine and combustion characteristics has been investigated by high speed photography [4]. In a single-cylinder DI diesel engine, the effect of pilot injection on emissions was investigated. In high pressure common rail diesel injection, diesel spray structure was studied using optical diagnostics. An increase of injection pressure is found to enhance the atomization at the nozzle outlet. This results in a more distributed vapor phase and hence results in a better mixture [7]. In the future, various technologies will be used for diesel emission, including a combination of

systems such as high-pressure injection, injection rate control, cooled EGR and etc. [8]. The effect of different cetane numbers on the engine performance and emissions have been investigated for different injection pressure and throttle position. It is shown that for higher cetane number, the engine performance, NOx emission and other emissions are increased [2]. In a lower compression ratio (LHR) diesel engine, engine performance and emissions have been compared with standard diesel engine (SDE) which has fixed compression ratio. In comparison with SDE, the specific fuel consumption and NOx emissions are, respectively, decreased about 2.9 % and 15 % [11].

In this research, the effects of injection pressure on engine performance and fuel consumption have been investigated, on a unit pump system direct injection diesel engine. Diesel engine performance values have been measured both for various engine speed-fixed load and fixed engine speed-various loads by changing the fuel injection pressure. In the engine performance investigation, there are two steps experiments. In the first experiment the diesel engine load is fixed at 80 % or 67 kW from maximum load of 83, 42 kW. The engine speed is set at 600 rpm rising to 1600 rpm to the maximum speed of 1800 rpm and the fuel injection pressures are set at 180 to 220 bar.

2. RESEARCH METHODOLOGY

This research of fuel injection pressure effect on the performance of direct injection diesel engine is based on experimental values. The four-cylinder two-stroke, direct-injection, and diesel engine were selected. The specification of the selected diesel engine model is shown in Table 1.

In this experiment an eddy current electrical dynamometer was used to investigate the engine power performance. The diesel engine is coupled with dynamometer using an adaptor and engine test rig stand. The dynamometer measures the outputs such as; engine speed, torque, and throttle position. The sensors for fuel consumption, intake temperature, intake pressure, in-cylinder pressure and temperatures are connected to a computer control system. Schematic of engine experimental set-up is shown in Figure 2.

TABLE 1. Specification of the Diesel Engine.

Engine Parameters	Value
Bore (mm)	108.0
Stroke (mm)	127.0
Number of Cylinder	4
Max. Cont. Net Power (HP)	112
Fuel Nozzle Injection Pressure (bar)	200
Max. Engine Speed (rpm)	1800

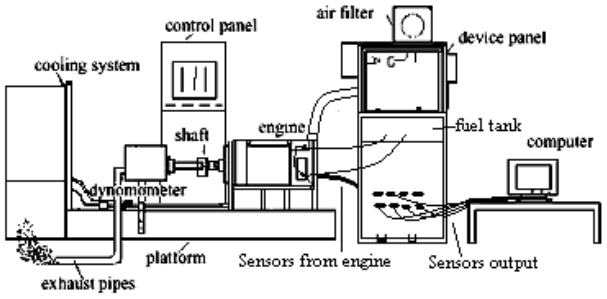

Figure 2. Schematic of engine experimental set-up.

The fuel injector pressure is changed manually by using washer and testing the pressure one bar at a time from 180-220 bar. The experiment started from 200 bar, which is the baseline pressure. For the adjustment, washer(s) were used to change the nozzles pressures. After that, the adjusted nozzles were fitted on the engine. Than, the air in the nozzles were transferred to the atmosphere and the engine ran. In the first experiment the computer controlled diesel engine which was connected to the electrical dynamometer was at 80 % or 67kW load position.

Engine is tested in ranges of 600 - 1600 rpm with 200 rpm intervals and the fuel injection pressure setting were from 180-220 bar with the interval of 10 bars. In the second experiment the diesel engine were tested at 55 %-80 % loads with 5 % intervals, engine speed is fixed at 1600 rpm and the fuel injection pressure setting from 180-220 bar with the interval of 10 bars. In this experiment maximum speed and maximum load

were not investigated. In the experiments, shaft horse power, brake horse power, indicated pressure and fuel consumption were recorded by computer. In addition, indicated horse power, break mean effective pressure and specific fuel consumption calculated from the experiments' data.

3. RESULT AND DISCUSSION

3.1. Experiment on Fixed Load of 67 kW and Variations in Engine Speeds The experimental investigation of 67 kW of fixed load, engine speeds 600-1600 rpm and the fuel injection pressure setting from 180-220 bar, the engine performance and specific fuel consumption results are shown in Figure 3-8.

