

Analysis of Port Injected Fuel Spray Under Cross Wind Using 2-D Measurement Techniques

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ABSTRACT

In a motorcycle gasoline engine, the port fuel injection system is rapidly spread. Compared to an automotive engine, the injected fuel does not impinge on the intake valve due to space restriction to install the injector. In addition, as the air flow inside the intake pipe may become very fast and has large cycle-to-cycle variation, it is not well found how the injector should be installed in the intake pipe to prepare “good” fuel-air mixture inside the intake pipe. In this study, the formation process of the fuel-air mixture is measured by using ILIDS system that is a 2-D droplets’ size and velocity measurement system with high spatial resolution. Experiments with changing conditions such as flow speed and injection direction are carried out. As a result, the effects of injection direction, ambient flow speed and wall roughness on the fuel-air mixture formation process was examined, considering the three conditions of cold start, light to medium load operation and high load operation.

INTRODUCTION

The fuel supply system of a gasoline engine for motorcycles is getting common to use the port fuel injection system. This system is basically the same as of a passenger car, but due to the space restriction, the injected fuel does not impinge on the intake valve as the injector is located at upstream position. This difference may cause worse characteristics such as slow vaporization since the surface of intake valve is hot, long time response and also fuel attachment on the intake pipe wall while it does good characteristics such as high degree of freedom in injector installation. The worse characteristics may be recovered by optimizing the injector settings. For this process, numerical simulations are useful, but the accuracy is not

evaluated and also detailed experimental study has been scarcely made [1].

Thereby, in this study, the spray characteristics injected upstream the intake valves are investigated by using a transparent duct to allow optical access. An improved ILIDS (Interferometric Laser Imaging for Droplet Sizing) method that can measure the velocity and diameter of spherical droplets on a plane, PDA (Phase Doppler Analysis) method that can measure the velocity and diameter of a spherical droplet in a small measurement volume and also laser tomography on a plane are applied. Experiments with changing conditions such as flow speed and injection direction are carried out using these techniques. As a result, the effects of injection direction, ambient flow speed and wall roughness on the fuel-air mixture formation process were examined, considering the three conditions of cold start, light to medium load operation and high load operation.

EXPERIMENTAL APPARATUS

MEASUREMENT DEVICE

Figure 1 shows the schematic of experimental apparatus including ILIDS optics. Details of ILIDS are already described in the author’s previous papers [2,3,4]. An acrylic passage with a square cross-section of 20 × 20 mm was used. To make a flow inside the passage, a blower was installed with a laminar flow meter.

A port fuel injector with four holes, spray angle of 5 degrees and volume flow rate of 145 cc/min was employed using n-heptane as a fuel and injection pressure was set at 0.3 MPa as a standard condition. The injection direction was changed

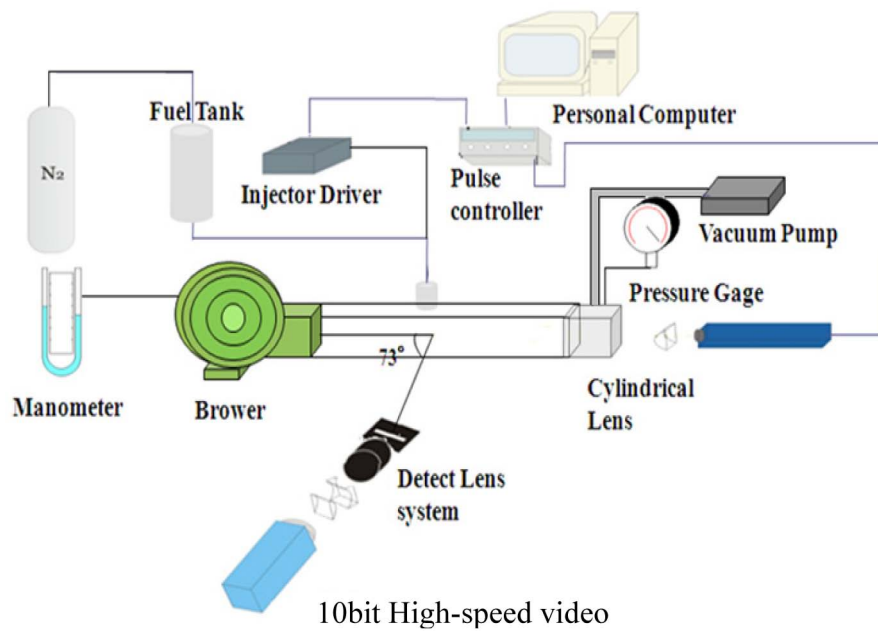


Fig. 1. Experimental apparatus of spray using ILIDS

from -60 to 60 degrees as illustrated in Fig. 2. Laser sheet was inserted into the passage from backward. The scattered light was detected with an angle of 73 degrees using a high speed video camera (Photoron FASTCAM APX-RS, 10 bit, 1024×1024 , 3000 fps). As the laser source, a high-frequency double-pulse Nd-YLF laser (Newwave research, 527 nm, 10 mJ/pulse, 1500 double pulses/s) was used. PDA system (Dantec DualPDA) was also employed using an Ar-ion laser (488/514.5 nm, 4W) as shown in Fig. 3.

