Numerical modelling of fluid-structure interactions

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ABSTRACT

Fluid-structure interactions (FSI) problems occur when a potentially deformable solid interacts with a surrounding fluid. The flow of the fluid deforms the solid and/or changes its position thus modifying the geometry of the fluid domain.

Arbitrary Lagrangian–Eulerian (ALE) formulations [1] provide a general framework for solving FSI problems. The ALE formulation represents a very versatile combination of the classical Lagrangian description for the solid and of the Eulerian description for the fluid. One of the major difficulties in ALE description of fluid-structure interactions is, knowing the displacement of the solid domain, to determine how to update the fluid mesh. If care is not taken, elements adjacent to the solid boundary can degenerate leading to computational problems and eventually to the divergence of the solution process. The computer implementation of the ALE technique thus requires the introduction of a mesh-update procedure that assigns mesh-node velocities or displacements at each time step of a calculation. The mesh nodes thus move with an arbitrary velocity. The choice of the mesh velocity constitutes one of the most important steps with the ALE description.

In most recent works, the mesh is moved by solving a partial differential equation knowing the displacement of the nodes on the boundary of the solid. In this paper, we focus on these mesh-update procedures for ALE formulations in FSI problems. More precisely, we will present different methods for updating the mesh and compare their efficiency. We will first present some test problems (coupled FSI problem) and then we will introduce different mesh-update methods for the model problem including those using a Laplace operator (see [2]), the elasticity equations (see [3]) and also using a kriging method also known as radial basis function interpolation (see [4]). We will also introduce a new differential operator allowing very large deformations. The efficiency of every mesh-update algorithm will be illustrated with numerical examples in both two and three-dimensional examples.

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