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Anistotropy and scaling of flow fluctuations in a rough fracture

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Is there a link between scaling laws characterizing fracture apertures and scaling laws of the velocity of the fluid flowing inside these fractures? A fluid inside a rough fracture is studied in laminar regime on the basis of the Stokes equation, using finite differences. Our model illustrates that the hydraulic flow may significantly differ from the cubic law which is obtained between flat parallel plates: for instance, the fracture roughness potentially induces channeling effects. Our computation is based on a self-affine aperture model, which has been shown to be representative of real-world fractures. However, in practice, for field measurements, it is impossible to know in detail the spatial variability of the geometrical aperture. Therefore, we search for the minimal information about the fracture morphology that is necessary and sufficient to get the right order of the hydraulic fracture permeability and its anisotropy. From several computations with various apertures, we observe that the largest scales of the aperture fluctuations control the hydraulic behavior. This remark leads us to filter the modeled aperture in the Fourier domain to remove the small scale aperture variations. Doing that, we propose an analytical model for the conductivity based on a small set of parameters which brings the right macroscopic transmissivity (within five percent accuracy). This model amounts to computing the flow in an aperture reduced to the only very few Fourier modes. In addition, an analytical expression of the velocity fluctuations in the Fourier domain as a function of the aperture fluctuation is computed, assuming the aperture to be self-affine. It shows that the scaling of the velocity heterogeneities is linked to the scaling of the aperture heterogeneities: the velocity fluctuations are as well self-affine, with the same Hurst exponent, but with a dipolar nature, i.e. with an anisotropic prefactor linked to the macroscopic pressure drop