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# BUOYANCY DRIVEN, MULTI-PHASE FLOW SIMULATIONS USING SMOOTHED PARTICLE HYDRODYNAMICS

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Smoothed Particle Hydrodynamics (SPH) is a fully Lagrangian, particle-based approach for fluid-flows simulations. This method was independently proposed by Gingold & Monaghan (Gingold et al., 1977) and Lucy (Lucy, 1977) to simulate some astrophysicial phenomena at the hydrodynamic level. Nowadays, SPH is more and more often used for flows in hydroengineering (Lee et al., 2010) and in geophysical applications (Prakash et al., 2011). Its main advantage over Eulerian techniques is no need of the numerical grid. Therefore, there is no necessity to handle the interface shape as it is done in Volume-of-Fluid, Level-Set or Front-Tracking methods. Thus, this approach is suitable to use for complex geometries, multi-phase flows with interfaces or free-surface flows. In SPH, the fluid dynamics is represented by particle evolution equations introduced through integral interpolants of field quantities.

Buoyancy driven, multi-phase flows are very common in many scientific and technical issues as nuclear reactor systems or foundry devices. In many cases, simulations of the interface position are crucial for properly modeling such processes. One of the examples is boiling process where the computed liquid-vapour interface location and interfacial area have a significant influence on the mass transfer. Due to this complexity, most recently developed Eulerian methods are not suitable for a full description of boiling phenomena, involving also: nucleation, growth, and detachment of vapor bubbles and transition into different boiling regimes with increasing heat flux though the wall.

In the present work we discuss the usefulness of the SPH approach for modeling the boiling phenomena. The study is supported by two- and three-dimensional validation cases involving: the Rayleigh-Bernard & Rayleigh-Taylor instabilities and an air bubble rising in water, cf. Fig. 1. To properly model the multi-phase flows with large density differences, Hu & Adams SPH formulation has been used (Hu et al., 2007). For modeling the surface-tension phenomena the Continuum Surface Force (Morris, 2000) technique is used. The natural convection phenomena are modeled using the general (Non-Boussinesq) formulation proposed in (Szewc et al. 2011). In the work we consider both incompressible (liquid) and compressible (air in bubbles) flow regimes. This constraint is assured using weakly compressible technique, where the standard set of governing equations is closed by suitably-chosen, artificial equation of state.

Due to the Lagrangian nature of SPH and consequently the irregular distribution of particles in domain, the modeling of the hydrostatic pressure is not straightforward. Therefore, we give special attention to the techniques of modeling the hydrostatic pressure in SPH.

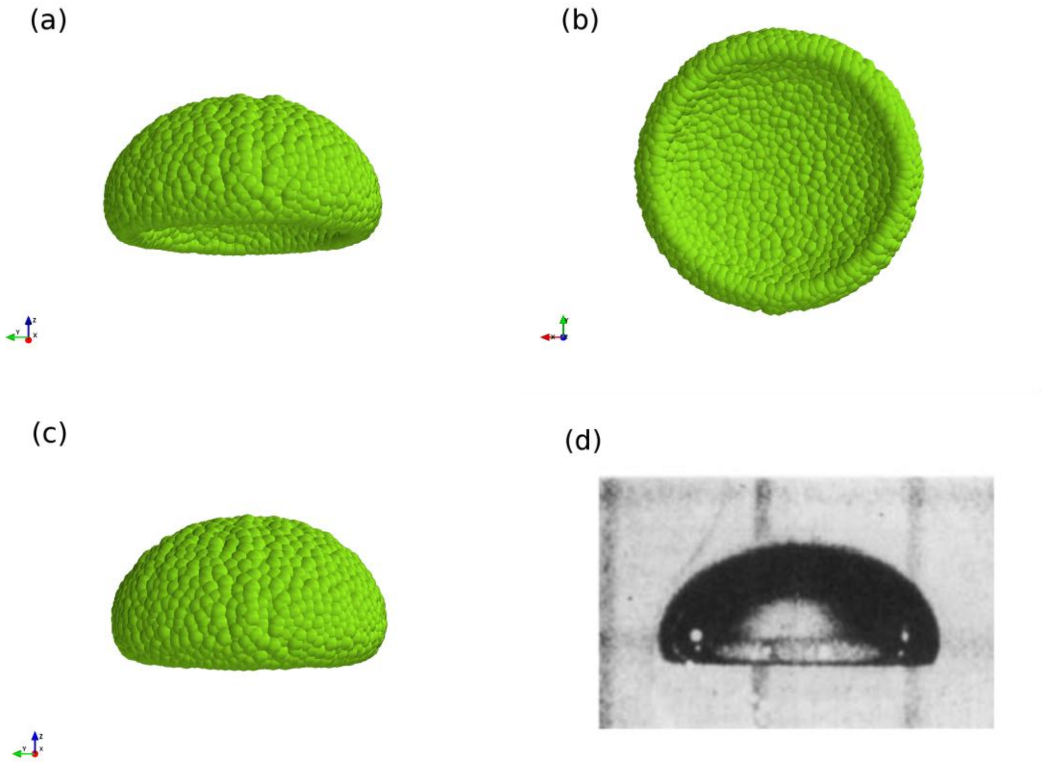


**Figure 1.** Air bubble rising in water at Re≈13, Bo≈115, Mo≈6: (a)-(c) SPH solution, (d) the experimental result obtained by Bhaga & Weber (Bhaga et al., 1981).

## References

Gingold, R. A., Monaghan, J. J., (1977): *Smoothed Particle Hydrodynamics: theory and appllication to non-spherical stars,* Monthly Notices of Royal Astronomical Society, Vol. 181, pp. 375-389.

Lucy, L. B., (1977): *A numerical approach to the testing of the fission hypothesis*, The Astronomical Journal, Vol. 82, pp. 1013-1024.

Lee E.S., Violeau, D., Issa, R., Ploix S., (2010): *Application of weakly compressible and truly incompressible SPH to 3D water collapse in waterworks*, Journal of Hydraulic Research, Vol. 48, pp. 50-60.

Prakash, M., Cleary P.W., (2011): *Three dimensional modeling of lava flow using Smoothed Particle Hydrodynamics,* Applied Mathematical Modelling, Vol. 35, pp. 3021-3035.

Hu, X. Y., Adams N. A., (2006): *A multi-phase SPH method for macroscopic and mesoscopic flows*, Journal of Computational Physics, Vol. 213, pp. 844-861.

Morris, J. P., (2000): *Simulating surface tension with smoothed particle hydrodynamics*, Journal of Computational Physics, Vol. 33, pp. 333-353.

Szewc, K., Pozorski, J., Taniere A., (2011): *Modeling of natural convection with Smoothed Particle Hydrodynamics: Non-Boussinesq formulation*, International Journal of Heat and Mass Transfer, Vol. 54, pp. 4807-4816.

Bhaga, D., Weber M. E., (1981*): Bubbles in viscous liquid: shapes, wakes and velocities, Journal of Fluid Mechanics*, Vol. 105, pp. 61-85.