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A Monolithic Arbitrary Lagrangian-Eulerian Finite Element Strategy for Partly Submerged Solid in Incompressible Fluid with Mortar Method for Modeling the Contact Surface

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Abstract : Accurate computation of hydrodynamic forces on floating structures and their deformation finds application in the ocean and naval engineering and wave energy harvesting. This manuscript presents a monolithic, finite element strategy for fluid-structure interaction involving hyper-elastic solids partly submerged in an incompressible fluid. A velocity-based Arbitrary Lagrangian-Eulerian (ALE) formulation has been used for the fluid and a displacement-based Lagrangian approach has been used for the solid. The flexibility of the ALE technique permits us to treat the free surface of the fluid as a Lagrangian entity. At the interface, the continuity of displacement, velocity and traction are enforced using the mortar method. In the mortar method, the constraints are enforced in a weak sense using the Lagrange multiplier method. In the literature, the mortar method has been shown to be robust in solving various contact mechanics problems. The time-stepping strategy used in this work reduces to the generalized trapezoidal rule in the Eulerian setting. In the Lagrangian limit, in the absence of external load, the algorithm conserves the linear and angular momentum and the total energy of the system. The use of monolithic coupling with an energy-conserving time-stepping strategy gives an unconditionally stable algorithm and allows the user to take large time steps. All the governing equations and boundary conditions have been mapped to the reference configuration. The use of the exact tangent stiffness matrix ensures that the algorithm converges quadratically within each time step. The robustness and good performance of the proposed method are demonstrated by solving benchmark problems from the literature.

Keywords : ALE, floating body, fluid-structure interaction, monolithic, mortar method
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