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A stress-driven DFN model to account for fracture network geometrical complexity

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Discrete Fracture Network (DFN) models are the geometrical basis for flow simulation of poro-fractured media in many industrial projects such as deep waste disposal, hydrogeology or petroleum resources. Because the spatial organization of fractures may control the hydrological and mechanical behavior of the fractured rock mass, the geometrical complexity of the network is a key point of the modeling workflow. This complexity is beyond the reach of purely stochastic DFN models, referred as "Poisson models", which neglect the potential importance of fracture-to-fracture interactions, and the consequent modifications of the spatial organization and connectivity of the network. Fracture network development is a complex feedback-loop process between the propagation of fractures and the emergence of new ones. Using genetic models of fracture networks to replace the lack of field information may be a solution for realism. Recent papers (Davy et al., 2010; Davy et al., 2013) have proposed a genetic model of DFN, called "UFM model", using simplified fracturing-relevant rules for nucleation, growth and arrest of fractures. With simple kinematic rules that mimic the main mechanical processes, the model produces fracture size distributions and fracture intersections that are consistent with observations. Our objective is to improve the model by explicitly considering the control of local stresses in both nucleation and fracture growth. This has the advantage of linking the geometry and topology of fracture networks with the assumed conditions of their formation. We introduce a stress-driven nucleation in the timewise process of this kinematic model to study the correlations between nucleation, growth and existing fracture patterns. The method calculates the stress field generated by existing fractures and the allegedly known remote stress as an input for a Monte-Carlo sampling of nuclei centers at each time step. The orientation and growth rate of each newly generated fracture is then a function of the local stress field at the selected center. Networks generated by this so-called "stress-driven UFM model"are found to have fractal correlations. We also perform a lacunarity analysis of fracture densities to quantify the textural heterogeneity of fracture patterns with observation scale. We show that our model brings closer to natural data in terms of spatial variability in comparison with "Poisson models". This heterogeneity in the fractures spatial organization has important consequences on the connectivity and flow properties of the rock mass.

References

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