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Numerical modelling of single-phase flow in rough fractures with contacts

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Fracture flow may dominate in rocks with low porosity and it can accompany both industrial and natural processes. Typical examples of such processes are natural flows in crystalline rocks and industrial flows in oil and gas production systems or hydraulic fracturing. Fracture flow provides an important mechanism for transporting mass and energy. The distribution of the apertures of fracture and contact area are the key parameters with regard to the fracture transmissivity.

We use the method of correlated random fields [Mourzenko, 1996] to generate synthetic fracture geometry in 3D. The flow of an incompressible Newtonian viscous fluid in geological formation can be approximated by the Stokes, the Stokes-Brinkman or the Reynolds models. We use our own implementation of the finite element method based on MILAMIN [Dabrowski, 2008] to solve governing partial differential equation over domain.

We compare the Stokes, the Stokes-Brinkamn and the Reynolds models for fracture flow based on systematic numerical simulations for a wide range of geometric parameters. Mismatch between the Reynolds and the Stokes models becomes significant with increasing fracture roughness or contact area. The Stokes-Brinkman model is more accurate than Reynolds models due to additional Laplacian term, which allows to fulfil no-slip boundary condition. We present condition when the Reynolds and the Stokes-Brinkman models are valid.

In the last three decades many authors used the Reynolds equation for studying fracture flow because of its simplicity. We recommend using the Stokes-Brinkman model for fracture flow, which allows to fulfil no-slip boundary condition on asperities boundary and is more accurate for rough fractures than the Reynolds model.