Interface tracking methods for complex flows

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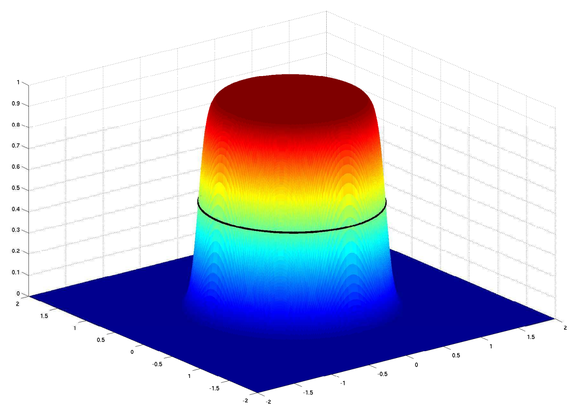
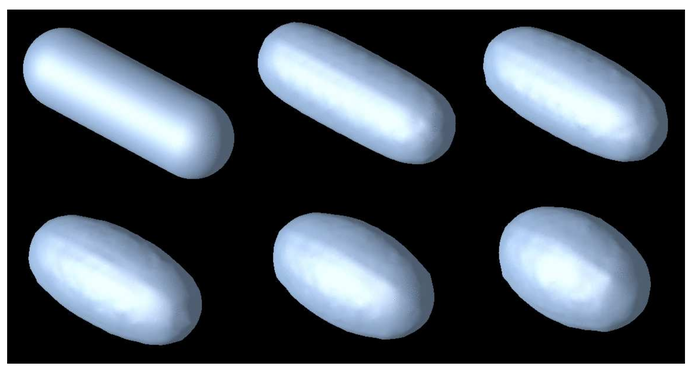
Multiphase flows commonly occur in nature. It is continuing to pose a challenge to many research scientists, specially in complex flows. The group "Complex flow" at Linné Flow Centre has been successfully developed and applied differrent methods for both simulation and experiment to study the multiphase flow problems. The interface tracking method based on (1) the front tracking method by using the conservation level-set function or the segment method; (2) The Volume Of Fluid method; (3) Lagrangian Particle Tracking; and (4) Diffuse Interface method. We can also applied several experimental methods as the Particle Image velocimetry (PIV) PIV/PIV; LDV/PDA and High-speed PTV.

Sharp interface methods

This method has been using for free boundary problems for interfaces separating immiscible fluids (liquids or gases) with different properties such as density and viscosity. The importance is the effects of surface tension as well as more complex surface physics e.g. dynamic wetting and influence of surfactants. For example, detergent is a surfactant that lowers the surface tension of an interface.
Methods: Incompressible Navier-Stokes for the fluids, interface modeled by sharp-interface models based on level-set technology or front tracking. Finite element and finite difference discretizations are used.



The interface is defined implicitly as the 0.5 contour of a regularized characteristic function. By using this function instead of the for level-set methods standard distance function, a good conservation of mass for both fluids is achieved by using a conservative numerical discretization.

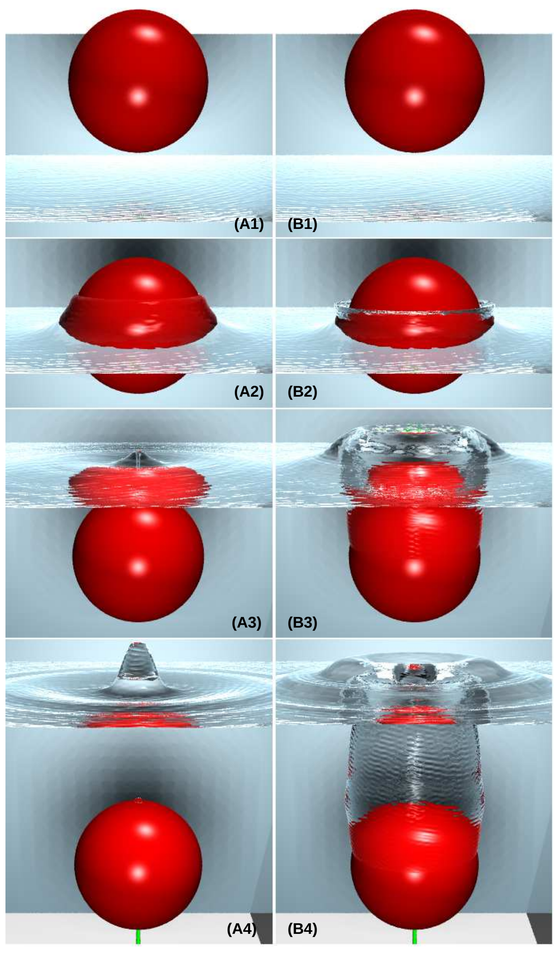


A 3D bubble oscillating computed by conservative level set method. The flow is capillary dominated, with $Ca = 1$, $Re \ll 1$.

