Implicit Multigrid Computations of Unsteady Multiphase Flows in Varying Cross-Sectional Area Channels

S. Gökaltun, H. Saygın and M. Muradoğlu
Informatics Institute, Istanbul Technical University,
Maslak, 34469 Istanbul, TURKEY
Department of Mechanical Engineering, Koc University, TURKEY

Abstract

An alternating direction implicit (ADI) multigrid scheme has been extended to treat incompressible unsteady multiphase flows using the concept of dual-time stepping (or temporal subiteration) similar to that developed by Caughey[1] and a front tracking method[2]. Since the incompressible Navier-Stokes equations are valid for all phases, a single set of governing equations is written for the entire computational domain and different phases are treated as one fluid with variable material properties. The surface tension acting on the phase interfaces is included in the momentum equations as body forces by representing it as delta function. The resulting field equations are solved by an ADI multigrid scheme using a dual-time stepping method in which pseudo time derivative terms are added to the continuity and momentum equations and temporal subiterations are performed until a steady state is reached in pseudo time for each physical time step.

In the present work, the method has been applied to compute two dimensional incompressible multiphase flows using body-fitted curvilinear grids. The interfaces are represented by Lagrangian marker points and are tracked explicitly in the curvilinear grids. An auxiliary regular Cartesian grid is utilized for efficient tracking of the marker points in curvilinear grids. The spatial derivatives are approximated using a finite volume method that is equivalent to a second order central difference scheme on regular grids. Numerical dissipation terms are added to the flow equations to stabilize the numerical method[5]. The physical time derivative terms are approximated with a second order three point backward implicit method. The convergence rate in pseudo time is further accelerated by using standard convergence acceleration techniques including a preconditioning method based on the concept of the artificial compressibility[3, 4], a multigrid method[1] and local time stepping method.

The method is first validated for a free rising bubble in a constant cross-sectional area channel under the action of buoyancy and the results are compared with the finite difference/front tracking method of Tryggvason et al.[2]. Then the method is used to compute bubbly flows in varying cross-sectional channels under various boundary conditions for a single bubble and many bubble cases. The issues regarding convergence in pseudo time and stability of the method are adressed and the grid convergence and time accuracy of the method are demosntrated for the test cases mentioned above.

The preliminary results show that the present method is very efficient and the results compare very well with the finite difference/front tracking method of Tryggvason et al.[2] for the standard test cases.

References

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