3.2. Experiment on Fixed Speed of 1600 rpm and Variations in Engine Loads The experimental investigation of fixed engine speed at 1600 rpm, with interval engine loads were tested (55 %-80 % with interval of 5 %, such as; 46 kW, 50 kW, 54 kW, 58 kW, 63 kW, and 67 kW) and the fuel injection pressure setting was at 180-220 bar, the engine performance and specific fuel consumption results are shown in Figure 9-14.

3.3. Discussion In the first experiment on fixed engine load and various engine speeds, the result showed that, on average, the best engine performance for indicated pressure (IP), indicated horse power (IHP), shaft horse power (SHP), break horse power (BHP) and break mean effective pressure (BMEP) were obtained at 220 bar and the best engine SFC was obtained at 200 bar or current fuel injection pressure. The experiment result showed that, increasing the fuel injection pressure will increase engine performance in IP, IHP, SHP, BHP and BMEP, also the higher the injection pressure the more power in engine performance. By increasing injection pressure the quality of fuel-air mixture in the combustion chamber reached its peak, so the un-burnt fuel was less than the lower injection pressure. Increasing the injection pressure offers the possibility of better and more complete air charge in the mixture formation and combustion process.

In the second experiment on fixed engine speed

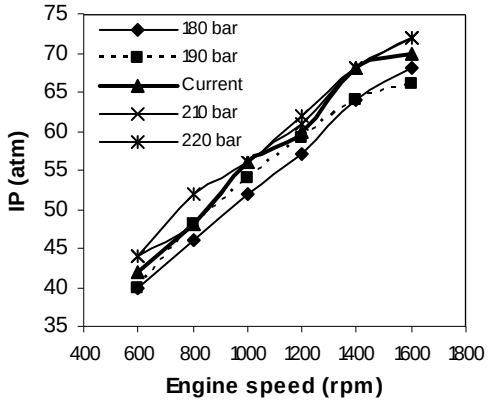

Figure 3. Fuel injection pressures effect for IP engine on fixed load.

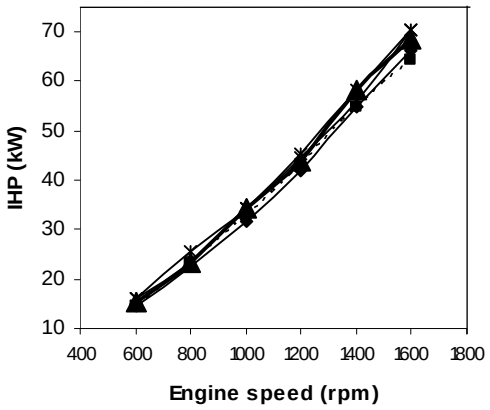

Figure 4. Fuel injection pressures effect for IHP engine on fixed load.

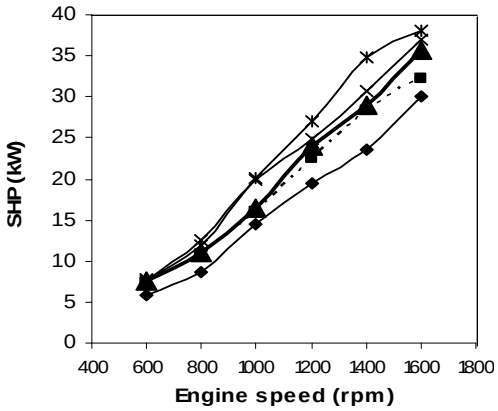

Figure 5. Fuel injection pressures effect for SHP engine on fixed load.

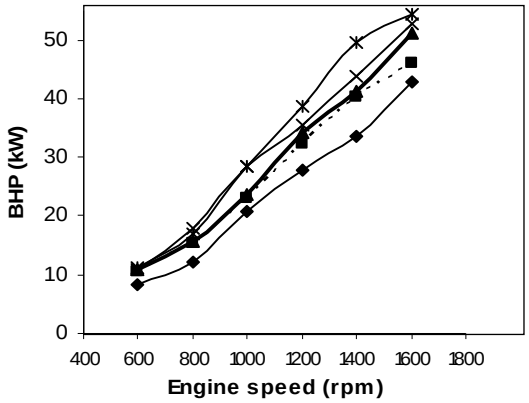

Figure 6. Fuel injection pressures effect for BHP engine on fixed load.

