A stabilized XFEM-based fixed-grid approach for fluid-structure interaction

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ABSTRACT

XFEM based fixed-grid methods represent very promising approaches when dealing with moving boundaries or more complex fluid-structure interaction (FSI) applications involving large deformations of the structure. Classical ALE-based FSI schemes are limited when the structure undergoes too large displacements or even topological changes. However, describing the entire fluid domain by a fixed-grid Eulerian formulation using cut elements allows for large and complex changes of the physical fluid domain without fluid mesh distortion and eventually, remeshing of the fluid domain. For the robustness and, hence the applicability of such fixed-grid FSI-approaches it is essential to satisfy highest demands on approximation quality, stability and accuracy of the fixed-grid formulation, particularly with regard to moving boundaries or interfaces in time. And most if not all existing approaches show severe weaknesses in one or all of these aspects.

In this talk we propose a novel robust fixed-grid FSI approach based on a stabilized fictitious domain fluid formulation for the 3D Navier-Stokes equations on moving fluid domains. The approach is built from the following essential ingredients: since the mesh is not fitted to the domain, boundary and coupling conditions are imposed weakly using a stabilized Nitsche-type approach [1][2]. In case of arbitrary cut fluid elements stability and the control of non-physical degrees of freedom outside the physical fluid domain are crucial. To retain accuracy in imposing boundary conditions recently developed Ghost Penalty stabilization based fictitious domain methods [2] have been applied. In a similar way, fluid instabilities are compensated by the usage of edge-based fluid stabilizations [3]. These techniques have been combined and extended to the 3D incompressible Navier-Stokes equations to obtain a robust, stable and accurate fluid formulation together with an improvement of the system conditioning without element manipulation or blocking strategies for degrees of freedom [1].

In the talk the method will be introduced and results from numerical analysis and simulations of fluid problems with moving structural interfaces will be shown. Time-discretization issues stemming from movement of the fluid-structure interface on fixed-grid fluid domains will be addressed [4] and different fluid-structure coupling schemes will be discussed. Furthermore, results from numerical simulations of fluid-structure-interaction problems will show the capability of this approach.

REFERENCES

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