

論文の要旨

題目 Characterization of Fuel Spray Injected by Hole-Type Nozzle into Cross-Flow Ambient
(横風気流中にホールノズルから噴射した燃料噴霧の特性)

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A Direct Injection (DI) technique has promoted the overall performances of a gasoline engine, since the technique offers opportunities to run the engine in the stratified charge combustion mode and the homogeneous charge combustion mode. The fuel injection usually occurs during the intake stroke in the homogeneous charge combustion mode, therefore the pressure in combustion chamber is close to the atmospheric pressure; while in the stratified charge combustion mode the fuel injection occurs during the compression stroke, and the pressure in combustion chamber is higher than the atmospheric pressure. To fundamentally understand the effects of the air flow on the fuel spray in the combustion chamber of the DI gasoline engine, the characteristics of the fuel spray in a uniform cross-flow field were experimentally investigated in this study. The experiments are divided into two parts, in which the measurement of the spray characteristics under the atmospheric and high pressure ambient conditions are taken coinciding to the two modes.

An atmospheric wind tunnel and a high pressure wind tunnel are utilized to provide the uniform cross-flow field in the atmospheric pressure and high pressure ambient. Ethanol is employed as test fuel in this study. The structure, velocity distribution and droplet size are measured by high speed video photography, particle image velocimetry and laser diffraction size analyzer. The spray was injected perpendicularly into the cross-flow field by the valve covered orifice nozzle. The trigger for the fuel injection was controlled by an automatic control system, which can emit a trigger signal when the pressure and velocity satisfying the experimental conditions in the experiments using the high pressure wind tunnel.

The structures of the spray are bended obviously by the cross-flow, especially in the lower part of the spray. The most droplets of the spray concentrate near the edge of the spray in the upstream of the cross-flow while some tiny droplets are entrained into the cross-flow in the upper part of the spray. The penetrations of the spray tip are measured and the empirical correlations are deduced. The structural fluctuations appears in the distribution of the velocity components in the horizontal, and the value exceed even the velocity of cross-flow. The vortex phenomenon in the leeward of the spray is verified by analyzing the velocity distributions and the structures of the spray in the horizontal planes. This phenomenon is similar to the Karman vortex street, which happen when a fluid flows passes a circular cylinder. Droplets are concentrated in the spray center without cross-flow, while the large amount of droplets are blown downstream of the spray with cross-flow. The larger droplets distribute in the high concentration area and the diameter of droplets is decreased along the direction of the cross-flow.

The numerical simulations were conducted under a few representative conditions. The real size simulating model with the same boundary conditions were selected in the simulations. The spray profiles, penetrations, velocity distributions, and droplet size distributions of the simulation have been represented and compared with the experimental results.

The experimental methods, which were used in this study, were illuminated with the backgrounds and principles. There are two main kinds of experiments in this study, the experiments based on the atmospheric wind tunnel and the experimental based on the pressure wind tunnel. The former is used to simulate the condition of the surrounding of the homogenous charge combustion model, while the latter is used to simulate the condition of the surrounding of the stratified charge combustion model.

The spray injected by the VCO nozzle is asymmetrical in the low ambient pressure due to the special structure of the nozzle. At constant injection pressure, the vertical penetration decreases with an increase of the cross-flow velocity, however, such tendency becomes weak when the injection pressure is increased. With increasing the velocity of the cross-flow and the injection pressure, the horizontal penetration increases. The droplets distribution presents inhomogeneous in the upper region of spray; the horizontal component of spray velocity shows large fluctuations, especially in the downstream region of the spray where the value even exceeds the cross-flow velocity. The structures in horizontal plane in the upper part of the spray present asymmetrical, and the droplet distributions are different in various horizontal planes. In the lower part of the spray the structure becomes symmetrical, however the strong movements can be observed.

The vorticity presents an interlaced distribution with different directions. The happening of the vorticity owns regional, in the range of the leeward of the spray the vorticity can be observed.

Droplets concentrated in the spray center under the no-cross-flow condition, while a large number of droplets remained in the upstream area of the spray with the cross-flow. Otherwise, larger droplets were distributed in the high-concentration area. Additionally, the diameter of the droplets decreased along the direction of the cross-flow.

The discussions of effects of ambient pressure on spray characteristics are focused on the profiles of the spray under quiescent ambient and the cross-flow ambient with various ambient pressure, the penetrations, the velocity distributions and the droplet concentrations of the spray under various ambient pressures.

The numerical simulation was taken for analyzing the cross-flow effects on spray. Some results have been presented, such as the spray profiles, penetrations, velocity distributions, and the droplet size distributions. Although there are some difference between the simulation results and experimental results, the most parts of them agree well.