論 文 の 要 旨

題 目: Characterization of Flat-Wall Impinging Fuel Spray under High-Pressure Cross-Flow Condition
（高圧横風気流中で平板に衝突する燃料噴霧の特性）

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Owing to the advantages of good fuel economy and high thermal efficiency, direct injection (DI) gasoline engines have widely been applied in the automotive field. The DI gasoline engines include two combustion modes: stratified charge combustion and homogeneous combustion. In either mode, the air flow movement in the cylinder is strong enough to influence the fuel spray characteristics, such as spray profile, spray breakup, and fuel–air mixing. In addition, the fuel spray might impinge on the piston cavity wall before being fully vaporized due to the high injection pressure and small cylinder. Spray impingement usually influences fuel atomization and combustion, resulting in excessive hydrocarbon (HC) and soot emissions. To examine the effect of cross-flow on the impingement spray characteristics, such as the spray structure, droplet size and velocity distributions, a comprehensive experimental investigation was carried out in a high-pressure wind tunnel. The impingement spray images in a vertical plane and two horizontal planes were recorded by a high speed video camera and a laser sheet technology. By employing the particle image analysis (PIA) optical diagnostic method, the Sauter mean diameter (SMD) and the droplet velocity components were investigated. The main conclusions are summarized as following.

By observing the spray structure in vertical plane, is can be seen that with the increase in cross-flow velocity, the spray area increases significantly, i.e., the cross-flow favors spray dispersion. Moreover, the spray outline distortion caused by cross-flow in the leeward side is larger than that in the windward side. Under the almost same liquid-to-air momentum flux ratio q, when the ambient pressure and cross-flow velocity were varied, the impingement spray outlines in the windward side were almost coincident, particularly at the upper part, but in the leeward side, the outline extended further at lower ambient pressure. With increase in the cross-flow velocity before impingement, the spray tip penetration decreased slightly, while it evidently increased after impingement. The increased cross-flow velocity led to an increase in the vortex height because of the enhanced spray dispersion. The high ambient pressure restrains the spray dispersion and leads to a shorter spray tip penetration and smaller vortex height. From the spray images observation in two horizontal planes, we found that in the plane of y = 25 mm, the movement of the Karman vortex-like structure was observed that resulted in a non-uniform distribution of droplets in the upper part of the spray in the leeward side. In the plane of y = 45 mm, in the vortex core region, the droplets density was quite low, showing an empty belt.

Droplet size and velocity distributions were measured by employing the PIA system. The results show that the increased cross-flow velocity leads to larger SMD in the windward side of spray and smaller SMD in the leeward side of spray. The two velocity components demonstrate a difference in the behavior of large and small droplets. The smaller droplets are more easily affected by the cross-flow than the larger droplets owing to their larger drag acceleration. The increased cross-flow velocity leads to the droplet splash region shifting to the downstream side, where numerous secondary droplets are formed during impinging. By employing the PIV optical diagnostic method, the flow field of wall-jet vortex was measured. In the quiescent cross-flow velocity ambient the droplet velocity distribution in spray tip formed as a vortex structure after impingement, while the vortex structure of droplet velocity disappeared with the increase of cross-flow velocity. Moreover, a stagnation region exists between the main spray and wall-jet vortex, and the droplets velocity in this region is almost 0 m/s. For near-field spray, the image at a higher ambient pressure shows few ligaments and droplets. The spray outline was wider at the initial stage (0.05 ms ASOI) than that at steady stage (2 ms ASOI) of spray evolution.

The numerical simulations were conducted by the validated spray models based on the CONVERGE software. The simulation results about spray structures, spray tip penetration, vortex height and velocity distributions have been shown and compared with the experiment results.