Immersogeometric fluid—structure interaction analysis of bioprosthetic heart valves: stability and mass conservation

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ABSTRACT

We present a methodology for immersing spline-based representations of thin flexible structures into stabilized discretizations of unsteady viscous incompressible flows \cite{1}. The fluid and structure sub-problems are coupled through a Lagrange multiplier field, augmented with penalization of the interface velocity difference. The fully discrete system is advanced in time using a semi-implicit algorithm. The stability of this algorithm may be analyzed by relating it to fully implicit integration of a surrogate problem, which penalizes the time integral of interface velocity difference.

We apply this methodology to the analysis of bioprosthetic heart valves, where mass conservation in the fluid sub-problem is essential to obtaining useful solutions. The Lagrange multiplier and penalty forces acting on the fluid sub-problem are concentrated on a surface of co-dimension one to the fluid domain, which can produce unacceptable violations of mass conservation in stabilized fluid discretizations. We find that a simple modification of stabilization parameters within an order-\textit{h} neighborhood of the structure can greatly reduce this error, even when the fluid is discretized using continuous equal-order pressure and velocity spaces, defined over a quasi-uniform mesh.

REFERENCES