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Quantitative Analysis of Lubricant Oil Splash by Impingement of Spray Droplets on Lubricant Film in Diesel Engine (Part 2)

Investigation of the Influence of K-factor and Non-Dimensional Film Thickness on Lubricant Splash Volume

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Ashes accumulated in the DPF is impossible to remove by combustion and may lead to serious problems such as reduced fuel efficiency and engine shutdown due to increased back pressure. One of the causes of ash formation is the combustion of lubricating oil that is splashed into the cylinder when atomized droplets impinge on the lubricating oil film during post-injection. Therefore, quantification of lubricant splashing amount and calculation of experimental equations were conducted to model the phenomenon based on clarification of the splashing mechanism of lubricant at the time of post-injection. To quantify the amount of lubricating oil dispersed, it is necessary to measure the mass fraction of lubricating oil in the secondary droplets, the secondary droplet diameter, and the number of secondary droplets. The mass fraction of lubricant in the secondary droplet was measured using the LIF method, while the secondary droplet diameter d_{out} and the number of secondary droplets N_{dop} were measured using magnification photography.

Regarding the non-dimensional number that affects the impact behavior, previous studies have shown that Mundo et al. evaluated the criticality of Splash/Deposition in the impact behavior of a droplet on a wall by using the K-factor ($K=We \cdot La^{0.2}$) with the Weber number ($We=\rho_d d_{in} v_{in}^2/\sigma_d$, ρ_d : Droplet density, d_{in} : Droplet diameter of the incident fluid, v_{in} : Droplet incidence velocity, σ_d : Surface tension of droplet) and the Laplace number ($La=\rho_d \sigma_d d_{in}/\mu_d^2$, μ_d : Viscosity coefficient of droplet). The K-factor suggests that the splash occurs when the inertia force of the droplet is much larger than the force due to surface tension. Cossali et al. also found that for the impingement behavior at the wetted wall, the Non-dimensional film thickness δ_{non} ($\delta_{non}=\delta/d_{in}$, δ: Liquid film thickness) contributes to the impingement behavior, as shown in the experimental results. Kittel et al. reported that the viscosity coefficient ratio κ ($\kappa=\mu_{oil}/\mu_{fuel}$, μ_{oil}: viscosity coefficient of the liquid film), in addition to the dimensionless number K-factor and Non-dimensional film thickness δ_{non}, affect the impact behavior in the formation of secondary droplets in the impact behavior between liquids with different physical properties. In this experiment, K-factor and Non-dimensional film thickness δ_{non} were used as parameters under constant viscosity ratio κ to investigate the effect of K-factor and Non-dimensional film thickness δ_{non} on lubricant splashing amount.

Figure 1 and Figure 2 show the relationship between K-factor, Non-dimensional film thickness δ_{non}, and Lubricating oil splash. When a fuel droplet impinges on the lubricating oil film, the mass of lubricating oil M_{oil} splashed from the oil crown is expressed as $M_{oil}/M_d=N_{dop}(d_{out}/d_{in})^3R_o$ as a dimensionless mass ratio with the mass of the impinging droplet M_d. The total mass of the secondary droplet, M_{out}, is expressed as $M_{out}/M_d= N_{dop}(d_{out}/d_{in})^3(\rho_{fuel}/\rho_{out})$ as a dimensionless mass ratio of the mass M_d of the incoming droplet. where $\rho_{out}=R_o \cdot \rho_{oil}+R_f \cdot \rho_{fuel}$ (ρ_{oil}: density of lubricating oil). Figure 1 shows that the amount of secondary droplet splashing and the amount of lubricating oil splashing from the oil crown decrease with increasing K-factor, while Figure 2 shows that the amount of secondary droplet splashing and the amount of lubricating oil splashing from the oil crown increase with increasing Non-dimensional film thickness δ_{non}. The lubricant dispersal ratio calculated from Figure 1 and Figure 2 as a function of K-factor and Non-dimensional film thickness δ_{non} is given by the following equation.

$$\frac{M_{oil}}{M_d}=9.78\times10^4 \cdot K^{-1.24}\frac{\delta_{non}{}^{0.05}}{1+e^{-21.0(\delta_{non}-0.15)}}$$

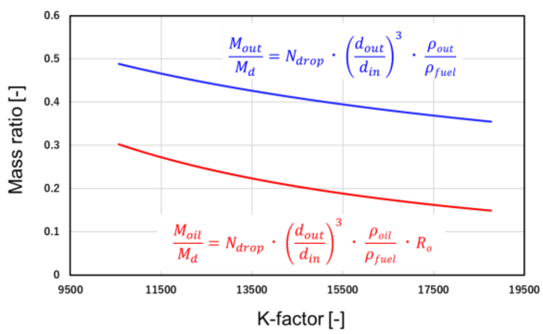

Fig.1 Influence of K-factor on total splashing secondary droplet and splashing lubricating

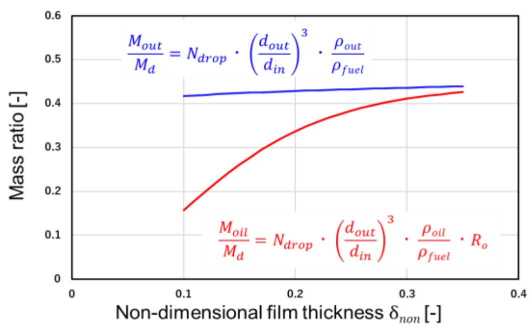

Fig.2 Influence of Non-dimensional film thickness δ_{non} on total splashing secondary droplet and splashing lubricating