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A novel CPR/block preconditioning framework for two-phase flow simulations in porous media by mixed hybrid finite elements

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Efficiency and robustness of the linear solver is a fundamental need in multiphase flow models in porous media, as sequences of large ill-conditioned systems of linearized equations have to be repeatedly solved during fully implicit simulations. This is a computationally intensive task, whose performance is usually dominated by the boosting capabilities of the preconditioner accelerating a Krylov subspace solver. Although efficient physics-based preconditioning techniques exist, notably the multistage Constrained Pressure Residual (CPR) method and its variants, their robustness is often sensitive to the specific structure of the Jacobian matrix, which can be modified depending on the discretization scheme used for the set of governing PDEs. This is the case with the Mixed Hybrid Finite Element (MHFE) method, where element and interface pressure variables are introduced as main unknowns in addition to the cell-centered water saturation. The resulting Jacobian matrix is characterized by a 3×3 block structure that differs from the 2×2 structure of conventional TPFA-based discretizations, originally targeted by the CPR method. Applying this tool to the 3×3 block Jacobian is ineffective, as general-purpose AMG usually struggles with the 2×2 element-face pressure subproblem. In this work, we address this issue by introducing a block preconditioner at the local pressure stage to exploit its inner 2×2 block partition. The resulting technique, mixing block preconditioning with the CPR method, has been denoted as Block CPR (BCPR). An extensive testing phase, even on challenging realistic problems, shows the robustness, efficiency, and flexibility of the proposed framework.

Participation

In-Person

References

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Primary author: Dr NARDEAN, Stefano (Hamad Bin Khalifa University, University of Padova)

Co-authors: Prof. FERRONATO, Massimiliano (University of Padova); Dr ABUSHAIKHA, Ahmad (Hamad Bin Khalifa University)

Presenter: Prof. FERRONATO, Massimiliano (University of Padova)

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