Simulations in complex poro-fractured media: computational issues and uncertainty quantification

Stefano Berrone[1], Sandra Pieraccini[2], and Stefano Scialò[1]

[1] *Dipartimento di Scienze Matematiche, Politecnico di Torino*

[2] *Dipartimento di Ingegneria Meccanica e Aerospaziale, Politecnico di Torino*

{*stefano.berrone, sandra.pieraccini, stefano.scialo*}*@polito.it*

In the framework of underground exploitation procedures (enhanced Oil & Gas production, geothermal applications, geological storage of either nuclear waste or carbon dioxide), a large number of numerical simulations at the scale of a geological basin are typically necessary. In order to properly take into account the strong and highly variable directionality of the underground flows due to the presence of fractures, an explicit representation of the rock fractures crossing the basin is required, as fractures provide preferable flow pathways. This is accomplished, e.g., by resorting to Discrete Fracture Network (DFN) models. Fractures usually do intersect each other in a dense and chaotic way. In this context, the possibility of applying a Galerkin method for the discretization of the differential models, while avoiding mesh generation problems, is of paramount importance, being almost impossible to accomplish all conformity mesh constraints with a moderate number of unknowns per geological block or fracture.

In [1, 2, 3] a new optimization approach for flow problems in large scale DFNs is presented. The approach is based on a reformulation of the problem as the minimization of a functional measuring the hydraulic head mismatch and the flux unbalance at fracture intersections, constrained by the flow equations on the fractures. This optimization approach can be extended to the coupling of DFN with the surrounding rock matrix. The minimization is performed via the conjugate gradient method and is suitably developed to be efficiently parallelized with several approaches and/or different parallel architectures (shared memory and distributed memory systems or graphical accelerators). Large scale systems (see Figures 1) have been tackled by this approach both considering an impervious surrounding rock matrix [3] and including in the model the flux exchange with the surrounding matrix [4]. Overcoming mesh generation problems is a key point both for addressing computations on huge networks, and for performing massive simulations for uncertainty quantification analyses in stochastically generated networks [5], which is a crucial issue in this framework, due to the high uncertainty in geological data and the possible risks related to most underground exploitation techniques.

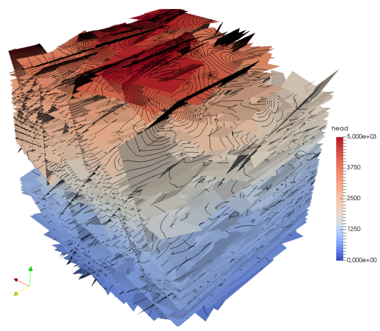

Fig. 1: Example of fracture network

References

[1] S. Berrone, S. Pieraccini, S. Scialò. *A PDE-constrained optimization formulation for discrete fracture network flows*, SIAM J. Sci. Comput., 35, (2013), B487-B510.

[2] S. Berrone, S. Pieraccini, S. Scialò. *Towards effective flow simulations in realistic Discrete Fracture Networks*, J. of Comput. Phys., 310, (2016), 181-201.

[3] S. Berrone, S. Pieraccini, S. Scialò, F. Vicini. *A parallel solver for large scale DFN flow simulations,* SIAM J. Sci. Comput., 37, (2015), C285-C306.

[4] S. Berrone, S. Pieraccini, S. Scialò. *Flow simulations in porous media with immersed intersecting fractures*, J. of Comput. Phys., 345, (2017), 768-791.

[5] S. Berrone, C. Canuto, S. Pieraccini, S. Scialò. *Uncertainty quantification in Discrete Fracture Network models: stochastic geometry*, to appear in Water Resour. Res. (2018).