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A FACE-ORIENTED STABILIZED XFEM APPROACH FOR CONVECTION DOMINATED FLOW PROBLEMS USING CUT ELEMENTS

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XFEM based fixed-grid methods represent very promising approaches when dealing with moving boundaries or interfaces for flow problems. Especially for applications like fluid-structure interaction or multiphase flows, fixed-grid methods using cut elements became attractive approaches. Whereas classical ALE-based discretization schemes are limited when the interface undergoes too large displacements or even topological changes, 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. However, for the robustness and, hence the applicability of such fixed-grid approaches it is essential to satisfy highest demands on approximation quality, stability and accuracy of the fixed-grid formulation. In particular convection dominated flow problems discretized on fixed grids involving moving boundaries or interfaces in time are still challenging. And most if not all existing approaches show severe weaknesses in one or all of these aspects.

In this talk, we propose a robust stabilized fixed-grid fictitious domain fluid formulation for 3D incompressible Navier-Stokes equations using cut elements for low and high Reynolds number flows [1, 2]. 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 [3]. Additional boundary/interface stabilization terms are applied to control the boundary conditions and the mass conservation for convection dominated flows [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 [3] have been applied. The idea of viscous ghost penalties has been extended to account for different fluid instabilities, i.e. the classical inf-sup instability and instabilities arising from the convective derivative and the incompressibility constraint for convection dominated flows. Face-oriented fluid stabilizations [1, 2, 4], adapted in the interface zone, and the need for additional velocity and pressure ghost penalty terms in the interface zone to obtain a robust, stable and accurate fluid formulation for convection dominated time-dependent fluid problems will be addressed.

In the talk, the different stabilization techniques are presented and focus is directed to stabilizing convection dominated flows in the boundary/interface zone. We propose major results from a numerical analysis of our stabilized method for Oseen equations [2] and show results of several numerical parameter and error convergence studies. Furthermore, results of different convection dominated flow problems involving moving domains like fixed-grid fluid-structure interaction and multiphase flow problems will show the applicability of the stabilized fluid formulation and the effect on the robustness of the simulations for practical relevant flow problems.

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