The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

A level-set model for two-phase flow with variable surface tension: Thermocapillary and surfactants

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Keywords: *Variable surface tension, Unstructured level-set method, Unstructured flux-limiters, Finite-volume method, Thermocapillary, Insoluble surfactants, Two-phase flow*

Two-phase flows with variable surface tension, e.g., thermocapillary and insoluble/soluble surfactants, are frequent in nature and industry. Multiple examples can be found in chemical processing plants, thermal energy technology, microfluidic devices, and micro-gravity environments. Variations in surface tension creates both normal and shear Marangoni forces in the surface, which can arise from temperature variations or inhomogeneous distribution of surfactants on the interface. This research introduces a novel unstructured level-set method [1, 2, 3] for two-phase flows with variable surface tension, which extends our previous work on thermocapillary motion of droplets [2], to include the effect of insoluble surfactants on the interface. The incompressible Navier-Stokes equations is coupled with the transport equation for interfacial surfactant concentration, trough the surface tension force, included in the framework of the called one-fluid formulation. An equation of state is used to relate the surface tension to the interfacial surfactant concentration. Transport equations are discretized by the finite-volume method on 3D collocated unstructured meshes [1, 2, 3]. Diffusive term is approximated by central-difference scheme. Convective term of momentum equation, interface concentration transport equation, and level-set advection equation, are solved by unstructured flux-limiters schemes, as first proposed by [1, 2, 3], to minimize the so-called numerical diffusion, and to avoid numerical oscillations on discontinuities. The pressure-velocity coupling is solved by the classical fractional-step projection method. Validations/verifications of numerical methods, as well as thermocapillary- and concentration-driven migration of bubbles/droplets are presented.

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