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The Flow of a Shear-Thinning Fluid in a Geological Fracture

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Subsurface flow processes involving non-Newtonian fluids play a major role in many engineering applications, from in-situ remediation to enhanced oil recovery. The fluids of interest in such applications (f.e., polymers in remediation) often present shear-thinning properties, i.e., their viscosity decreases as a function of the local shear rate. We investigate how fracture wall roughness impacts the flow of a shear-thinning fluid. Numerical simulations of flow in 3D geological fractures are carried out by solving a modified Navier-Stokes equation incorporating the Carreau viscous-shear model. The numerical fractures consist of two isotropic self-affine surfaces which are correlated with each other above a characteristic scale (Meheust et al, 2003). Perfect plastic closing is assumed when the surfaces are in contact. The statistical parameters describing a fracture are the standard deviation of the wall roughness, the mean aperture, the correlation length, and the fracture length, the Hurst exponent being fixed (equal to 0.8). The objective is to investigate how varying the correlation length impacts the flow behavior, for different degrees of closure, and how this behavior diverges from what is known for Newtonian fluids. The results from the 3D simulations are also compared to 2D simulations based on the lubrication theory, which we have developed as an extension of the Reynolds equation for Newtonian fluids. These 2D simulations run orders of magnitude faster, which allows considering a significant statistics oSf fractures of identical statistical parameters, and therefore draw general conclusions despite the large stochasticity of the media.

References

Méheust, Y. & Schmittbuhl, J. (2003). Scale effects related to flow in rough fractures. Pure and Applied Geophysics, 160(5-6), 1023-1050.

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