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Low order fictitious domain method for FSI with enhanced stability and interfacial mass conservation

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Fictitious domain methods are one of the most widespread numerical schemes for the approximation of incompressible fluid-structure interaction problems with immersed thin-walled solids. Besides this popularity, these methods are also known to suffer from several inaccuracies. In particular, major mass conservation issues have to be faced when using continuous pressure approximation across the interface (see, e.g., [3]). This is particularly striking in the case of low-order finite element approximations. Several approaches have been proposed in the literature with the aim of enhancing interfacial mass conservation, such as grad-div penalty or the addition of global mass constraints (see, e.g., [2, 1]), but at the price of compromising matrix conditioning or the stability of the numerical approximation. In this work, we propose a low-order fictitious domain method which overcomes these issues. The fundamental idea consists in combining a stabilized Lagrange multiplier formulation with a global mass constraint. We also show that the latter can be formulated as a specific enrichment of the pressure space with a simple Heaviside function, which yields inf-sup stability. The behavior of the method will be illustrated through several numerical experiments motivated by heart valve simulations.

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