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研究課題名（和文）Development of an accurate and efficient particle method for practical simulations o f multiphase fluid flows

研究課題名（英文）Development of an accurate and efficient particle method for practical simulations of multiphase fluid flows

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研究成果の概要（和文）：本研究では，気液二相流を対象に，実務的な数値シミュレーションの実施を可能とする完全ラグランジュ型数値解析手法としての高精度粒子法の開発を目的とした．研究の第一段階では，粒子法を用いた高精度かつ安定性の高い二相流モデルを新たに構築し，複数のベンチマークテストからモデルの再現性を詳細に検討した．本成果は，Journal of Computational Physics にて発表済みである．開発したモデルでは，対象粒子の周囲に配列する近傍粒子について，各粒子が保持する密度および対象粒子間との密度に関する空間微分を新たに考慮することで，テイラー展開に則した数学的により厳密な密度を対象粒子へ付与する．

研究成果の概要（英文）：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.

研究分野：Hydraulics

キーワード：Particle Method　Multiphase flows　gas-liquid flows　CFD

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.

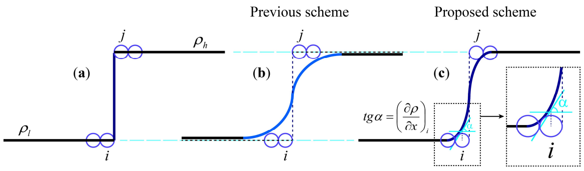

Fig. 1. A schematic sketch of the mathematical discontinuity of density at a phase interface (a) and the basic concept of interface density smoothening (b) and the proposed scheme (c)

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.

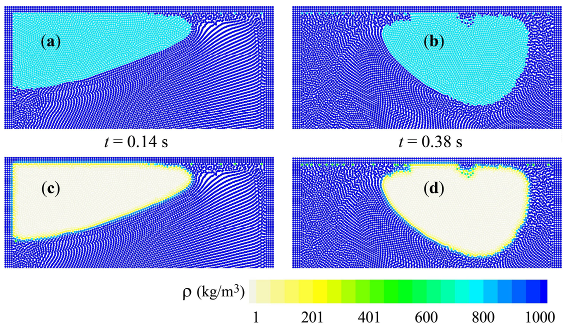

Fig. 2 Typical snapshots corresponding to simulation of a two-phase gas-liquid violent sloshing flow

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.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計　2　件）

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〔図書〕（計　　件）

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○出願状況（計　　件）

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〔その他〕
ホームページ等

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