Simulating gas-liquid flows using single phase formulation using a meshless method

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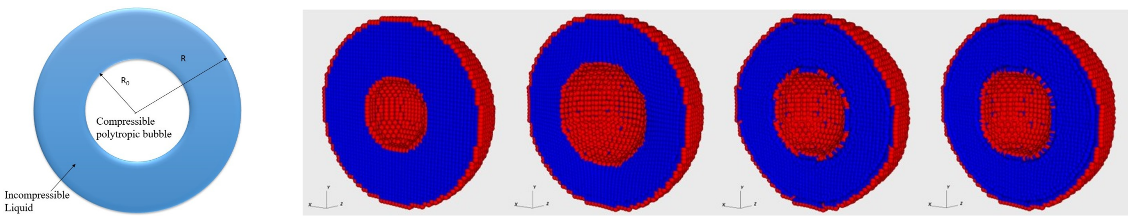
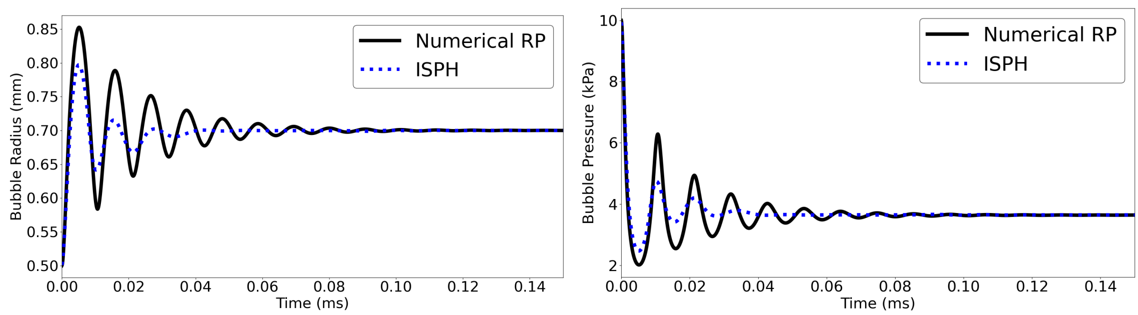
Gas-liquid two phase flows is at the heart of several energy-related industrial processes such as bubble column reactors and effervescent atomization. Typically, the gas phase is entrained as bubbles into the nearly incompressible liquid phase with large pressure. These bubbles respond to ambient pressure variation, resulting in instabilities at the liquid's interfaces, leading to a variety of dynamical phenomena such as bubble growth, implosion or even rupture at the free surface. Modeling the gaseous phase as a compressible fluid is required in such bubble dynamics applications, where the gas bubbles are enclosed by a finite domain of incompressible liquid. Assuming spherical symmetry, the dynamics can be modeled by the Rayleigh-Plesset (RP) equation[1] [2] , and is being employed to study a wide range of phenomena such as cavitation. We introduce a polytropic gas-law based gas-liquid model that assumes a compressible gas phase with zero inertia. The model is implemented in Lagrangian meshless framework, employing the incompressible smoothed particle hydrodynamics (ISPH)[3] framework, where the stress balance at the gas-liquid interface is effectively modeled as a pressure boundary condition to the liquid phase. The model is schematically represented in Figure 1a. The model and its implementation is validated against the Rayleigh-Plesset equation solutions solutions with different initial conditions and dynamic parameters as shown in Figure 2, and the dynamics are captured very well. The method is then employed to simulate non-axisymmetric bubble dynamics problems, such as in cavitation problems and the results are validated against experiments in literature.

Keywords: Polytropic bubble, modeling, SPH



(a) (b)

Figure 1: (a) 3D bubble geometry (b) Cut-section view of evolving bubble using ISPH.



(a) (b)

Figure 2: Comparison plots of RP numerical solution (black-solid) with SPH simulations (blue-dotted)

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