

Effects of Fuel Physical Properties on Spray and Combustion Characteristics in a Diesel Engine (First Report)

- Effects of Fuel Physical Properties on Air Entrainment Near the Nozzle in Diesel Sprays -

Ryota Kobayashi ¹⁾ Gakuto Aizawa ²⁾ Yoshio Zama ¹⁾ Takeshi Hashizume ³⁾

1) Gunma University, Graduate School of Science and Technology

1-5-1 Tenjincho, Kiryu, Gunma, 376-8515, Japan

2) Gunma University, Faculty of Science and Technology

1-5-1 Tenjincho, Kiryu, Gunma, 376-8515, Japan

3) Toyota Motor Corporation

1200 Mishuku, Susono, Shizuoka, 410-1193, Japan

KEY WORDS: Heat engine, Compression ignition engine, Mixture formation, Physical properties, Entrainment [A1]

The mixture formation of air and fuel plays an important role in combustion and exhaust emissions in diesel engines. The use of carbon-neutral (CN) fuels in diesel engines is expected to further reduce environmental impact. However, CN fuels may have different physical properties, such as surface tension, compared to diesel fuel, and there is a possibility that those differences affect the air entrainment characteristics of a fuel spray, which directly affects mixture formation. Therefore, this study experimentally investigated the effect of fuel properties, such as kinematic viscosity and surface tension on flow rate of air entrained into the spray near the nozzle.

The fuel spray exchanges momentum with the surrounding air as it loses momentum, and sprays entrain air to form an air and fuel mixture. Based on the continuity equation, the flow rate of entrained air can be calculated from the air entrainment velocity and the surface area of the fuel spray. Therefore, it is necessary to measure air entrainment velocity and the surface area of the spray simultaneously. Figure 1 shows the experimental setup used in this study. LIF-PIV using fluorescent particles was applied to measure the velocity field of the ambient air entrained into the spray, and the spray boundary was visualized using scattered laser light from the spray to measure the spray surface area. In this study, n-Tetradecane and n-Heptane were chosen as reference test fuels for hydrocarbon, representing high and low levels of surface tension and kinematic viscosity. Moreover, several test liquids were prepared using silicone oil and glycerol solution to control physical properties of the test liquid.

As the results obtained in this study, the flow rate of air entrainment decreased with increasing surface tension. This is caused by a reduction in momentum exchange between the test liquid and the surrounding air due to the suppression of spray deceleration. This occurs because liquid atomization is suppressed by the higher surface tension, enabling coarse droplets to maintain their momentum.

Here, the air entrainment is closely related to the momentum exchange between the surrounding air and spray. Therefore, this study focused on the jet number, which is a dimensionless number of the relative velocity and momentum ratio between the gas and liquid phases. Jet number is expressed by the following equation.

$$Je = \left(\frac{\rho_l v^2 D}{\sigma_l} \right) \left(\frac{\rho_a}{\rho_l} \right)^{0.55} \quad (1)$$

In this equation, the density and surface tension of test fuel are ρ_l kg/m³ and σ_l N/m. v m/s is the velocity of test fuel. Nozzle diameter is D m. Ambient density is ρ_a kg/m³.

Figure 2 shows the relationship between the jet number and the total amount of entrained air at distance from normalized by spray tip penetration ($y/y_{STP} = 0.5$). The flow rate of air entrainment tends to increase as the jet number increases, suggesting that air entrainment can be correlated with the jet number.

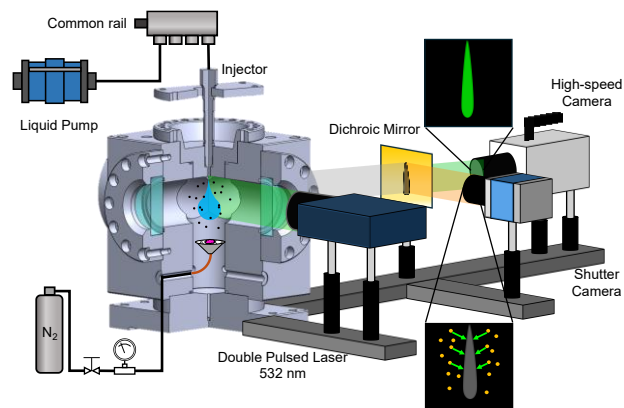


Fig.1 Experimental setup

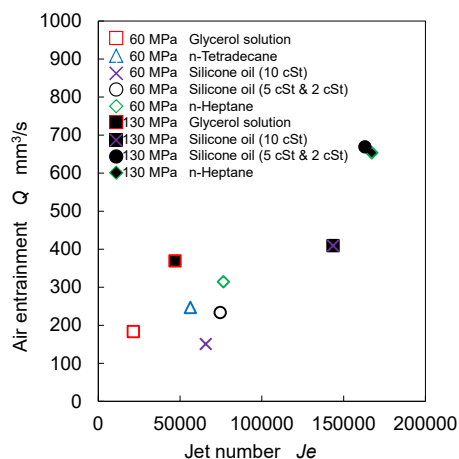


Fig.2 Relationship between Jet number and air entrainment