Modeling fluid flow through complex fracture network in geological media by using hierarchical hydraulic properties

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Hydraulic stimulation is the process of initiating fractures in a target reservoir for subsurface energy resource management with applications in unconventional oil/gas and enhanced geothermal systems. The fracture characteristics (i.e., number, size and orientation with respect to the wellbore) determines the modified permeability field of the host rock and thus, numerical simulations of flow in fractured media are essential for estimating the anticipated change in reservoir productivity. However, numerical modeling of fluid flow in highly fractured media is challenging due to the explosive computational cost imposed by the explicit discretization of fractures at multiple length scales. A common strategy for mitigating this extreme cost is to crudely simplify the geometry of fracture network, thereby neglecting the important contributions made by all elements of the complex fracture system.

The proposed “Hierarchical Finite Element Method” (Hi-FEM; Weiss, Geophysics, 2017) reduces the comparatively insignificant dimensions of planar- and curvilinear-like features by translating them into integrated hydraulic conductivities, thus enabling cost-effective simulations with requisite solutions at material discontinuities without defining ad-hoc, heuristic, or empirically-estimated boundary conditions between fractures and the surrounding formation. By representing geometrical and geostatistical features of a given fracture network through the Hi-FEM computational framework, geometrically- and geomechanically-dependent fluid flow properly can now be modeled economically both within fractures as well as the surrounding medium, with a natural “physics-informed” coupling between the two.

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