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A hybrid ALE-fixed-grid approach for 3D fluid-structure interaction

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ABSTRACT

For fluid-structure interaction problems involving large deformations, fixed-grid methods sparked quite some interest in recent years. In fixed-grid methods, the entire fluid domain is described by an Eulerian fluid formulation without any moving or deforming fluid meshes. Thus fixed-grid methods allow large and complex deformations of the structure. An important prerequisite for achieving reliable results for complex FSI problems is a proper mesh resolution around the structural surface. The inability of existing fixed-grid approaches to match this requirement usually prevents fixed-grid methods to be used for complex FSI problems in real world scenarios. A rather straightforward solution would be local, adaptive mesh refinement combined with error-estimator-based and/or heuristic refinement indicators. However, such an adaptive approach becomes rather inefficient for 3D problems involving large motions of structural surface, since either often larger regions have to be refined and/or the mesh updates may have to be done very often during the course of a simulation. Furthermore, it is almost impossible to produce extremely stretched elements in 3D that are needed in boundary layers. Thus, a hybrid approach combining fixed-grid and ALE techniques based on a Lagrange-multiplier approach was proposed in [1] for 2D FSI problems. In this approach a surface layer of deformable fluid elements based on an ALE formulation is added and deformed with the structural surface.
In this talk, we introduce a new method for 2D and 3D problems to efficiently add a deformable fluid domain around the structure surface. Again the ALE fluid that surrounds the structure is embedded into the background fluid [2]. The surface coupling condition between the two fluid domains is imposed weakly using a stabilized Nitsche formulation together with edge-based and Ghost-penalty stabilization [3,4] to retain accuracy and stability [5]. The coupling between the moving ALE-fluid domain and the structure is handled in the same way as in traditional ALE-FSI schemes. Numerical examples will demonstrate the applicability of this approach for FSI problems.

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