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The X-Mesh method applied to Multiphase Flows

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One challenging problem in computational mechanics is the modelling of moving boundaries and interfaces. We use a new approach X-Mesh to simulate with the finite element method the interaction between two immiscible flow keeping a precise description of the interface at low cost. Numerous techniques have been developed for this field of applications: Arbitrary Lagrangian-Eulerian (ALE) method, level set method, diffuse methods etc. Although they all have interesting advantages, each one of these methods suffer from drawbacks: inability to take into account large motions of the interface as well as changes of topology, loss of simplicity and robustness of the classical finite element method, over-diffusion of the interface etc.

X-Mesh [1] is a new approach that tries to combine the advantages of the existing methods, leaving aside their drawbacks. In this method a deforming mesh with fixed topology and continuous movements of nodes permanently match the interfaces of interest, even in the case of topological changes of the fluid domains. To achieve this goal the method authorises zero-measure elements, meaning a triangle can deform to an edge or even a point. This allows the mesh to deform in a time continuous manner and provides the relaying of the front. The interface is transferred from one node to another node located at the same position enabling interface propagation.

The simulation of two immiscible fluids is computed by coupling this new interface tracking method to a fully implicit incompressible Navier-Stokes solver. In order to capture the interface, a level set is advected based on the velocity field provided by the solver. The advection equation is solved by a Crank-Nicholson scheme described within the Arbitrary Langrangian-Eulerian (ALE) formulation to manage the moving nodes. Finally the obtained non-linear system is solved with Newton-Raphson and the interface position is updated.

The validation of the method is given for challenging problems such as bubble rise, bubble merging, Rayleigh-Taylor instabilities and sinusoidal perturbation. The quality of the results and the method efficiency show the large potential of this approach to simulate such challenging physical phenomena.

REFERENCES

[1] Nicolas Moes, Jean-François Remacle, Jonathan Lambrechts and Benoit Le *The eXtreme Mesh deformation approach (X-MESH) for the Stefan phase-change model.*