Velocity measurement inside a diesel spray by using time-resolved PIV under high ambient density condition

Y. Zama*, W. Ochiai, T. Furuhata, M. Arai
Department of mechanical system engineering, Gunma University, Japan
yzama@gunma-u.ac.jp, t11801209@gunma-u.ac.jp, tfuruhata@gunma-u.ac.jp and arai@gunma-u.ac.jp

Abstract

Recently, exhaust gas recirculation (EGR) ratio and boost pressure of a diesel engine tend to increase for improvement of diesel engine performance and emission. In ultra-high boost engine, compressed gas density in combustion chamber became 3 or 4 times higher than that in natural aspirated (NA) engine. It seems that a diesel spray behavior in high gas density surroundings might differ from that in a conventional diesel engine. There are many reports regarding the effect of ambient gas density on diesel spray behavior. In high gas density surroundings, some researchers investigated spray behavior in terms of spray tip penetration and spray angle. Regarding the investigation of spray behavior and spray velocity, there were some results obtained with Laser Doppler Velocimetry (LDV) and Particle Image Velocimetry (PIV). PIV is velocity field measurement technique with high spatial resolution and is currently applied to various sprays. There are some PIV reports regarding velocity of air entrainment motion around diesel spray. However, a few investigations on the velocity measurement inside diesel spray were carried out. To understand the diesel spray behavior completely, both of instantaneous and time averaged velocity fields inside the spray should be investigated. Therefore, it is necessary to obtain not only instantaneous velocity field but also temporal change of velocity fields for the analysis of transient and average behavior of diesel spray. In this study, velocity distribution inside diesel spray was measured in various gas density surroundings and injection pressures. Maximum velocity gradient positions were evaluated using the Gaussian type distribution function fitted to velocity distribution. Further, effects of ambient gas density and injection pressure on these positions were discussed.

Experimental apparatus consisted of fuel injection system, high pressure vessel and optical system for visualization of a diesel spray. Using a single-hole diesel nozzle with a single shot injection system, diesel fuel was injected into the pressure vessel. Ar^+ ion continuous laser was utilized as a light source, and a laser-light sheet with 1mm thickness was formed with a cylindrical lens and a convex lens. Digital high-speed camera (Vision Research, Phantom V710) was used for capturing sequential images of a diesel spray. Frame rate of high speed camera was set over 0.1Mfps. Ambient gas densities ρ_a in high pressure vessel were 5.8kg/m^3, 11.6kg/m^3, 23.2kg/m^3 and 46.5kg/m^3 under the room temperature condition. Here, ambient gas density of 11.6kg/m^3 was equivalent for a compressed gas density of 3MPa at 800K. This density and temperature condition corresponded to a combustion chamber condition at injection timing of a conventional NA diesel engine. Moreover, various fuel injection pressures were adapted.

According to time-series instantaneous velocity fields inside spray, in high gas density surroundings, cluster of spray droplets near the spray periphery hardly moved, and it was re-entrained into main spray flow. These phenomena were coupled with vortex formation near the spray periphery. Mean velocity distributions inside a diesel spray at 40mm and 60mm from a nozzle were evaluated from over 1000 instantaneous velocity data analyzed with PIV, and the velocity distribution was well fitted with Gaussian function. According to mean axial velocity distribution normalized with center velocity, it was clear that the position of intense mixing zone at Z = 40mm shifted from the periphery to the inside of spray with increasing ambient gas density and injection pressure. However, its trend did not appear for normalized axial velocity distribution at Z=60mm.

* Corresponding author: yzama@gunma-u.ac.jp