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Effect of compression ratio and injection pressure on ignition lag

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Abstract

The compression ratio and injection pressure both are influenced the ignition lag of an IC engine. The ignition lag is defined as the time interval between the start of injection and the start of combustion. This delay period consists of (a) physical delay, wherein atomization, vaporization and mixing of air fuel occur and (b) of chemical delay attributed to pre-combustion reactions. Diesel engine is a compression ignition (CI) engine and the typical compression ratios are in the range of 14:1 to 22:1. In order to achieve spontaneous ignition, the compression stroke must raise the air to a much higher temperature than that in the SI engine, and this requires a high compression ratio. The combustion characteristic ignition delay at varying compression ratio (9.20:1, 11.65:1 and 13.99:1) and fuel injection pressure (150, 250 and 350 bar) based on diesel and gasoline. The tests have been performed in a constant combustion chamber with single-hole pintle nozzle which the conditions were similar to real DI engine conditions. The results showed that with increase in compression ratio from 9.20:1 to 13.99:1 the ignition delay decrease for diesel as well as gasoline. If we talk about the injection pressure it is found that the minimum value of ignition delay was found at maximum pressure for both fuel.

Keywords: Fuel injection pressure, ignition delay, compression ratio and direct injection (DI) diesel engine

1. Introduction

The percentage of NO_X emission in engines directly depends upon the inside temperature of the cylinder. The inside temperature of the cylinder directly coupled with compression ratio and injection pressure. For controlling the temperature the DI engines are used. Also the IDI engine is less efficient than the DI engine. This is because the high velocity air motion in the combustion chamber causes high heat transfer rates resulting in greater loss of fuel energy. The lower efficiency of the IDI engine has resulted in it being out-of-favour and although there are a large number of these engines currently being produced, virtually all new engine designs use direct injection technology [1].

The 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, ambient air temperature, compression ratio, cylinder air pressure are directly affects the engine performance and emissions rate also. 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 1700atm depending on the engine size and type of combustion system employed [2]. In this work our aim is to investigate the effect of compression ratio and fuel injection pressure on ignition Lag of DI diesel. The experiments performed at different fuel injection pressures (150, 250 and 350 bar) and compression ratio (9.20:1, 11.65:1 and 13.99:1) fuelled with diesel and gasoline.

Some experimental studies have proved the effect of fuel injection pressure on performance, emission and combustion characteristics for the format of DI diesel engine [3]. In those study it was found that high injection pressures decreases the injection duration thus maximizing the time available for fuel/air mixing prior to ignition. It is also noticed that the injection pressure affects the mixture formation, ignition delay, flame pattern, turbulence. Low ignition delay and combustion duration were observed at high fuel injection pressure. In a research [4], the effects of mixture formation on ignition and combustion of a multi-hole diesel spray were investigated. The results of testing showed that increasing injection pressures makes spray tip penetration longer and promotes a greater amount of fuel-air mixing occurs during ignition delay as compared at lowest injection pressure (P_{inj}=100 MPa). In another work [5], the combustion duration was decreases by 2-3^0 with increase in

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compression ratio due to less ignition delay and maximum amount of charge was burnt in the first 20^0 of crank angle rotation during combustion stage. In addition the few studies have been investigated the effect of cylinder compression ratio and injection pressure on performance of the engine [6-7].