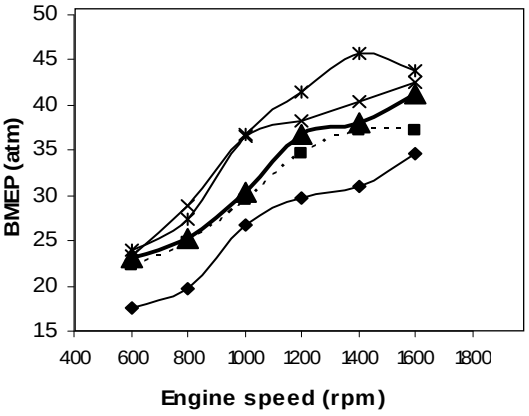

Figure 7. Fuel injection pressures effect for BMEP engine on fixed load.

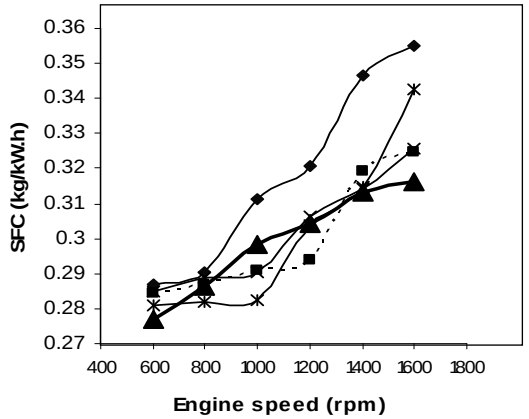

Figure 8. Fuel injection pressures effect for SFC engine on fixed load.

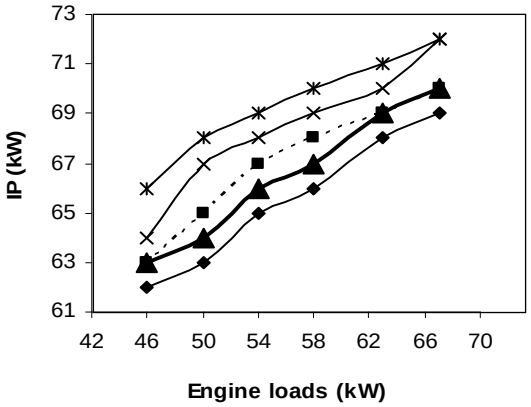

Figure 9. Fuel injection pressures effect for IP engine on fixed speed.

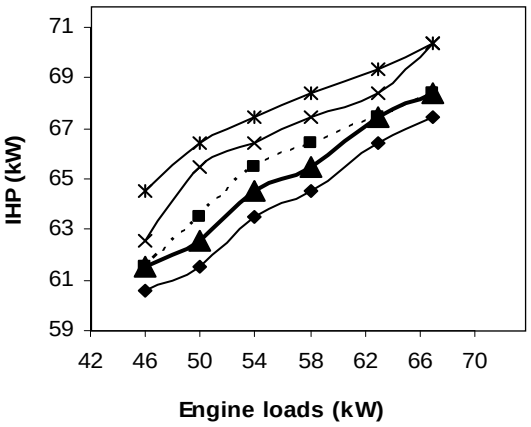

Figure 10. Fuel injection pressures effect for IHP engine on fixed speed.

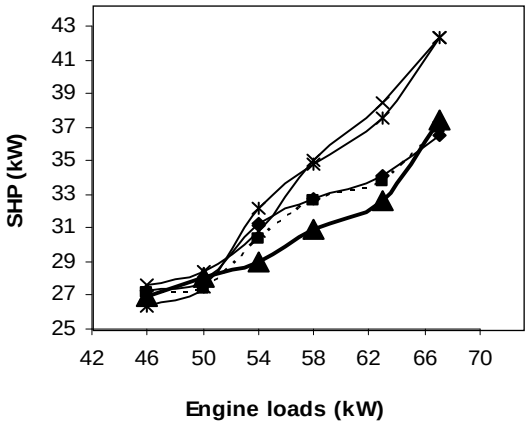

Figure 11. Fuel injection pressures effect for SHP engine on fixed speed.

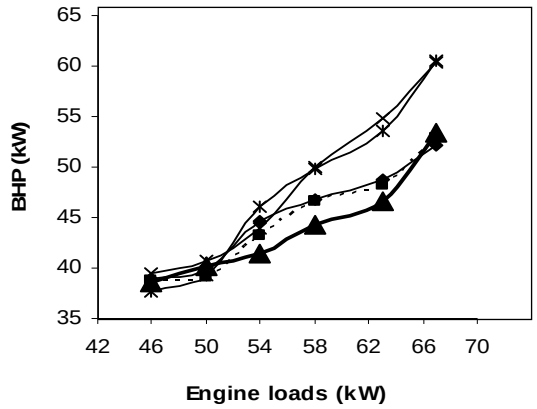

Figure 12. Fuel injection pressures effect for BHP engine on fixed speed.

