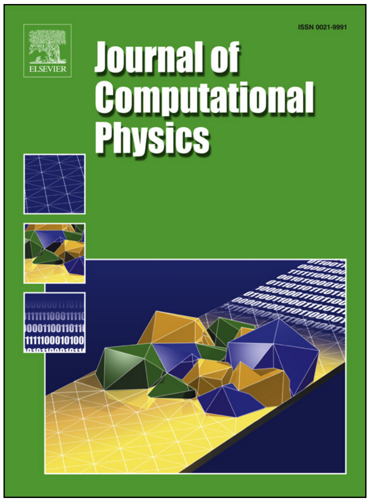

Multiscale level-set method for accurate modeling of immiscible two-phase flow with deposited thin films on solid surfaces

Moataz O. Abu-Al-Saud, Amir Riaz, Hamdi A. Tchelepi

PII: S0021-9991(16)30700-8
DOI: http://dx.doi.org/10.1016/j.jcp.2016.12.038
Reference: YJCPH 7038

To appear in: *Journal of Computational Physics*

Received date: 5 August 2016
Revised date: 9 December 2016
Accepted date: 19 December 2016

Please cite this article in press as: M.O. Abu-Al-Saud et al., Multiscale level-set method for accurate modeling of immiscible two-phase flow with deposited thin films on solid surfaces, *J. Comput. Phys.* (2016), http://dx.doi.org/10.1016/j.jcp.2016.12.038

Multiscale level-set method for accurate modeling of immiscible two-phase flow with deposited thin films on solid surfaces

Moataz O. Abu-Al-Saud, Amir Riaz, Hamdi A. Tchelepi

Abstract

We developed a multiscale sharp-interface level-set method for immiscible two-phase flow with a pre-existing thin film on solid surfaces. The lubrication approximation theory is used to model the thin-film equation efficiently. The incompressible Navier-Stokes, level-set, and thin-film evolution equations are coupled sequentially to capture the dynamics occurring at multiple length scales. The Hamilton-Jacobi level-set reinitialization is employed to construct the signed-distance function, which takes into account the deposited thin-film on the solid surface. The proposed multiscale method is validated and shown to match the augmented Young-Laplace equation for a static meniscus in a capillary tube. Viscous bending of the advancing interface over the precursor film is captured by the proposed level-set method and agrees with the Cox-Voinov theory. The advancing bubble surrounded by a wetting film inside a capillary tube is considered, and the predicted film thickness compares well with both theory and experiments. We also demonstrate that the multiscale level-set approach can model immiscible two-phase flow with a capillary number as low as 10^{-6}.

1. Introduction

Wetting phenomena are important in determining the behavior of a wide range of physical processes. Examples include two-phase flow in porous media (enhanced oil recovery [41] and CO_2 sequestration [9]), microfluidic devices [71], coating flows [37], and inkjet printing [40]. There are several challenges in modeling multiphase flow with wetting dynamics from both the physical and numerical standpoints. The physics of problems involving wetting dynamics is fundamentally multiscale and can include effects that originate at the molecular scale [59]. With the conventional hydrodynamics assumptions of no-slip, Newtonian fluids, and a rigid solid, there will be an unbounded stress singularity when the fluid interface comes in contact with the solid surface (also known as the Moving Contact Line (MCL) problem) [30].

To circumvent the stress singularity associated with MCLs, several mechanisms that have plausible physical basis have been proposed including interface diffusion [58], and evaporation/condensation processes [70]. The most common approaches include slip-based models [20], and film models based on intermolecular