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INCOMPRESSIBLE GAS-LIQUID TWO PHASE FLOW ANALYSIS USING A PARTICLE METHOD FOR FUEL CELLS

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ABSTRACT

Particle methods are studied to analize complex motion of free surface flow. Since motion of the particles is the same as that of the surface of the fluid, surface tracking is not needed. Particle methods are also applied to multi-phase flow including gas-liquid two phase flow. However, the large density ratio of two fluids causes instabilities. Colagrossi and Landrini[1] proposed a formulation to calculate gas-liquid two phase flow stably. However thier method is limited to weekly compressible flow. On the other hand, Hu and Adams[2] developed a method to analize incompressible multi-phase flow, though their was used for small density ratios. In this study, a large density ratio as gas-liquid two phase flow is calculated with the incompressible condition. We use Moving Particle Semi-implicit (MPS) method, which is one of the particle methods for continuum mechanics.

In MPS, models for differential operators are fomulated using a weight function:

$$w(|\mathbf{r}_{ij}|) = \frac{r_e}{|\mathbf{r}_{ij}|} - 1, \tag{1}$$

where $\mathbf{r}_{ij}$ and r_e are the relative coodinate and the cutoff radius, respectively. Particle number density and normalization factor λ are defined as

$$n_i = \sum_j w(|\mathbf{r}_{ij}|) \tag{2}$$

and

$$\lambda = \frac{\sum_j |\mathbf{r}_{ij}|^2 w(|\mathbf{r}_{ij}|)}{\sum_j w(|\mathbf{r}_{ij}|)}. \tag{3}$$

We propose new particle interaction models, with which large density ratio can be calculated.

The lapcican of pressure used in Poisson's equation of the pressure is discritized to

$$\left(\nabla\left(\frac{1}{\rho}\nabla P\right)\right)_i = \frac{2d}{n^0\lambda}\sum_j \frac{\rho_i+\rho_j}{2\rho_i\rho_j}(P_j-P_i)w(|\mathbf{r}_{ij}|) \tag{4}$$

where d is the spacial dimensions. The laplacian model is reformulated including ρ_i and ρ_j, which are the densities of paricles i and j, respectively.

The gradient model of pressure is also re-formulated as

$$\nabla P_i = \frac{2d}{n^0}\sum_j \frac{\rho_i P_j+\rho_j P_i}{\rho_i+\rho_j}\frac{\mathbf{r}_{ij}}{|\mathbf{r}_{ij}|^2}w(|\mathbf{r}_{ij}|). \tag{5}$$

We also adopted the formulation to suppress the numerical oscillation or pressure[3]. The source term of Poisson's equation of pressure was re-formulated as

$$\left(\nabla\left(\frac{1}{\rho}\nabla P\right)\right)_i = -\frac{1}{\Delta t^2}\frac{n_i^*-n_i^k}{n^0}. \tag{6}$$

With this formulation the change of the particle number density is kept almost null. Additionally stability was also improved.

Dam break is analyzed using the proposed models.

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