論文の要旨

題　目 Experimental and Computational Study of Diesel Spray under Non-Evaporating and Evaporating Conditions

（非蒸発および蒸発条件におけるディーゼル噴霧の実験およびシミュレーション）

氏　名　SAFIULLAH

NOx and particulate emissions have been a matter of concern since the diesel engine is invented. It is understood that the emission process in the diesel engine is directly associated with the combustion. The proper combustion would result in less emissions whereas incomplete combustion produces particulate matter, NOx, CO and Unburnt Hydrocarbon emissions. Hence, phases prior to combustion process including injection process need to be investigated. The injection process starts when the fuel is injected in the spray form in the combustion chamber. Factors such as injection pressure, Injector nozzle hole number and nozzle hole diameter are responsible for the injection process. Thus, this study is an attempt to examine effects of the nozzle hole number, orifice diameter and injection pressure on the diesel spray under non-vaporizing and vaporizing conditions.

Diesel spray experiments are performed in Constant Volume Vessel where ambient temperature and pressure are adjusted base on the interest of the study. In the non-evaporating condition, the experiments are performed at the room temperature and ambient gas pressure is maintained at 1.4MPa to attain 16kg/m3 ambient gas density. Whereas, in the evaporating condition, the ambient gas temperature and pressure are set to 770K and 3.6MPa, respectively. The diesel spray is visualized using Diffused Backlight Illumination method in the former condition, while Laser Absorption Scattering technique is implemented, in latter, to observe the vapor phase and measure the mixture concentration. Results obtained through experiments are validated against computational study. AVL Fire CFD commercial code using k-ζ-f turbulence model and SIMPLE algorithm is used. Prior to the spray simulation, the input parameters including injection rate and initial spray trajectory angle are determined by means of careful measurements. The injection rates are measured using Zeuch and Bosch method whereas the initial spray trajectory angle is obtained though near nozzle field spray experiments. The non-evaporating results are further predicted using analytical models.

CFD model study was performed to choose the best combination of numerical model and sub-models. In this regard, spray results using primary breakup, secondary breakup and evaporation models were compared with experiments. Spray simulation using KHRT and Multicomponent secondary and evaporation models respectively, in the absence of primary breakup model, showed an appropriate agreement with experiments; thus, the said combination was used to compare the experimental results asusming effects of hole size, number of nozzle holes and injection pressure on diesel spray.

Through the experiments considering effects of orifice diameter and injection pressure, it is found that the largest nozzle hole diameter with highest injection pressure produces longest spray tip penetration owing to its highest injection momentum. While, the smallest nozzle hole diameter injector with highest injection pressure shows greatest spray angle. On the other hand, the computational study shows that the primary breakup region depends on the nozzle hole diameter i.e. larger the nozzle hole diameter is, the longer would be the primary breakup region. Also, numerical sprays are narrower due to the RANS turbulence model.

Overall, a reasonable qualitative agreement is extracted from the computational study and analytical studies when spray tip penetration is compared; although spray angle comparison shows a poor agreement.

Results obtained through the experiment under evaporating condition proved that the liquid length is a function of nozzle hole diameter rather than the injection pressure. Moreover, the vapor length is longer when nozzle hole diameter is smaller and injection duration is longer. With computational study it was understood that the increases in the injection pressure results in better atomization and lower vapor equivalence ratio. Also, evaporation ratios depend on the injection pressure.

Experimental penetration of three single hole injectors under similar injection rate profiles is identical; however, a greater spray angle is noticed in smallest nozzle hole diameter case. The spray simulation showed promising prediction at the initial stage in the smallest hole diameter injector; however, an overall discrepancy is observed. In the experiments of evaporating condition, longer vapor length, shorter liquid penetration and higher evaporation ratios were seen for the smallest nozzle hole injector. The computational study agreed with experiments in terms of vapor penetration and evaporation ratios of largest nozzle hole injector.

The experimental penetration length of largest nozzle diameter in multi hole injector showed concurrent results with the single hole injector. However, the spray angle of multi hole injectors is found to be lower. Liquid length of multi hole injectors under evaporating condition is linear and less-fluctuating; also, the vapor equivalence ratios are lower after the end of injection which indicates that the ambient gas entrainment is higher in multi hole injectors' spray. However, a longer vapor length and higher evaporation ratios are witnessed for single hole injectors. The computational study shows an excellent agreement with experimental results of multi hole injectors under evaporating condition; albeit a poor prediction is displayed under non-vaporizing case.