An apropos finite element model for analysis of closed membranes interacting with internal and surrounding fluids

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ABSTRACT

This work proposes a Finite Element model for studying closed membranes interacting with internal and surrounding fluids, extending the previous work of the authors in the field of fluid-structure interaction on moving grids [1,2,3,4].

The approach is based on embedding a Lagrangian monolithic model describing the membrane containing an internal fluid into an Eulerian surrounding fluid model. This apropos kinematic framework allows for accurate fluid-membrane interface tracking as well as naturally represents discontinuities across the membrane. The model for internal fluid adopts displacements as primary kinematic variable. The internal fluid pressure is condensed globally in order to obtain the monolithic fluid-membrane momentum equation. For the fixed grid model standard velocity-pressure formulation is used. In order to obtain stable coupling for membrane materials with low density, a slight fluid compressibility is assumed. The coupling between the membrane and the internal fluid is implicit due to the monolithic setting. The filled membrane and the external fluid are coupled in a Dirichlet-Neumann fashion. Interface Dirichlet condition representing the movement of the membrane within the surrounding fluid is applied in a weak sense (i.e. as an integral over the interface) [5]. Neumann condition is obtained by projecting the surrounding fluid stress onto the embedded Lagrangian boundary (membrane surface) and subsequently adding the corresponding force term to the monolithic momentum equation. The model is extensively validated in several numerical examples and its application to a civil engineering problem of coast protection [6] via water-inflated membrane reefs is shown.

REFERENCES