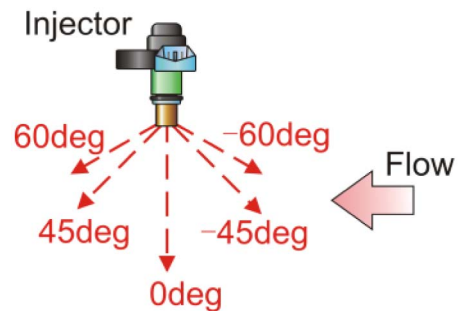


Fig. 2. Definition of injection direction to the flow

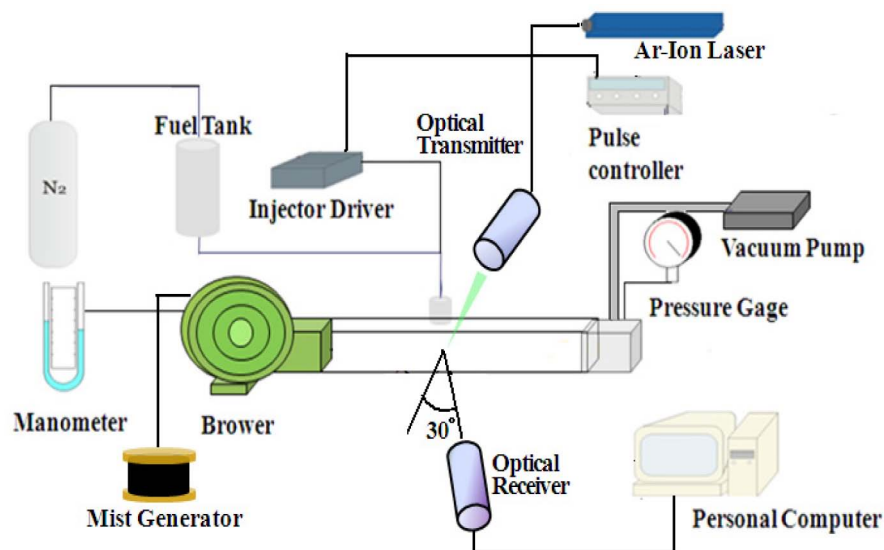


Fig. 3. Experimental apparatus of spray using PDA

PRELIMINARY MEASURED RESULTS

Figure 4 indicates the operation timing of devices. The first and second pulses of a double-pulsed laser are respectively defined as LASER1 and LASER2. The frame signal of the high-speed video camera was used as the standard clock.

The gas velocity inside the passage was measured using a 2D-LDV system along the passage and across the passage at the injector location. The measurement points are indicated in

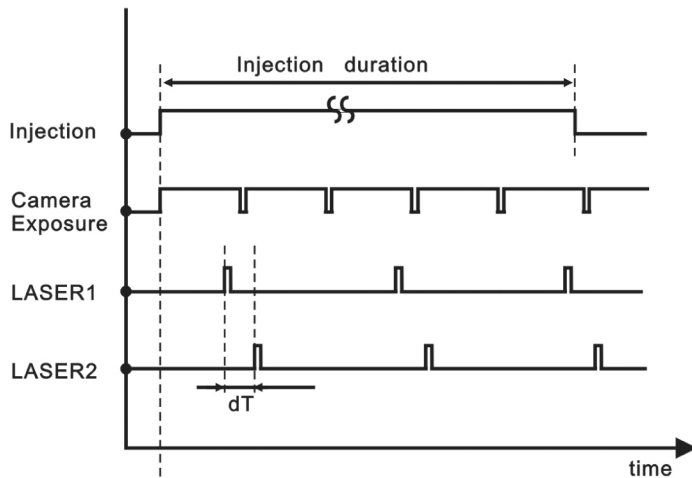


Fig. 4. Timing chart for experiments

Fig. 5. The horizontal mean velocity at medium flow velocity condition is shown in Fig. 6. At each point, both the horizontal and vertical velocities were simultaneously measured. Along the passage, the mean horizontal velocity was almost constant around 55 m/s and the mean vertical velocity was almost zero. In both high and low flow velocity conditions, the speed was around 72 and 20 m/s, respectively. On the cross section, velocity was nearly homogeneous and the boundary layer thickness was found less than 2.5 mm.

