Modeling of Cavitation Phenomenon inside a Nozzle Under High Fuel Pressure Condition

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Abstract

Direct fuel injection system is getting popular in internal combustion engines due to the superior performance in fuel economy and power. To optimize the fuel-air mixture distribution inside the cylinder, the geometry of nozzle and the mixture formation process must be well designed. To attain this, the numerical simulation will be a good tool, but the prediction ability is not enough for the practical design. In this study, a two-phase flow of fuel and gas including cavitation inside an axi-symmetrical nozzle was evaluated to improve the prediction ability. Two kinds of cavitaion model (quasi-steady dynamic bubble model and discrete bubble tracking model) are proposed and implemented into a commercial code FLUENT 6.4.

As a result, the discrete bubble tracking model could obtain converged solutions even for a high differential pressure conditions between the nozzle entrance and the exit up to 100 MPa and predict the cavitaion phenomenon qualitatively. The calculated results at Δp = 5 MPa for both quasi-steady dynamic bubble model and discrete bubble tracking model were compared with the measurement of just taking pictures using a back light. As the image is line-of-sight result, only the length of cavitation is available from this picture. Experiment demonstrates that the cavitation starting point is just nozzle entrance and disappears just nozzle exit in the experiment while it starts a little downstream and continues from the nozzle exit downstream in the left result. Thus, the prediction ability was not good and calculation was diverged for other differential pressure conditions using quasi-steady dynamic bubble model. The calculated result at Δp = 5 MPa using discrete bubble tracking model was also compared to the experiment. The cavitation length is underestimated in the calculation, but in other condition of. Δp = 6 MPa, better agreement between the calculation and measurement was found.

Finally, in order to see the temporal variation of fuel injection with cavitation, calculation of fuel injection from a hole to an open space was carried out using bubble tracking model. It was apparently found that as the cavitaion model is not used, very stable jet with a smooth surface comes out while unstable and uneven surface is formed around the jet with cavitaion model. This effect enhances the primary atomization of fuel jet.

Key words: Modeling, Direct injection, Internal combustion engine

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