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A new finite element method without boundary unknowns for a three-dimensional fluid-solid interaction problem

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Resumen

We introduce and analyze a new finite element method for a fluid-solid interaction problem in 3D. The media are governed by the acoustic and elastodynamic equations in time-harmonic regime, and the transmission conditions are given by the equilibrium of forces and the equality of the corresponding normal displacements. We employ a dual-mixed variational formulation in the solid, in which the Cauchy stress tensor and the rotation are the only unknowns, and mantain the usual primal formulation in the fluid. The main novelty of our method, with respect to previous approaches for a 2D version of this problem, consists of the introduction of the first transmission condition as part of the definition of the space to which the stress of the solid and the pressure of the fluid belong. As a consequence, and since the second transmission condition becomes natural, no Lagrange multipliers on the coupling boundary are needed, which certainly leads to a much simpler variational formulation. We show that a suitable decomposition of the space of stresses and pressures allows the application of the Babuška-Brezzi theory and the Fredholm alternative for concluding the solvability of the whole coupled problem. The unknowns of the fluid and the solid are then approximated, respectively, by Lagrange and Arnold-Falk-Winther finite element subspaces of order 1, which yields a conforming Galerkin scheme. In this way, the stability and convergence of the discrete method relies on a stable decomposition of the finite element space used to approximate the stress and the pressure variables, and also on a classical result on projection methods for Fredholm operators of index zero. Finally, we illustrate our analysis with some numerical experiments. This is a joint work with A. Marquez and S. Meddahi.

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