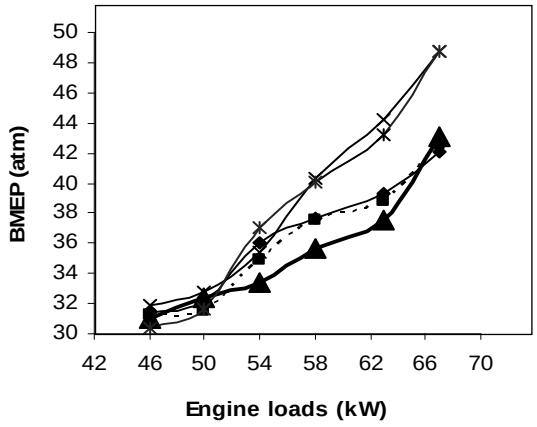

Figure 13. Fuel injection pressures effect for BMEP engine on fixed speed.

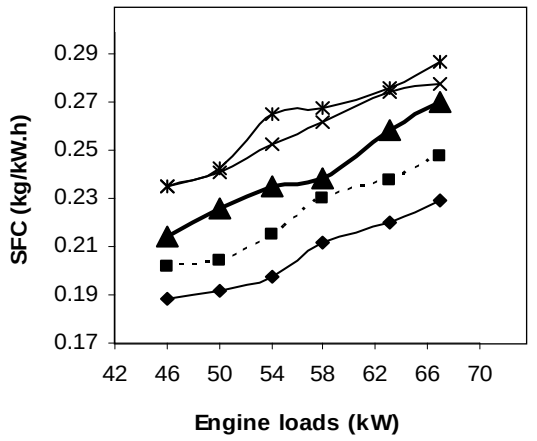

Figure 14. Fuel injection pressures effect for SFC engine on fixed speed.

and various engine loads, the result showed that, increasing injection pressure caused engine performance to increase for indicated pressure(IP), indicated horse power (IHP), shaft horse power (SHP), break horse power (BHP) and break mean effective pressure (BMEP). Higher injection pressure increased engine performance and the highest of which was obtained at the injection pressure of 220 bar.

The fuel injection pressure effects, for specific fuel consumption for the first experiment have been given in Figure 8. The result showed that the effect of increasing engine speed can increase the specific fuel consumption for the engine. The highest specific fuel consumption of 180 bar pressure and the economic specific fuel consumption at 200 bar of injection pressure was used. The fuel injection pressure at 200 bar were used for the engine that was more stabile in specific fuel consumption for different engine speed, but with the engine speed of 800 rpm, the specific fuel consumption was higher than the injection pressure at 220 bar, with engine speed of 1000 rpm the specific fuel consumption was higher than the injection pressure at 190 bar, 210 bar, 220 bar and with engine speed of 1200 rpm the specific fuel consumption was higher than the injection pressure at 190 bar. Based on the engine speeds, the results of the experiments shows a trend of the specific fuel consumption at injection pressure of 200 bar is more economical than other injection pressure.

The results of injection pressure for fuel consumption in the second experiment; have shown increasing injection pressure, increased the engine performance and specific fuel consumption. The best engine SFC was obtained at injection pressure of 180 bar. Figure 14 shows that the current fuel injection pressure at 200 bar is not as economic as 180 and 190 bar. The more load on the engine the more engine power was needed, and the more engine power the more specific fuel consumption was needed to produce the power to take the given load. So, the fixed engine speed and various engine loads showed that; increasing injection pressure increases engine performance.

When fuel injection pressure is low, fuel particle diameters will enlarge, and ignition delay period during the combustion will increase. This condition will increase the pressure. Engine

performance will decrease, since combustion process will not be in good condition. When injection pressure increases, fuel particle diameter will become smaller and since the formation of air-fuel mixture improves during ignition period, engine performance will increase. But, if injection pressure is too high, ignition delay period becomes shorter. So, possibilities of homogeneous mixing decrease and combustion efficiency will drop.

Hence, the more injection pressure is increased, the more energy is needed to drive the injection system by reducing the leak flow and by dynamically adjusting the maximum pressure to the actual needs of the engine, depending on the operating point. So, the effect of increasing injection pressure, increases fuel consumption both in fixed load-variations engine speeds and fixed engine speed-variation engine loads.

4. CONCLUSIONS

The experiment of the fixed load-various speed and fixed speed-various loads has shown that; higher engine speed (rpm) and higher fuel injection pressure gives higher engine power. The increasing injection pressure is inline with increasing power. The result of the fuel consumption experiment for fixed load-various speed and fixed speed-various loads also showed increasing injection pressure which will increase fuel consumption for the diesel engine.

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