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Flow upscaling in propped fracture

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Proppants in combination with hydraulic fracturing are widely used to maintain the production of oil or gas from low permeability formations (i.e. shale rocks). There are also examples of proppants use in geothermal reservoirs. Flow patterns in propped fracture control transport processes and give information about fracture/matrix exchange surface. Our main motivation is to understand flow behavior in such structures using direct numerical simulations and to find a good upscaling technique to be able to investigate models on reservoir scale.

We study fracture made of two parallel plane walls, where void space between them is filled with partial monolayer of proppant. As the fracture is affected by closing pressure, the proppant grains are squeezed between two opposite fracture walls which can change the grain shapes or embed the grains into impermeable rock matrix. To take this effect into account and simplify the geometry, the grains are approximated as cylinders. Imposed macroscopic pressure gradient invokes flow in such medium. As the flow is considered in the low Reynolds number regime, a stationary velocity flow field is obtained by solving the Stokes equations in 3D by means of finite element method. Void space between the grains is accurately discretized by using tetrahedral mesh. To reduce computational effort, the Stokes equation is reduced over the fracture aperture to 2D Stokes-Brinkman equation, which is further numerically solved and compared against numerical solution in 3D.

Systematic flow calculations using 2D Stokes-Brinkman equation are performed for periodic domain and no slip boundary condition on the grain surface. Results are discussed in terms of effective properties as a function of geometrical parameters of the medium, such as proppant packing fraction and proppant grain diameter to fracture aperture ratio.