Development of Breakup Model for Large Eddy Simulation of Diesel Spray

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Abstract

Diesel engines emit soot and NOx. The formation of these emissions is affected by heterogeneous distribution in diesel spray. This heterogeneous distribution is affected by turbulent vortex structure. Thus, the high accuracy prediction for the amount of these emissions needs to estimate finer turbulent vortex structure. Conventional CFD for the engine combustion is performed using Reynolds Averaged Navier Stokes (RANS) approach as turbulent analysis method. However, RANS approach has no enough capability to describe the finer vortex structure. Recently, Large Eddy Simulation (LES) approach has gotten a lot of attention as the alternative way of RANS approach. LES approach is able to describe the finer structure of the turbulent vortex than RANS approach.

LES has been applied for non-evaporative, evaporative diesel spray in earlier studies. It is found that grid length sensitivity is quite high in LES so that finer grid should be set in order to reproduce finer diesel spray structure. In addition, central difference method and forth order Runge-Kutta method for the convection term of momentum equation are adopted in order to reduce the numerical viscosity. As a result, good agreements of the spray shape and spray tip penetration are obtained in LES analyses. However, spray droplet diameter of LES analyses underestimated in the comparison with the experimental results. This is because Kelvin-Helmholtz and Rayleigh-Taylor (KHRT) model is used for breakup model. It is reported that KHRT model underestimate Sauter mean diameter. KH model and RT model are modeled for high Weber number condition. Even if the fuel is injected with high pressure, the downstream region of spray is corresponding to relatively low Weber number condition due to the momentum exchange with ambient gas. To overcome this problem, we develop KH-MTAB model. This is hybrid breakup model where KH model and Modified Taylor Analogy Breakup (MTAB) model are used for primary and secondary breakup respectively. MTAB model is more suitable for description of secondary breakup, compared to RT model. The LES results with KH-MTAB model show that spray tip penetration, spray volume and sauter mean diameter of LES analyses are good agreement with experimental results at relatively low density condition. However, the tendencies of droplet size distribution are not agreement with experimental results due to the problem with hybrid method of KH model and MTAB model.

This study is focused on the investigation of breakup model which improves coupling of KH model and MTAB model. LES analyses of non-evaporating diesel spray are performed using modified KH -MTAB model at different ambient density and the spray injection pressure. Then, LES analyses were compared with experimental results in terms of spray tip penetration, spray volume, sauter mean diameter, droplet size distribution and spray shape.

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