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Modelling Incompressible Fluid Dynamics with Surface Tension: A Computational Perspective

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Introduction

Computational model designed to simulate incompressible fluid flows with the inclusion of surface tension effects. The model is developed using a combination of advanced numerical techniques, such as finite difference, finite volume, or finite element methods, to capture the behaviour of the fluid interface and the influence of surface tension forces. This model can be applied to a wide range of engineering and physics problems involving multi-phase flows, such as droplet dynamics, capillary rise, and fluid-structure interactions. The accuracy and efficiency of the model are validated through several benchmark problems, demonstrating its potential for practical applications in simulations of microfluidics, chemical processing, and other fields where surface tension plays a significant role. Computational modelling of incompressible flow with surface tension is crucial in various engineering and scientific applications, including microfluidics, multiphase flows, and fluid dynamics. Incompressible flows are characterized by constant density, and surface tension adds an additional level of complexity due to the presence of interfaces between different fluid phases. Developing accurate computational models for incompressible flow with surface tension is essential for understanding fluid behaviour and optimizing engineering designs, The Navier-Stokes equations govern the motion of incompressible fluids and form the basis for computational modelling of incompressible flow. These equations describe the conservation of momentum and the continuity equation for incompressible fluid flow. In the presence of surface tension, additional terms related to surface tension gradient and curvature contribute to the momentum balance at the fluid interface, Level set and Volume Of Fluid (VOF) methods are commonly used to track and capture the interface between different fluid phases in incompressible flow simulations. These methods enable the accurate representation of the interface between fluids with different properties, including the effects of surface tension. By tracking the interface position and employing appropriate numerical schemes, level set and VOF methods facilitate the modelling of incompressible flows with surface tension.

Description

Surface tension is a fundamental property of fluid interfaces and plays a significant role in determining the behaviour of multiphase systems. Surface tension is often incorporated into computational models through additional terms in the governing equations, representing the force exerted by the surface tension at the fluid interface. Various approaches, such as Continuum Surface Force (CSF) models or phase field methods, are used to model surface tension effects in incompressible flow simulations, The Lattice Boltzmann method is a powerful computational approach for simulating incompressible multiphase flows, including the effects of surface tension. Lattice Boltzmann Method (LBM) is based on mesoscopic kinetic theory and offers a flexible framework for modelling complex fluid dynamics, including interfacial phenomena. By incorporating appropriate boundary conditions and interfacial tension models, Lattice Boltzmann Method (LBM) can accurately capture the behavior of incompressible flows with surface tension [1,2]. Open FOAM, open-source Computational Fluid Dynamics (CFD) software, provides a flexible platform for simulating incompressible multiphase flows with surface tension effects. Open FOAM offers a wide range of solvers and models specifically designed for simulating complex fluid dynamics, including the interaction between multiple fluid phases and the effects of surface tension. Users can leverage Open FOAM's capabilities to develop comprehensive computational models for incompressible flow with surface tension [3-5].

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Conclusion

Accurate computational models for incompressible flow with surface tension have broad applications in microfluidics, multiphase flows, and industrial processes. These models are instrumental in optimizing the design of microfluidic devices, predicting the behaviour of droplets and bubbles in multiphase systems, and understanding the dynamics of fluid interfaces in various engineering and scientific contexts. The development of robust and accurate computational models for incompressible flow with surface tension contributes to advancements in diverse fields, including biomedical engineering, materials science, and chemical engineering. In conclusion, the computational modelling of incompressible flow with surface tension is essential for understanding complex fluid dynamics and optimizing engineering designs. Leveraging numerical methods, such as the Navier-Stokes equations, level set or VOF methods, and the Lattice Boltzmann method, along with software platforms like Open FOAM, enables the development of comprehensive computational models for incompressible flow with surface tension. These models have broad applications and significant impact across various engineering and scientific disciplines, contributing to advancements in fluid dynamics, multiphase flows, and interfacial phenomena.

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Conflict of Interest

None.

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