A Parallel Fully-Coupled Fluid-Structure Interaction Simulation of a Cerebral Aneurysm

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ABSTRACT

A parallel fully-coupled approach has been developed for the fluid-structure interaction problem in a cerebral artery with aneurysm. An Arbitrary Lagrangian-Eulerian formulation based on the side-centered unstructured finite volume method [1] is employed for the governing incompressible Navier-Stokes equations and the classical Galerkin finite element formulation is used to discretize the constitutive law for the Saint Venant-Kirchhoff material in a Lagrangian frame for the solid domain. A special attention is given to construct an algorithm with exact fluid mass/volume conservation while obeying the global discrete geometric conservation law (DGCL). The resulting large-scale algebraic linear equations are solved using a one-level restricted additive Schwarz preconditioner with a block-incomplete factorization within each partitioned sub-domains. The parallel implementation of the present fully coupled unstructured fluid-structure solver is based on the PETSc library for improving the efficiency of the parallel algorithm. The proposed numerical algorithm is initially validated for a Newtonian fluid interacting with an elastic bar behind a rigid cylinder, a pressure wave propagating in a flexible circular tube, a three-dimensional simulation of vortex-induced vibration of a flag attached behind a rectangular rigid body and a two-dimensional elastic circular shell moving in a channel. Then a more complicated problem involving unsteady pulsatile blood flow in a cerebral artery with aneurysm is solved as a realistic fluid-structure interaction problem encountered in biomechanics.

REFERENCES

[1] B. Erzincanli and M. Sahin, An arbitrary Lagrangian-Eulerian formulation for solving moving boundary problems with large displacement and rotations. *Journal of Computational Physics*, 255:660-679, (2013).