Effect of Varying Hot Surface Temperature on Ignition Delay Characteristics for Different Fuel Sprays

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Abstract: An experimental work is performed in a constant volume combustion chamber to study the effect of varying hot surface temperature on ignition delay characteristics for different fuel sprays (Hollow cone spray and Solid cone spray). For ejecting the sprays pintle and single hole nozzles were used. In this experimental work hot surface temperature (HST) varied from 350°C to 550°C, air pressure inside the cylinder varied from 10 to 25 bar while fuel injection pressures varied from 10 to 20 MPa. Optical method is used for detecting the flame appearance while a digital Oscilloscope is used to measure ID of sprays by recording the gap between injection event and the event of appearance of flame. During the work it is found that ID is strong function of HST rather than other operating parameters. It is also found that on increasing HST, for both sprays ignition delay is decreasing at every injection pressures.

Keywords: Spray, Pintle nozzle, Single hole nozzle, Cetane number, ID, HST.

1. INTRODUCTION

Primary source of power for the heavy duty vehicles like large trucks, buses and mining equipments are diesel engines [1]. So they are commonly used in transportation. Along with environment pollution increasing diesel price is also another problem [2]. The popularity of diesel engines is mainly due to low fuel consumption. However, the major air pollutants are also emitted from the Diesel engines. To achieve all these standards and norms, the engineer has to develop new processes and techniques used for diesel engines combustion. Diesel engines combustion nature is mainly determined by the quality of fuel spray its mixing and distribution inside the combustion chamber. In-cylinder conditions like nozzle design and geometry, air motion, temperature, density and injection pressure mainly governed the breakup and distribution of the spray [3].

In the today’s world, Different countries adopted different emissions norms to check the air pollution. Presently Bharat Stage IV norms are adopted in India. Soon India will adopt Bharat Stage VI norms (in year 2020) by taking euro norms VII as its reference. Researchers are trying to find ways to reduce pollutants emitted from engines by studying diesel combustion processes, various alternative fuels and different geometry of nozzle. Less emissions, fuel efficiency and cost effectiveness can be optimized by getting proper combustion inside the engine. This led to advancement of new combustion systems. In this study, fabrication and experiment is carried out to investigate the effect of different geometry of fuel spray (Pintle nozzle and Single hole nozzle) on diesel combustion characteristic.

A. Diesel engine combustion: The combustion process, emission characteristics and spray pattern inside the diesel engine (CI Engine) can be understood by the following diagrams:

Figure 1: ROHR Curve for Diesel Engine [4]

The four stages of the entire combustion process in CI engine are categorizes as Ignition delay (ab), Premixed combustion phase (bc), Mixing controlled combustion phase (cd), Late combustion phase (de). The combustion steps, taking place in DI-Diesel engines are briefly given in Fig 2.
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B. Ignition Delay

In diesel engines, ignition delay of the fuel is the time lag between beginnings of fuel injection to the initiation of combustion [4].

It is subdivided into two parts:

- Physical delay
- Chemical delay

Physical delay involves atomization, vaporization and mixing of fuel with air while chemical delay involves pre-flame reactions until ignition occurs [5].

C. Spray pattern

The two types of basic spray cone patterns (Hollow cone and solid cone) were used in this work. Each has certain advantages depending on its use. Pintle nozzle is used for getting hollow cone spray while Single hole nozzle is used for getting solid cone spray in this work. Hollow cone spray is a spray with very little or no fuel in the center of the spray while more concentration is at the outer periphery of spray and in the solid cone spray uniform distribution of fuel droplets is present everywhere in spray.

By reducing ignition delay, NOx emissions can be reduced as larger ignition delay generate higher peak of ROHR [6].

II. EXPERIMENTAL SETUP AND ITS COMPONENTS

Many experiments have been done to know the spray behavior and emissions liberated during combustion. Some of them are as follows:

Ignition delay decreased due to the better mixing at higher injection pressures [7]. Effect of nozzle size was very important factor to affect the spray characteristics [8]. To reduce the emissions very high injection pressure and smaller diameter nozzles can be used [9]. Spray-guided combustion is very nice strategy to reduce fuel consumption and CO2 emissions in S.I. engines [10]. Between diesel and biodiesels, to know the difference of spray flame characteristics combination of non evaporating spray and spray combustion measurements can be used [11]. At higher injection pressure, although emissions of CO and UHC are reduced but emissions of NOx and CO2 are increased [12]. Split injection reduces soot rapidly instead of single injection [13]. By improving airflow inside the engine intake, efficiency of engine can be increased. [14]. Ignition delay is a decreasing function of low and moderate injection pressure [15]. Controlling the fuel injection timing, soot formation can be reduced [16]. For diesel and gasoline blended diesel, ignition delay is a strong function of hot surface temperature [17]. Higher fuel injection rate and wider fuel spray distribution can be used to reduced fuel consumption and PM emissions [18].

Figure 2: Combustion steps in DI diesel engine [4]

Figure 3: hollow cone spray and solid spray

Figure 4: Block Diagram for the Experimental Setup

Various Components of Experimental Set Up

1. Bosch Fuel Injection Pump
2. Pump Plate:
3. Striking Pin
4. Rocker and Lever Arm
5. Fuel Metering
6. Piezo-electric Sensor
7. Photo Sensor
8. Injection Nozzle
9. Combustion chamber
10. Digital Oscilloscope
11. Temperature Controller
12. Air Compressor
13. Temperature Indicator
III. RESULT AND DISCUSSION

From the above figure it is clear that for all air pressures, value of ignition delay is always more for solid cone spray than hollow cone spray at 350°C while the pattern is reversed at 450°C. At 550°C there is not so much variation in the value of ignition delay. It means at 350°C hollow cone spray gives better result while at 450°C solid cone spray gives better results and at 550°C both sprays are showing same performance.
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At 550°C there is not so much variation in the value of ignition delay for both types of sprays. It means that at 350°C hollow cone spray gives better result while at 450°C solid cone spray gives better results and at 550°C both sprays are showing same performance.

From the above figure it is clear that for all air pressures, value of ignition delay is always more for solid cone spray than hollow cone spray at 350°C. Although the value of ignition delay is lower for solid cone spray than hollow cone spray at 450°C but the variation in values is very less.
IV. CONCLUSION

1. Although air pressure, injection pressure and HST all are responsible for variation in ID but HST is more strongly affect the ID compared to other parameters. However at high temperatures the strong dependency is diluted.

2. On increasing the hot surface temperature, ignition delay is decreasing for both types of spray but this decrement is faster for solid cone spray than the hollow cone spray.

3. At 350°C, ID is higher for Solid Cone Spray than the Hollow Cone Spray for any Injection Pressure and Air Pressure. So pintle nozzle is recommended at this temperature.

4. At 450°C, ID is lower for Solid Cone Spray than the Hollow Cone Spray for 100 bar and 150 bar Injection Pressure while at 200 bar Injection Pressure ID is almost same for both on all Air Pressure. So single hole nozzle is recommended at this temperature.

5. At 550°C, ID for both types of Sprays is almost same at any Injection Pressure and Air Pressure. So we can use any type of nozzle at this temperature.

6. At lower Air Pressure and HST the variation in ID is more between Solid Cone Spray and Hollow Cone Spray while at higher values of Air Pressure and HST the variation is very much less.

7. ID of diesel fuel is decreasing by increasing the Injection Pressure.

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