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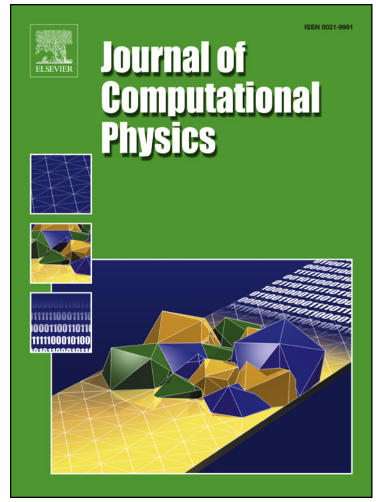

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A numerical model of two-phase flow at the micro-scale using the volume-of-fluid method

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Abstract

This study presents a simple and robust numerical scheme to model two-phase flows at small scales in which capillary forces dominate over viscous effects. The volume-of-fluid method is employed to capture the interface whose dynamics is explicitly described based on a finite volume discretization of the Navier-Stokes equations. Interfacial forces are calculated directly on reconstructed interface elements such that the total interface curvature is preserved. The computed interfacial forces are explicitly added to the Navier-Stokes equations using a sharp formulation which effectively eliminates spurious currents. The stability and accuracy of the implemented scheme is validated on several two- and three-dimensional test cases, which indicate the capability of the method to model two-phase flow processes at the micro-scale. In particular we show how the co-current flow of two viscous fluids leads to greatly enhanced flow conductance for the wetting phase in corners of the pore space, compared to a case where the non-wetting phase is an inviscid gas.

Keywords: two-phase flow, micro-scale modelling, volume-of-fluid method, spurious currents.

1. Introduction

Understanding multiphase flow through porous media is of great importance in a variety of environmental, industrial and engineering applications such as contaminant cleanup [35], fluid separation in fuel cells [48], enhanced oil recovery [29] and carbon dioxide storage in geological porous media [32]. However, accurate modelling and quantification of such flows at the pore level is challenging when the interfacial tension effects become dominant. Inaccurate numerical modelling of the interfacial force may upset the balance of forces in the momentum conservation equation and lead to instabilities and unphysical results [54, 16, 17].

Popular approaches to simulate multiphase pore-scale processes in porous media include pore-networks models [13, 7, 6, 53], lattice Boltzmann models [47, 40, 2], mesh-free

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