Research Report（April, 2022- March, 2023）

Enrollment from April 2022

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I. List of Papers

No papers

II. List of Talks

1. **T. Nakamura**, Y. Otoguro, K. Takizawa, and T.E. Tezduyar, "A variational multiscale formulation for the Navier–Stokes–Korteweg equations", in Proceedings of the 36th Symposium on Computational Fluid Dynamics, Online due to the COVID-19, (2022).

III. Research Results in AY2022

In 2022, we conducted a multiscale formulation for cavitation analysis, numerical analysis in a single scale and a formulation for bubble generation.

First, we formulated the isothermal Navier–Stokes–Korteweg (NSK) equations based on residual-based variational multiscale method. There are many terms in the formulation. It is difficult to validate the formulation to do numerical analysis. Therefore, we did Space–Time formulation for single scale analysis.

In the numerical analysis, we considered the pressure is equation of state for ideal gas and did not consider the surface tension effect. Computational domain is a 1 mm square. We set two initial conditions. One is a flat interface, another is one bubble in liquid. On the first condition, we could obtain the result that interface moved higher pressure side to lower pressure side. On the second condition, we could obtain the result that the bubble shrinked. However, the velocity distribution near the boundaries is wrong because the computational domain is too small for a bubble size. In addition, the pressure gradient is large compared with actual that. Therefore, the pressure should be used van der Waals model. It can represent thermal situation between two phases. I made a presentation about above research on the conference[1].

A formulation of bubble generation is difficult. Bubble generation is a micro phenomenon. There are some nucleus and bubbles will be generated from the nucleus. The NSK equations cannot represent the bubble generation. We are going to formulate it based on the homogeneous nucleation theory. Nucleation rate can be derived from the theory, and we are going to incorporate it to the multiscale formulation. In the multiscale formulation, *finescale* is defined as a functional related to the residual of *coarse scale.* I made a presentation about bubble generation in the international workshop.

IV. Research Plan for AY2023

We are going to do following research for multiscale formulation including bubble generation.

- Numerical analysis considering surface tension and van der Waals model
- Formulation of bubble generation
- Validate the multiscale formulation to do numerical analysis for bubbles which are not resolved by mesh