Flow simulation in 3D Discrete Fracture Networks

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Natural fractured media are characterized by their diversity of structures and organization. Numerous studies in the past decades have evidenced the existence of characteristic structures at multiple scales [1]. At fracture scale, the aperture distribution is widely correlated and heterogeneous. Fractures themselves have widely varying sizes with no obvious dominating or characteristic scale. At network scale, the topology is complex resulting from mutual mechanical interactions as well as from major stresses. The diversity of structures results in widely varying mechanical, hydraulic and transport properties that require some description of the underlying fracture geometries to be predicted.

Modeling mixes dimension in a non-standard way as fracture networks consist in a large number 2D fractures interconnected in the 3D space. It is no longer 2D and not already 3D. Intricate local configurations of fracture intersections cannot be precluded and the multiple scale of the fracture structures require adapted mesh generation and discretization methods. Numerical modeling should not only be specific but also efficient to cope with essentially the statistical characterization of the fracture properties.

We have worked on three alternative strategies. The first one follows the classical methodology of finite element methods [2]. The fracture network is classically meshed with standard mesh generation methods. The flow equation is further discretized using a flow-conservative mixed hybrid finite element. While standard, this method requires an efficient mesh generator that complies with the intricate configurations when not only two but three fractures intersect close together. While these situations might not be relevant physically depending on the fracture generation process, they cannot be avoided in a stochastic framework.

The second strategy relies on the discretization of the fracture boundaries and intersections on a regular 3D grid [2]. Each fracture is then meshed independently with a re-projection in the fracture plane of its boundary and intersections with the other fractures. All elements smaller than the grid size are removed. Any discretization scheme can subsequently be applied. While difficult to implement, this method is quite general.

The third strategy decouples the problem at the fracture scale by (1) generating independent meshes at the fracture scale, (2) using a flow-conservative mixed hybrid finite element methods in the fracture planes, and (3) reconnecting fluxes at fracture intersections with Mortar-like methods [3, 4]. While it requires advanced developments in numerical methods, this method can potentially handle fracture networks by refining the meshes in the most important fractures (*Figure 1*).

*Figure 1:* Left: example of fracture network with associated heads computes with a vertical main flow direction. Right: Differential discretization with Mortar-like non-conforming methods [4].

We investigate the respective advantages and drawbacks of these three strategies according not only to their accuracy and efficiency, but also to their implementation complexity and generality.