Diffuse interface method

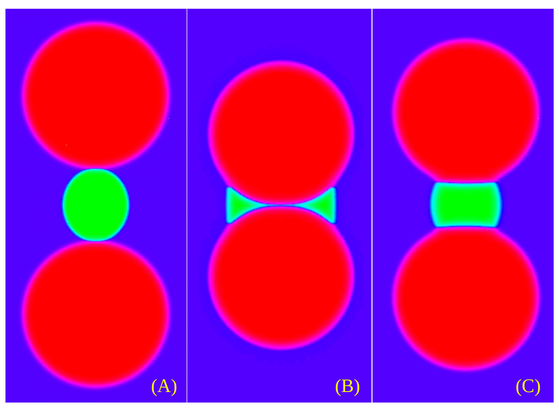
Diffuse interface methods model a fluid interface as having a finite thickness endowed with physical properties such as surface tension, phase change, dynamic wetting and reactive wetting, etc. This method allows to model the two-phase flows including problems related to microfluidics or more complicated multiphase flows such as liquid phase sintering with reactive or nonreactive wetting.

Simulation of the impact of a solid object on a free liquid surface by solving the Navier-Stokes together with the Cahn-Hillard equations, which allows us to simulate the motion of a free air-water surface in detail, in the presence of surface tension and dynamic wetting.



Hydrophilic (A) and hydrophobic (B) sphere impacting on a water surface.

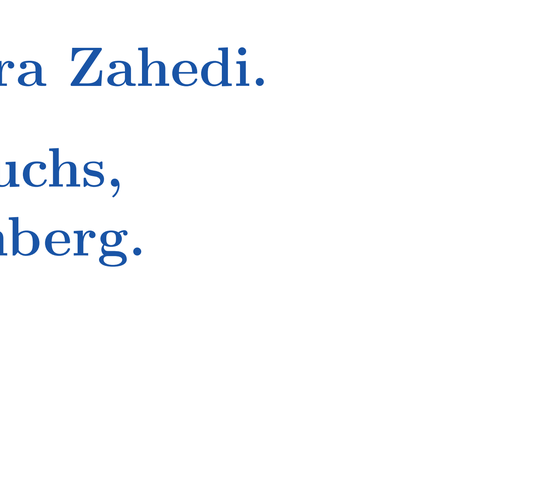
The motion of two solid particles connected by a liquid bridge is very important in material processing as phase sintering etc. This problem can be simulated by using the multicomponent and multiphase modeling with reactive or nonreactive wetting.



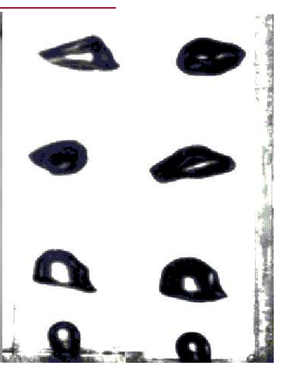
Initial configuration (A), final configuration for contact angles $\theta = 36°$ (B) and $\theta = 101°$ (C).

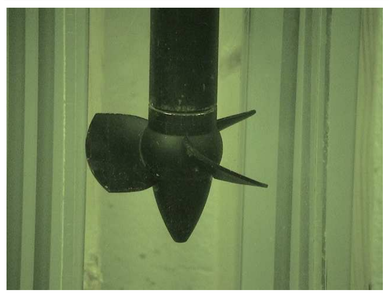
Interface tracking using patches.

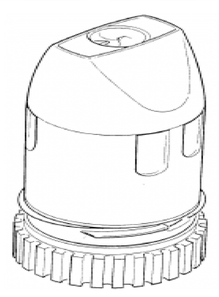
Considering the interface between two fluids as a union of overlapping segments. This provides an explicit ("sharp") interface tracking method without many of the drawbacks of front tracking. Suitable equations for the dyanmics of the interface have been derived, and a method for their numerical solution been developed.



Multi-phase flows







Areas of multi-phase flow research

- Fuel sprays (gas turbines, IC-engines)
- Bubbly flows (bio-reactors)
- Particle laden flows (drug delivery)
- Cavitation (hydro-turbines, fuel injection).

Experimental methods:

- Particle Image velocimetry (PIV) PIV/PIV,
- LDV/PDA,
- High-speed PTV.

Computational methods:

- Lagrangian Particle Tracking;
- Volume of Fluid (VOF);
- Volume of Solid (VOS);
- Local homogenous mixture models;
- Lattice Boltzmann.