Integrated Computation of Micro-Cavitation in Gasoline Injector Atomization

Jun Ishimoto*
Institute of Fluid Science,
Tohoku University
Sendai 980-8577 Japan

Abstract

Taking focus in the primary breakup process, the effect of micro-cavitation which is generated in the upstream of nozzle aperture is found to be very important factor to determine the atomization behavior. Micro-cavitation can be thought of as slight vaporization induced by flow generated local pressure drop and the region of vapor may be large continuous bubbly cloud. Therefore, micro-cavitation in high-speed flow as in gasoline injectors is near-isothermal but compressibility effects may be important particularly if the cavitation is unstable and vapor bubbles enter the liquid core and collapse causing pressure waves to interfere/enhance the liquid jet. The effect of micro-cavitation on 3-D structure of liquid atomization process through a gasoline injector nozzle is numerically investigated and visualized by a new type of integrated CFD technique. The present CFD analysis focused on primary breakup phenomenon of a liquid column which is closely related to the micro-cavitation, the consecutive formation of liquid film, and generation of droplets of a lateral flow in the outlet section of the nozzle. The governing equations for high-speed lateral atomizing injector nozzle flow taking into account the micro-cavitation generation based on the Barotropic LES-VOF model in conjunction with the CSF model are presented, and then an integrated parallel computation are performed to clarify the detailed atomization process coincident with the micro-cavitation of a high speed nozzle flow. Furthermore, we acquire the data which is difficult to confirm by experiment such as aspects and volume fraction of micro-cavity, atomization length, liquid core shapes, droplets size distributions, spray angle and droplets velocity profiles. According to the present integrated computational technique, the atomization rate and the droplets-gas atomizing flow characteristics are found to be controlled by the generation of micro-cavitation coincident with primary breakup caused by the turbulence perturbation upstream of the injector nozzle, hydrodynamic instabilities at the gas-liquid interface, and shear stress between the liquid core and periphery of the jet. Furthermore, stable and a high-resolution computation can be attained in the large density ratio of liquid- and gas-phases including the effect of micro-cavity generation by using our numerical method.

Key words: Micro-cavitation, Injector nozzle, LES, Breakup, Barotropic model, CFD

*Corresponding author, Email: ishimotojun@ieee.org