2. Experimental Set-Up

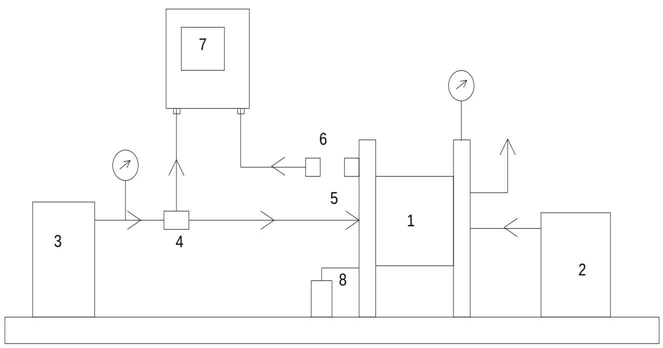

Figure 1: Block Diagram of Present Experimental Set-Up

1. Constant Volume Combustion Chamber
2. Centrifugal Air compressor
3. Fuel injection pump
4. Piezoelectric sensor
5. Fuel Injector with Single-hole Pintle Nozzle
6. Photo sensor
7. Scope Meter
8. Temperature Indicator

Fig. 1 shows the block diagram of present experimental set-up. It consists of a constant combustion chamber of size 30 mm length, 95 mm diameter and 7.5 mm thickness. For increasing the temperature of air with maximum temperature of 1400°C a heating coil was used. The compressed air supplied to combustion chamber through an inlet valve fitted in the combustion chamber. And one exhaust valve is fitted for releasing of exhaust gas. For injecting the fuel into the combustion chamber an injector with single-hole nozzle is used. The ignition delay is measured with a digital storage two channel Scope Meter.

2.1 Methodology of Experiment

- A heating coil is used to increase the temperature of the combustion chamber and compressed air entered to the combustion chamber by means of air compressor.
- Fuel spray into the combustion chamber through injector with a single-hole pintle nozzle.
- The fuel pump is had operated and injection timing is varied and controlled by handle of fuel injection pump. The digital Scope Meter record all the event.
- A piezoelectric sensor fitted on the line of injection system records the injection timing and photo sensor which is placed in front of optical window is used to record the combustion phase.
- Ignition delay is measured in ms by noting the difference between event of injection and that of combustion.
- The ignition characteristics can be observed in the Scope Meter screen by noting the two pulses of photo and piezoelectric sensors.

3. Results and Discussions

Ignition delay is very important parameter in combustion phenomenon [7]. The delay period in the compression ignition engine exerts a very great influence on both engine design and performance. It is of extreme importance because of its effect on both combustion rate and knocking and also its influence on engine starting ability and the presence of smoke in the exhaust. The fuel does not ignite immediately upon injection into the combustion chamber. There is a definite period of inactivity between the time when the first droplet of fuel hits the hot air in the combustion chamber and the time it starts through the actual burning phase. This period is known as the ignition delay period [8]. In the present study this period is counted from the start of injection to the start of combustion in ms.

Fig. 2 and 3 show the ignition delay with compression ratio for gasoline and diesel respectively. The pressures are taken in gauge pressure. It is clearly seen from Figs. 2 and 3 that with increase in compression ratio the ignition delay decreases. Because when the air pressure inside the combustion chamber increases the mixing of fuel and air improves due to increase in turbulence and oxygen concentration. Due to increase in cylinder pressure the inside temperature of cylinder also increases (increasing the kinetic energy or air impingement of air molecules). The self-ignition temperature has a vital effect on delay period. If any fuel have low self-ignition temperature then it have low delay period [8].

The self-ignition temperature reduces with the increase in cylinder air pressure. This is due to the increased density of the compressed air, resulting in closer contact of the molecules which thereby reduces the time of reaction when the fuel is injected.

As shown in Figs. 2 and 3, the delay period for both fuels is decreases with increasing the compression ratio as well as injection pressure. As the result shows that when the compression ratio is taken 14:1 and injection pressure 350 bar the delay period for gasoline is 6ms and for diesel it is 3.4ms. The ignition delay of gasoline is longer than diesel because as the self-ignition temperature of gasoline is more than diesel [9].

