A Second-Order Explicit Splitting Scheme for Fluid–Poroelastic Structure Interaction Problems

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ABSTRACT

Fluid–poroelastic structure interaction problems arise in many biomedical and engineering applications, including deformable porous materials, tissue perfusion, implantable bioartificial devices, and drug-eluting stent design [1, 2]. In this talk, we present a fully discrete second-order explicit Robin-Robin splitting scheme for the time-dependent Stokes–Biot problem on fixed domains. The method is based on a Robin reformulation of the fluid–poroelastic interface conditions and combines BDF2 time discretization in the Stokes and Biot subproblems with AB2 extrapolation of the interface data. This produces a fully explicit partitioned algorithm in which the fluid and poroelastic subproblems can be solved independently and in parallel at each time step [4].

We also establish a discrete stability estimate for the fully discrete scheme using BDF2 energy identities, a decomposition of the extrapolated interface terms, and trace inequalities. The resulting stability bound is closed under a parabolic CFL condition linking the time step and mesh size. Besides, we develop an a priori error analysis in a discrete energy framework using a Fortin projection for the fluid variables and Ritz-type projections for the poroelastic variables. Under suitable regularity assumptions and second-order accurate initialization, we prove convergence in the natural energy norms, with total errors in fluid velocity, structure velocity, pore pressure, and elastic displacement bounded by $C(h^k + \Delta t^2)$. Numerical experiments based on manufactured solutions confirm the predicted convergence. This work extends earlier explicit splitting analysis for fluid–poroelastic interaction [3] and provides a justified, second-order, parallelizable method for Stokes–Biot problem.

ACKNOWLEDGMENTS

Yifan Wang's research has been supported in part by the National Science Foundation under grant DMS-2247001 and by a Simons Foundation Travel Award.

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