The spray characteristics in atmospheric condition were measured first. Two kinds of fuel (n-heptane and CCF) were used. The spray profile was taken by using a high-speed video camera in 10000 fps with 1/92000 s exposure time. The results are shown in Fig. 7. The diameter and velocity of droplets on a 2D area were measured using ILIDS system. The measurement was made with two injection pressures of 0.25 and 0.3 MPa.

The probability function of droplets diameter in number density and volume density are shown in Fig. 8. SMD (Sauter Mean Diameter) increases along the spray axis as only spherical droplets can be measured and ligament exits upstream. Figure 9 shows SMD values along the spray axis for both injection pressure of 0.25 and 0.3 MPa. CCF shows larger SMD values as its surface tension is larger than of n-heptane, leading to lower Weber number and breakup is suppressed.

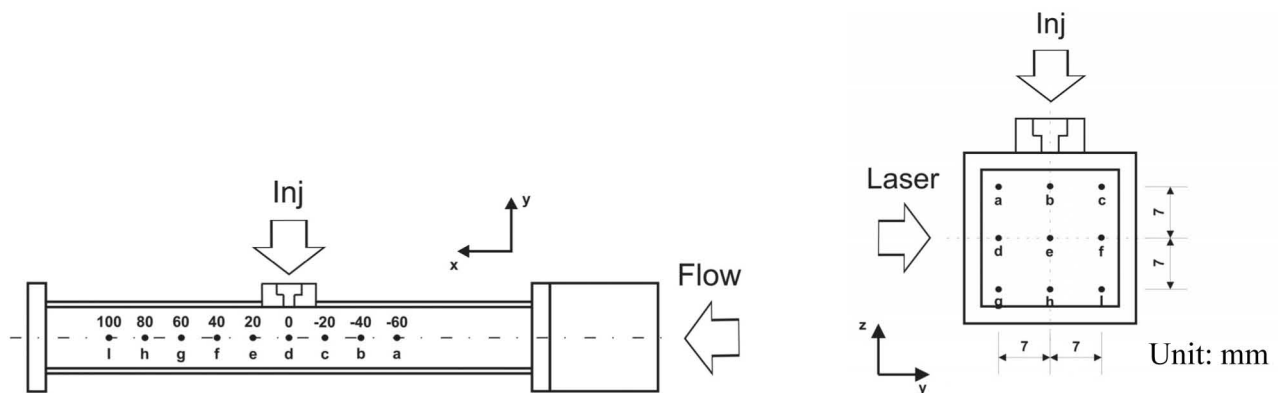


Fig. 5. LDV measurement locations

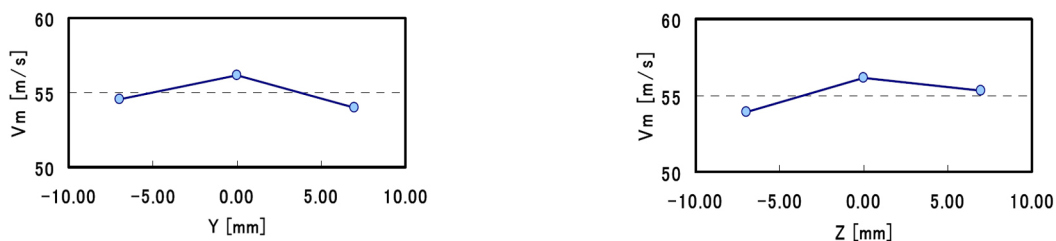


Fig. 6. LDV measured mean velocity

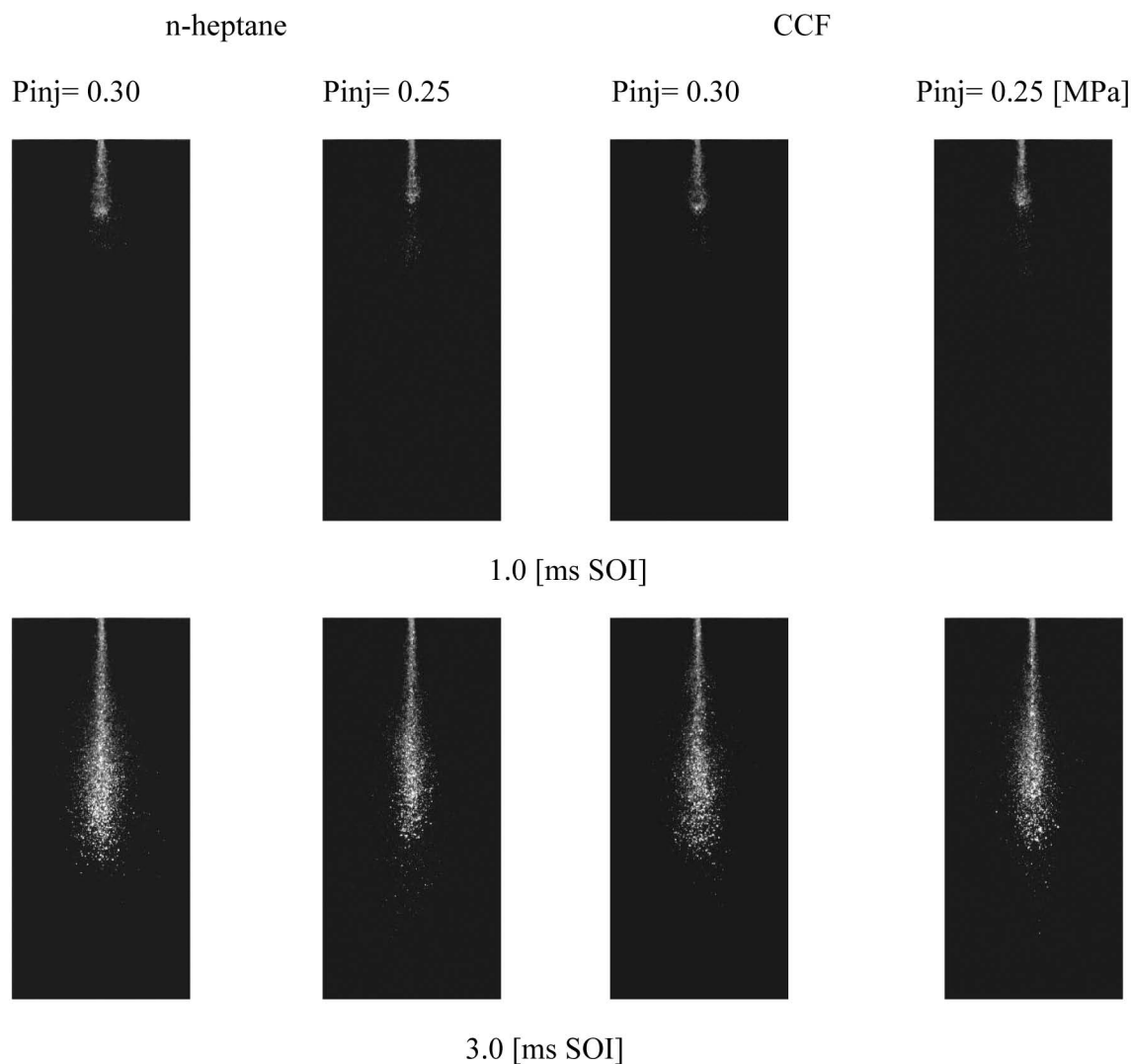


Fig. 7. High-speed photograph of spray for comparison of fuel and Injection pressure

FEATURES OF ILIDS

