

Kinetic Energy Conversion Process in a Non-evaporating Diesel Spray

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In diesel engines, the formation process of the spray mixture by fuel injection is very important because it has a significant impact on combustion characteristics. However, due to the difficulty of measuring the high concentration liquid phase, there is little knowledge on the mechanism of mixture formation by atomization and dispersion of sprays. In a previous report, laser-induced fluorescence was applied to non-evaporated sprays to clarify the dispersion process of sprays, and a new image processing method was developed using momentum theory and injection rate. In this paper, the kinetic energy of droplets passing through the cross-section perpendicular to the spray axis per unit time and the conversion process of the kinetic energy input are discussed using the liquid-phase concentration distribution obtained by quantitative concentration analysis.

Spray is injected as a liquid jet, and the liquid jet undergoes a primary breakup due to shear with the surrounding gas. Droplets break up into smaller droplets while taking in the surrounding gas. During this process, the total surface area of the droplet increases due to the atomization effect, which promotes momentum exchange. In addition to the jet flow within the spray due to momentum exchange with the droplet, the motion of the surrounding gas at the outer edge of the spray is also induced. Considering the energy that passes through an arbitrary cross-section perpendicular to the spray axis per unit time in a non-evaporating spray, the input jet energy is equivalent to the kinetic energy of a liquid jet. Spray breakup and entrainment change the energy into kinetic energy of droplet groups, energy used for atomization, kinetic energy of the jet within the spray, and flow energy of the gas surrounding the spray, some of which is dispersed due to viscosity. Each energy is given by the following equations (1 - 5). Since the dissipation due to viscosity is negligible, the flow energy of the gas surrounding the spray is obtained by subtracting the sum of the other energies from the injection energy.

$$\dot{E}_{injection} = \frac{1}{2} \rho_l \frac{\pi d_{nozzle}^2}{4} U_{injection}^3 \tag{1}$$

$$\dot{E}_{droplet} = \int \frac{1}{2} C U_{spray}^3 dA \quad (= \int n \frac{1}{2} \rho_l \frac{\pi d_{droplet}^3}{6} U_{spray}^3 dA) \tag{2}$$

$$\dot{E}_{atomization} = \int n \sigma \pi d_{droplet}^2 U_{spray} dA \tag{3}$$

$$\dot{E}_{entrained\ gas\ in\ spray} = \int \frac{1}{2} \rho_g \left(1 - \frac{C}{\rho_l}\right) U_{spray}^3 dA \tag{4}$$

$$\dot{E}_{ambient\ flow} = \dot{E}_{injection} - \dot{E}_{droplet} - \dot{E}_{atomization} - \dot{E}_{entrained\ gas\ in\ spray} \tag{5}$$

Figure 1 shows the average energy flow through an arbitrary cross section perpendicular to the spray axis at 30 to 40 mm from the nozzle tip in the direction of the spray axis, a region where the liquid phase concentration distribution can be quantitatively evaluated. In the region between 30 mm and 40 mm from the nozzle in the direction of the spray axis, about 0.7% of the kinetic energy input is the kinetic energy of the droplet group, about 8% is the kinetic energy of the jet in the spray, about 0.007% is the surface tension energy of the droplet, and the remaining 91% is the kinetic energy of the surrounding fluid.

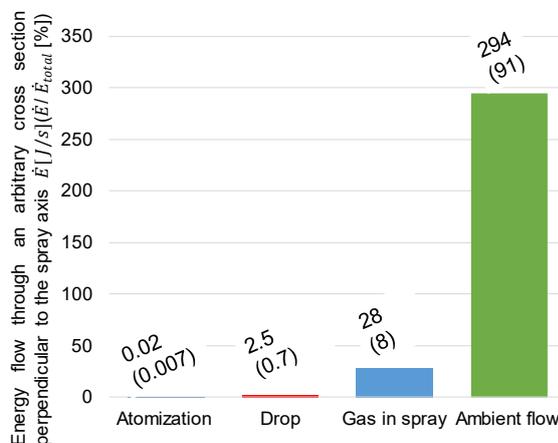


Fig.1 Energy flow through an arbitrary cross section perpendicular to the spray axis. ($P_{inj}=100$ MPa, $\Phi d=0.125$ mm, $\rho_a=27.2$ kg/m³ ($P_a=1.5$ MPa), $T_a=293$ K, ASOI 3.0 ms.)