Development of an accurate and efficient particle method for practical simulations of multiphase fluid flows

The research aimed at proposing an accurate, reliable particle-based computational tool for practical simulations of two-phase gas-liquid flows. During the first phase of this research an accurate two-phase particle method was developed and rigorously verified. This part of research was published in Journal of Computational Physics. The developed multiphase method was characterized by a mathematically-physically consistent scheme for interface density modeling based on Taylor series expansion. The scheme could tackle the mathematical discontinuity of density at the interface and could also keep the sharpness of spatial density variations. Although the second phase of research was initially devoted to GPU-based implementation of the developed multiphase code, the method was decided to be further enhanced for a comprehensive and accurate modeling of multiphase flows, including surface tension and turbulence modeling. An accurate surface tension model was then proposed.
1. 研究開始当初の背景

Multiphase flows are ubiquitous in a wide range of engineering and industrial processes at different length scales and flow regimes. Multiphase flows are also well-known to manifest themselves as unsteady processes characterized by inherently complicated physics. Hence, numerical simulation of multiphase flows has been one of the most challenging issues in Computational Fluid Dynamics. One of the most difficult challenges correspond to large/abrupt density drop at the gas-liquid interface.

2. 研究の目的

The purpose of this research was to develop an accurate and reliable particle-based computational method for practical simulations of multiphase fluid flows. The developed method is characterized by accurate/consistent numerical schemes and is supposed to provide adequate resolution of interfacial physics.

3. 研究の方法

The key issue for stable and reliable two-phase gas-liquid flows is to derive an accurate/conservative numerical scheme to model the spatial variation of density at the phase interface in a mathematically sound and physically consistent manner. Hence, a high-order, accurate scheme based on the Taylor series expansions of density field at a target particle $i$ with respect to that at a neighboring particle $j$ was derived. This scheme can be schematically shown by Fig. 1 (c, proposed scheme) where the interface sharpness is conserved and mathematical discontinuity of density (Fig. 1a) is also resolved.

![Fig. 1](image)

Fig. 1. A schematic sketch of the mathematical discontinuity of density at a phase interface (a) and the basic concept of interface density smoothening (b) and the proposed scheme (c)

4. 研究成果

The research aimed at proposing an accurate, reliable particle-based computational tool for practical simulations of two-phase gas-liquid flows. During the first phase of this research an accurate and reliable two-phase particle method was developed and was rigorously verified by a number of academic benchmark tests. This part of research was published in Journal of Computational Physics. Fig. 2 shows a typical result of the performed research corresponding to simulation of two-phase gas-liquid sloshing flows in LNG tanks.

![Fig. 2](image)

Fig. 2 Typical snapshots corresponding to simulation of a two-phase gas-liquid violent sloshing flow

The developed multiphase method was characterized by a mathematically-physically consistent scheme for interface density modeling based on Taylor series expansion of density fields at target particles with consideration of approximated values at neighboring particles and their spatial derivatives. The scheme could tackle the mathematical discontinuity of density at the
interface and could also keep the sharpness of spatial density variations.

Although the second phase of research was initially devoted to GPU-based implementation of the developed multiphase code, the method was decided to be further enhanced for a comprehensive and accurate modeling of multiphase flows, including surface tension and turbulence modeling. An accurate surface tension model was then proposed. The studies on turbulence modeling and further enhancement of the code for reliable and accurate simulations are ongoing.


Khayyer, Abbas, Kyoto University, Civil and Earth Resources Engineering Department, Associate Professor

研究者番号: 80534263
研究分担者（　）

研究者番号：

連携研究者（　）

研究者番号：