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An energy-preserving MAC numerical scheme for the Volume Of Fluid method and application on Taylor flows

Wednesday, 2 June 2021 15:00 (15 minutes)

This work focuses on numerical simulations of two-phase flows in porous media at pore-scale in the framework of Volume Of Fluids (VOF) methods. The numerical scheme consists in solving on staggered grids the transport equation for the color function using an alternate directions algorithm together with the variable density incompressible Navier-Stokes equations using a pressure correction technique. A particular attention is paid to the discretization of the surface tension forcing term performed within the Continuum Surface Force formalism. Following the pioneering work of Jacqmin [1], we propose here an energy-conserving numerical scheme that consists in estimating the capillary force following a convex combination of the curvature with respect to the color function.The implementation is carried out in the CAFIF3S platform, a parallel open-source multiphase flow solver developed by IRSN and used for a wide range applications, including laminar or turbulent flows [2].

To validate our approach, we evaluate our results against several benchmark and test cases available in the literature. We first compare the energy-balanced discretization to the CSF Brackbill for a static bubble. An advanced comparison is carried out for the quantification of spurious currents using dimensionless velocity and vorticity for different Laplace numbers. We find that our scheme reduces spurious currents compared to CSF and generally performs well against other approaches that do not use a surface reconstruction (Abadie & al [3]). In a second step, we focus on the drainage of a liquid phase in a vertical cylindrical tube for a range of capillary numbers. We compare our results for film thickness against numerical approaches in the literature and the Bretherton model, as presented in Lasseux [4]. We find good agreement for several capillary numbers with Horgue & al [5], Lasseux [4] and the Bretherton model. We further discuss the robustness of our approach and general guidelines for optimizing mesh.

At last, we consider Taylor bubbles in a horizontal cylindrical tube, as presented in Gupta & al [6]. This type of flow is characterized by the presence of elongated bubbles, with diameters close to the width of the tube, that are separated by liquid plugs. The flow also features liquid films along the wall, which depend on the capillary number and can be extremely thin, thus posing a numerical challenge. A mesh convergence study is carried out for the calculation of film thicknesses. Our results are in good agreement with those of the benchmark. We also study of spurious currents at the interface as well as bubble shapes and gas hold-up.

Time Block Preference

Time Block B (14:00-17:00 CET)

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Primary authors: ID MOULAY, Mohamed (Institut Des Mécaniques Des Fluides De Toulouse); DAVIT, Yohan (Institut de Mécanique des Fluides de Toulouse); Mr DUVAL, Fabien (Institut de Radioprotection et de Sûreté Nucléaire (IRSN)); Mr LATCHÉ, Jean-Claude (Institut de Radioprotection et de Sûreté Nucléaire (IRSN)); QUINTARD, Michel (Institut de Mécanique des Fluides de Toulouse)

Presenter: ID MOULAY, Mohamed (Institut Des Mécaniques Des Fluides De Toulouse)

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