A geometrically based method for predicting stress-induced fracture aperture and flow in discrete fracture networks

Modeling of fluid flow in naturally fractured reservoirs is often done through modeling and upscaling of discrete fracture networks (DFNs). The two-dimensional fracture geometry required for DFNs is obtained from subsurface and outcropping analog data. However, these data provide little information on subsurface fracture aperture, which is essential for quantifying porosity and permeability. Apertures are difficult to obtain from either outcropping or subsurface data and are therefore often based on fracture size or scaling relationships, but these do not consider the orientation and spatial distribution of fractures with respect to the in situ stress field. Using finite-element simulations, mechanical aperture can be modeled explicitly, but because changes in fracture geometry require renewed meshing and simulating, this approach is not easily integrated into subsurface DFN modeling workflows. We present a geometrically based method for calculating the shear-induced hydraulic aperture, that is, an aperture of up to 0.5 mm (0.02 in.) that can result from shear displacement along irregular fracture walls. The geometrically based method does not require numerical simulations, but it can instead be directly applied to DFNs using the fracture orientation and spacing distributions in combination with an estimate of the regional stress tensor and orientation. The frequency distribution of hydraulic aperture from the geometrically based method is compared with finite-element models constructed from five real fracture networks, digitized from outcropping pavements. These networks cover a wide range of possible geometries and spatial distributions. The geometrically based method predicts the average hydraulic aperture and equivalent permeability of fractured porous media with error margins of less than 5%.

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