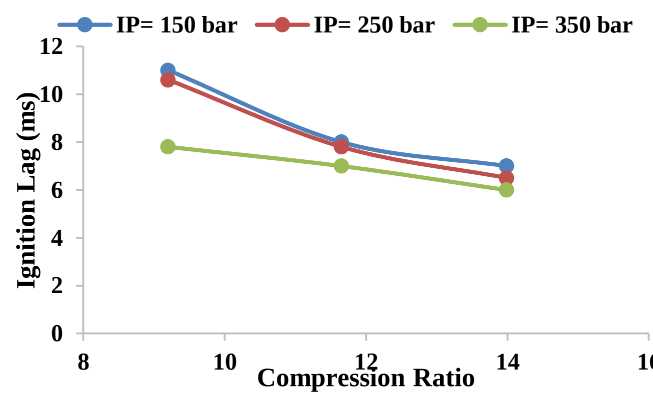

Figure 2: Variation of Ignition Delay with Compression Ratio at Different Injection Pressure for Gasoline

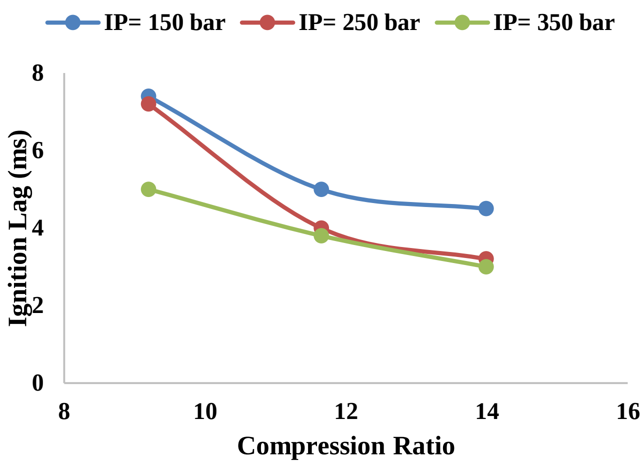

Figure 3: Variation of Ignition Delay with Compression Ratio at Different Injection Pressure for Diesel

Also the duration of injection and the intake air temperature improves the vaporization of the fuel [10]. In the present study, the influence of different fuel injection pressure is also investigated. The fuel injection pressure was changed by adjusting the fuel injector spring tension. From the data as shown in Fig. 2 and Fig.3, it can be seen that with increasing fuel injection pressure from 150 bar to 350 bar, the ignition delay decreases for diesel. The reason of reduction of ignition delay is the reduction in the physical delay. The physical delay is the time between the beginning of injection and the attainment of chemical reactions. During this period, the fuel is atomized, vaporized, mixed with air and raised to its self-ignition temperature. This physical delay depends on the type of fuel, i.e., for light fuel the physical delay is small while for heavy viscous fuels the physical delay is high. The physical delay is greatly reduced by using high injection pressures, higher combustion chamber temperatures and high turbulence to facilitate breakup of the jet and improving evaporation [8].

The droplet diameter is reduced by increasing the injection pressure. These small diameter droplet longer penetrate the air envelope inside the cylinder and helpful to proper mixing of the fuel which reduces the physical delay. It can be seen from Figs. 2 and 3 that the minimum values of ignition delay approximately observed at the fuel injection pressure of 350 bar for both fuel at varying cylinder air pressure in the present experimental work.

4. Conclusion

The purpose of this experimental work is the effect of compression ratio and fuel injection pressure on ignition lag. The range of injection pressure was from 150 to 350 bar and compression ratio 9 to 14:1 (appr). The experimental set-up fabricated for this study was a constant combustion chamber a small sample of DI diesel engine. The results lead to the following conclusions:

- With increase in compression ratio the ignition delay decreases due to the reduction in the physical delay for both diesel and gasoline.
- Ignition delay and fuel injection duration of gasoline are longer than diesel.
- Combustion duration decreases as the cylinder air pressure increases. This is because of the increase in the end-of-compression temperature and pressure and decrease in the fraction residual gases.
- With increasing fuel injection pressure from 150 bar to 350 bar, the ignition delay decreases for gasoline and diesel both.

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