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IMMERSED FLUID-STRUCTURE INTERACTION FOR ISOGEOMETRIC SHELL STRUCTURES, WITH APPLICATION TO BIOPROSTHETIC HEART VALVES

David Kamensky[1,*], Ming-Chen Hsu[2], Dominik Schillinger[3], John A. Evans[4], Yuri Bazilevs[5], Michael S. Sacks[1], Thomas J.R. Hughes[1]

[1] Institute for Computational Engineering and Sciences, The University of Texas at Austin, Austin TX 78712, USA
[2] Department of Mechanical Engineering, Iowa State University, 2025 Black Engineering, Ames, IA 50011, USA
[3] Department of Civil Engineering, University of Minnesota, 500 Pillsbury Drive S.E., Minneapolis, MN 55455, USA
[4] Department of Aerospace Engineering Sciences, University of Colorado at Boulder, 492 UCB, Boulder, CO 80309, USA
[5] Department of Structural Engineering, University of California, San Diego, La Jolla, CA 92093, USA
[*] Correspondence to `kamensky@ices.utexas.edu`

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The aim of this work is to produce a geometrically flexible technique for computing fluid-structure interaction (FSI) between thin shell structures and incompressible fluids. The motivating application is simulation of a bioprosthetic heart valve (BHV), where the fluid domain undergoes large deformations, including changes of topology. We present a method that directly analyzes a NURBS surface representation of the structure by immersing it into a non-boundary-fitted discretization of the surrounding fluid domain.

Our starting point is an augmented Lagrangian (AL) formulation for FSI that enforces kinematic constraints with a combination of Lagrange multipliers and penalty forces. Previous work with this AL FSI formulation formally eliminated the multiplier field by substituting a fluid-structure interface traction, computed from the fluid Cauchy stress [1]. When the non-boundary-fitted discrete representation of the fluid requires that the pressure field be continuous through an immersed shell structure, the tractions from opposite sides cancel, leaving a penalty method. We find this penalty method sufficient to accurately compute quantities of interest for some problem types, but application to a BHV, where there is a large pressure jump across the leaflets, reveals shortcomings that we attempt to remedy.

To counteract steep pressure gradients through the structure without the conditioning problems that accompany strong penalty forces, we add additional unknowns to approximate the multiplier field. Further, since the fluid discretization is not tailored to the structure geometry, there is a significant error in the approximation of pressure discontinuities across the shell. This error interacts badly with residual-based stabilized methods for incompressible flow, leading to problematic compressibility at practical levels of refinement. We modify existing stabilized methods to improve performance. Results from benchmark problems and simulation of a BHV demonstrate the effectiveness of our techniques.

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