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Single-phase flow simulations in large-scale fractured porous media : solver challenges

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In the subsurface, fractures are discontinuities in the medium in the form of narrow zones. Fractures are very numerous and present at all scales, with highly varying sizes and permeabilities. The permeability of the neighboring rock matrix is generally about two orders of magnitude lower than that of the fractures. This is why fractures are preferential channels for flow and, therefore, play a vital role in a large number of industrial and environmental applications.

One commonly used geometrical representation of fractured porous media is the discrete fracture matrix model (DFM) in which fractures are represented as manifolds of codimension 1. The model for single-phase flow in DFMs is described in [1], where Darcy's law in the fractures includes an additional source term that takes into account the coupling with the rock matrix.

Meshing the fracture network is carried out thanks to a specialized surface mesh generator called *MODFRAC* [2]. The surface mesh is then used as input for a volume mesh generator named *GHS3D* [3]. We developed *nef-flow-fpm*, a mixed hybrid finite element (MHFE) code for simulating steady-state incompressible single-phase flow in 3D DFMs. The MHFE method is conservative and leads to a square, sparse, symmetric, positive and definite linear system. Both direct [4, 5] and iterative [6, 7] solvers are integrated in *nef-flow-fpm*. Our code has been validated on a test case from the benchmarks in [8].

Because of the growing geometric complexity in large fracture networks, test cases recently proposed in the literature are mainly 2D, or 3D but with a limited number of fractures. In this talk, with the help of *nef-flow-fpm*, we analyze the computational costs from simulations with fracture networks of increasing complexity. The goal is to assess the performance of the linear solvers mentioned before and the challenges they face. We propose large-scale test cases, up to 87 329 fractures, generated with a genetic algorithm [9]. As expected, direct solvers suffer from large memory consumption, while iterative solvers may need a large number of iterations. Thus, we conclude that it is necessary to develop a dedicated, robust and efficient linear solver for even larger networks with more than one million fractures [10].

Participation

In-Person

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