A new approach for two-phase flows simulation: X-Mesh

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ABSTRACT

The accurate modeling of moving interfaces is a numerical difficulty arising in a wide range of problems of computational mechanics. Recently a new method called X-Mesh was developed and tested for the case of phase changing simulations with the Stefan model. This approach is similar to the Arbitrary Lagrangian Eulerian (ALE) method but instead of always placing the same nodes on the interface, X-Mesh will place the nodes of the mesh on the interface one after the other in the way of a relay race. The mesh movement can thus lead to extremely deformed and almost degenerated elements. This new method allows us to track the interface in a sharp manner while having large interface displacements, phase topology changes without remeshing.

We are interested in using this method to simulate complex two-phase flows. Numerous techniques have been developed for this field of applications: Arbitrary Lagrangian-Eulerian (ALE) method, level set method (LS), diffuse methods (DM) 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 (ALE), loss of simplicity and robustness of the classical finite element method (LS), over-diffusion of the interface (DM) etc.

In this work we used a level set function to represent the interface between our two-fluids. The mesh is deformed to be conform to the interface following the X-Mesh approach. The elements are always considered either being completely filled with one fluid or the other, avoiding the mushy zone of the diffuse method and the elements that are partially filled by each fluid from the level set methods. That allows us to recover the simplicity and robustness of the classical finite element method without introducing over-diffusion of the interface. The surface tension between the two immiscible fluids is added using the ghost fluid method. Unlike the classical ghost fluid method applied on a fixed mesh, we have the nodes of the mesh positioned on the interface and thus the pressure jump is truly sharp. This approach allow us to reduce parasitical current in the case of the static bubble down to the numerical precision.

The validation of the method is given for challenging problems such as bubble rise, Rayleigh-Taylor instabilities and dam break simulations. The precise tracking of the interface at low cost shows the potential of this approach to simulate such challenging physical phenomena.

REFERENCES

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