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A 3D XFEM/LAGRANGE MULTIPLIER BASED APPROACH FOR FLUID-STRUCTURE INTERACTION

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ABSTRACT

This talk illustrates the ongoing effort to develop a fixed grid fluid-structure interaction scheme that can be applied to the 3-dimensional interaction of most general structures with incompressible flows.

The most common approaches to simulate fluid structure interaction (FSI) are based on Arbitrary-Lagrangean-Eulerian (ALE) formulations, where the interface between fluid and structure is tracked and the fluid mesh deforms according to the interface movement. When dealing with large deformations and complex problems, robust, efficient and especially general mesh moving algorithms still set limitations to ALE approaches. To completely circumvent such restrictions one can also do FSI problems on fixed fluid grids, i.e. in the way of interface capturing methods. The mathematical foundation and the implementation of such a method for 3-dimensional problems is the topic of this presentation.

As a core feature, the eXtended Finite Element Method (XFEM) in combination with stabilized, equal order (Q2Q2) elements is used to account for the moving interface on the fixed fluid grid. The commonly used Lagrangean structural formulation is not affected by the extended fluid formulation. Hence, no restrictions exist with respect to possible deformation modes or the choice of structural material models. Along the fluid-structure interface, Lagrange multiplier techniques ensure a consistent coupling between kinematic and kinetic variables of both fields allowing both monolithic and partitioned solution approaches. For the examples given in this presentation, the extended Eulerian fluid field and the Lagrangian structural field are coupled using a partitioned, iterative approach that we have successfully applied to ALE methods before.

While mathematically the extension of the XFEM and Lagrange multiplier formulations from 2d to 3d is ‘straight forward’, many challenges have to be met to allow an efficient and accurate 3d implementation. This includes among others, geometric questions like locating the interface on the fixed grids. In this presentation, we sketch our approach of finding and intersecting higher order fluid elements with curved structural surfaces in a parallel environment that is needed for 3-dimensional large scale problems The closely related problem of properly integrating domain integrals in intersected elements as well as surface integrals along the FSI interface will be discussed as well.

Finally, the presentation of fluid and FSI benchmark simulations shall verify the correctness of our approach.

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