ILIDS has features of simultaneous measurement of every droplet on 2-D plane while the measurement limit of small droplet size is around $10\text{ }\mu\text{m}$ and measurement is difficult in a dense spray. Thereby, the spatial resolution is better than of PDA while temporal resolution is not so good as of PDA. However, as ILIDS can detect instantaneous spray characteristics that cannot be realized by PDA, it is favorable to see the cycle-to-cycle variation of spray.

Figure 10 shows a comparison of correlation of droplet diameter and velocity between ILIDS and PDA near the spray tip in a quiescent condition shown in lower Fig. 7. Because ILIDS has a wide measurement area of $10 \times 10\text{ mm}$, PDA was carried out at three points and all results are plotted together. Except for the difference in small droplet region, the profile is

similar to each other. This is probably due to that small droplets easily follow to the ambient flow which causes cycle-to-cycle variation of spray and that small droplets less than $10\text{ }\mu\text{m}$ cannot be detected by ILIDS. Thereby, ILIDS is convenient to see the area-averaged information.

RESULTS AND DISCUSSION OF SPRAY WITH CROSS WIND

ILIDS MEASUREMENT

Figure 11 shows tomograms of spray in different injection directions and ambient flow speeds of 20 and 72 m/s. Figure 12 shows the temporal variations of SMD in area (a) near injector. Area (a) is $10 \times 10\text{ mm}$ and the center is located at $X = -10\text{ mm}$, $Z = 5\text{ mm}$. X axis is along the flow and its zero