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RESEARCH PAPER

SPH simulation of selective withdrawal from microcavity

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Abstract The selective withdrawal of weakly compressible fluids is investigated by smoothed particle hydrodynamics (SPH) with a revised model of surface tension. In our model problem, fluid is withdrawn from a two-dimensional microcavity through a narrow outlet above the interface of two immiscible fluids. The outflow boundary is implemented by a particular zone of fluid particles with prescribed velocity, together with the introduction of artificial boundary particles. Based on the average number density of fluid particles, the effective contribution of boundary particles is corrected for the compressible context. It is found that there exists a critical withdrawal rate for each initial interface height, beyond which the lower phase becomes entrained in a thin spout along with the upper phase. Besides, the Froude number with redefinition for this kind of multiphase flow could serve as a criterion of flow behavior. Furthermore, larger surface tension, smaller dynamical viscosity and density of the upper phase all lead to longer threshold time of formation of the spout state, and thus are favorable to the withdrawal of upper phase both in terms of higher efficiency and larger quantity.

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1 Introduction

Multiphase flow of immiscible fluids is frequently encountered in varieties of microfluidic systems, including oil recovery, emulsification, contaminant transport, and so forth. A comprehensive understanding of topological transitions in multiphase flow is crucial to the advance of technological applications. Compared to gas–liquid two-phase flow in microfluidic devices (Xu et al. 1999; Triplett et al. 1999), immiscible liquid–liquid two-phase flow have not been extensively studied. Besides, most researches on liquid–liquid microsystems are restricted to the incompressible flow within the common microchannels (Zhao et al. 2006; Xu et al. 2008), particularly focusing on the identification of different flow patterns. As for the so-called "selective withdrawal", fluid is withdrawn through a nozzle suspended above the flat interface of two immiscible fluids (Case and Nagel 2007). The potential applications of selective withdrawal have been investigated recently, such as coating of microparticles (Cohen et al. 2001) and formation of droplets using flow-focusing technique (Anna et al. 2003). Consequently, in addition to previous researches on incompressible fluids with free surface, a detailed understanding of selective withdrawal for weakly compressible fluids with confined boundaries is of great significance.

Apart from traditional experimental methods, the emerging numerical techniques play an important role in the studies of microfluidic technologies. Actually, a number of numerical algorithms based on Eulerian grids have been applied to capture or track the dynamical interfaces in