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Block AMG Preconditioners For Mixed Finite Element Discretization of Porous Media Flow Problems

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The Darcy and the Brinkman equations are two fundamental models describing the dynamics of an inviscid (Darcy) or viscid (Brinkman) fluid in a matrix of an inhomogeneous porous medium, alternating bubbles and open channels. Typical applications of these models are in underground water hydrology, petroleum industry, automotive industry, and biomedical engineering. In these applications, the high variability in the PDE coefficients, that may take extremely large or small values, negatively affects the conditioning of the discrete problem which poses a substantial challenge for developing accurate and efficient solvers.
In this talk, we consider mixed formulations of the Darcy and Brinkman equations based on the de Rham sequence $H(\text{curl})$-$H(\text{div})$-L^2. We first give a brief overview of our previous results for their finite element discretizations with Nédélec, Raviart-Thomas and piecewise discontinuous elements and for the construction of respective block-diagonal AMG preconditioners. The theoretical results are illustrated with numerical experiments. Then we outline some progress towards the construction of specialized coarse space correction exploiting an element-based algebraic multigrid approach (AMGe) aimed at ensuring better robustness of the resulting preconditioners.
We also present an application of practical relevance in the field of petroleum industry based on the popular SPE10 dataset, a challenging benchmark for oil reservoir simulations.