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考虑接触角的两相格子玻尔兹曼模型：无界面速度滑移和非物理密度层

摘要

本文评估了各种作用力格式在运动条件下的适用性以及各种接触角格式的表现。研究发现，大多数作用力格式存在界面速度滑移问题，而其他格式则无法实现热力学一致性。此外，大多数接触角格式会在壁面附近产生非物理密度层，导致速度剖面出现显著偏差。为解决这些问题，本文提出了一种新型伪势模型，该模型结合了新的伪势力和改进的接触角格式。新的伪势力确保了热力学一致性，同时消除了界面速度滑移；改进的接触角格式有效去除了非物理密度层，并可在很大范围内灵活调整接触角。使用所提出的伪势模型模拟了方腔和圆管中的毛细提升现象。模拟结果与解析解吻合良好，准确捕捉了毛细提升的稳态和动态行为。这些结果体现了该模型在模拟毛细现象方面的巨大潜力。

关键词

格子玻尔兹曼方法；两相流；接触角；毛细提升

Abstract

The applicability of various force schemes under moving conditions is evaluated using two-phase Poiseuille flow simulations. Most force schemes are found to suffer from interfacial velocity slip, while others fail to achieve thermodynamic consistency. Additionally, the performance of various contact angle schemes is assessed. It is observed that most contact angle schemes produce unphysical density layers near the wall, leading to significant errors in velocity profiles. To address these challenges, we propose a novel pseudopotential model incorporating a new pseudopotential force and an improved contact angle scheme. The new pseudopotential force ensures thermodynamic consistency while eliminating interfacial velocity slip. Furthermore, the improved contact angle scheme effectively removes the unphysical density layer and allows for flexible adjustment of contact angles across a wide range. The proposed pseudopotential model is applied to simulate capillary rise in cavities and tubes. The simulation results show excellent agreement with analytical solutions, accurately capturing both the steady-state and dynamic behaviors of capillary rise. These findings highlight the significant potential of our model for simulating capillary phenomena.

Keywords

Lattice Boltzmann method, Two-phase flow, Contact angle, Capillary rise.

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