A monolithic fluid-structure interaction formulation for solid and liquid membranes including free-surface contact

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ABSTRACT

A unified FSI formulation is presented for solid, liquid and mixed membranes. Nonlinear finite elements (FE) and the generalized-α scheme are used for the spatial and temporal discretization. The membrane discretization is based on curvilinear surface elements that can describe large deformations and rotations, and also provide a straightforward description for contact. The fluid is described by the incompressible Navier-Stokes equations, and its discretization is based on stabilized Petrov-Galerkin FE. The coupling between fluid and structure uses a conforming sharp interface discretization, and the resulting non-linear FE equations are solved monolithically within the Newton-Raphson scheme. An arbitrary Lagrangian-Eulerian formulation is used for the fluid in order to account for the mesh motion around the structure. The formulation is very general and admits diverse applications that include contact at free surfaces. This is demonstrated by two analytical and four numerical examples. They include balloon inflation, droplet rolling and flapping flags. They span a Reynolds-number range from 0.001 to 2000. One of the examples considers the extension to rotation-free shells using isogeometric FE.