A solution for the incompressibility dilemma in partitioned fluid-structure interaction with pure Dirichlet fluid domains

Abstract:
In a subset of fluid-structure interaction (FSI) problems of incompressible flow and highly deformable structures all popular partitioned approaches fail to work. This also holds for recently quite popular strong coupling approaches based on Dirichlet-Neumann substructuring. This subset can be described as the special case where the fluid domain is entirely enclosed by Dirichlet boundary conditions, i.e. prescribed velocities. A vivid simple example would be a balloon with prescribed inflow rate. In such cases the incompressibility of the fluid cannot be satisfied during standard alternating FSI iterations as the deformation of the coupling surface is determined by the structural displacement that usually does not know about the current constraint on the fluid field. By analysing this deficiency of the partitioned algorithm a small augmentation is proposed which allows to overcome the dilemma of incompressibility and fixed boundary velocities by introducing the volume constraint on the structural system of equations. In contrast to the original accelerated strong coupling partitioned method the relaxation which
ensures convergence of the iteration over the different fields has now to be performed on the coupling forces rather than on the displacements. In addition two alternative approaches are discussed for the solution of the dilemma. The capability of the proposed method to deal with largely changing volumes of enclosed fluid is demonstrated by means of numerical examples.

Stichworte: incompressible fluid, fluid-structure-interaction, pure Dirichlet domain, augmented Dirichlet-Neumann approach

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