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A POWERFUL NEW FIXED-GRID APPROACH FOR FLUID-STRUCTURE INTERACTION

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ABSTRACT

This talk mainly discusses a new fixed-grid approach for fluid-structure interaction that is able to get rid of limitations most existing fixed-grid approaches are suffering from. We will demonstrate the individual building blocks needed to empower this approach to deal with realistic three-dimensional fluid-structure interaction examples.

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. While many such fixed-grid approaches exist in the literature most of them are suffering from a number of more or less severe limitations [1]. Hence, it is very difficult or impossible to apply these methods to a wide range of general problems.

This was our motivation to develop a new fixed-grid approach that is able to get rid of those limitations. As a core feature an enrichment of fluid elements is used to account for the moving interface on the fixed fluid grid. This enrichment is done in the spirit of the eXtended Finite Element Method (XFEM) in combination with stabilized, equal order (Q2Q2) elements. 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. The basic idea of this approach in a two-dimensional setting has been presented in [2].

In order to toughen such an approach up for dealing with three-dimensional realistic fluid-structure interaction examples is however not straightforward. In the talk we will present solutions to many challenges that have to be met along this way. These are among others: - to realize appropriate fluid meshes (like boundary layer meshes) where needed [3]; - to locate the interface and to intersect fluid elements with structural elements – this should be possible also for higher order fluid elements and for curved structural elements [4]; - to establish an appropriate Lagrange Multiplier formulation in such a context; - to find suitable ways for intersected domain and surface integration; and to set all these algorithms up in a parallel environment that is needed for 3-dimensional large scale problems. And last but not least one also desperately needs proper coupling schemes [5, 6] in order to get an efficient overall approach.

REFERENCES

[1] W.A. Wall, A. Gerstenberger, P. Gamnitzer, C. Förster, E. Ramm. "Large deformation fluid-structure interaction advances in ALE methods and new fixed grid approaches". in: H.-J. Bungartz, M. Schäfer (eds.), Fluid-Structure Interaction: Modelling, Simulation, Optimisation, LNCSE, Springer Verlag, 2006.

[2] A. Gerstenberger, W.A. Wall. "An extended finite element method / Lagrange multiplier based approach for fluid-structure interaction". *Computer Methods in Applied Mechanics and Engineering*, in press (doi:10.1016/j.cma.2007.07.002), 2007.

[3] A. Gerstenberger, W.A. Wall. "Enhancement of fixed-grid methods towards complex fluid-structure interaction applications". *International Journal for Numerical Methods in Fluids*, submitted, 2007.

[4] U.M. Mayer, A. Gerstenberger, W.A. Wall. "Three-dimensional interface localization for higher-order XFEM computations in fluid-structure interaction". in preparation, 2008.

[5] U. Küttler, W.A. Wall. "Fixedpoint fluidstructure interaction solvers with dynamic relaxation". *Computational Mechanics*, submitted, 2007.

[6] U. Küttler, W.A.Wall. "Vector extrapolation for strong coupling fluidstructure interaction solvers". *Journal of Applied Mechanics*, submitted, 2007.