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Reduced Dimension Fracture Flow – Beyond Poiseuille Flow Models

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There are many applications which require a fracture flow model that accounts for variations in aperture beyond surface roughness. Large-scale simulations of fluid flow through fractures are almost exclusively based on the cubic law (Poiseuille flow) for steady-state flow through rigid parallel plates. When the fracture aperture is time and/or spatially varying, flow is transient, and/or flow rates are modest ($Re \geq 1$), cubic law predictions can deviate substantially from the full solution to the Navier-Stokes equations, and generally do not satisfy conservation of energy.

In this presentation, we present a new Reduced Dimension Fracture Flow (RDFF) model which is capable of capturing inertial and transient fluid behaviour through fractures of time and spatially varying aperture and conserves energy. The RDFF model is derived from the Navier-Stokes equations and yields a two-field model (fluid flux and pressure) governed by the conservation of mass and momentum. The increased complexity of the RDFF model requires novel numerical techniques to solve the governing equations. We present an explicit finite volume method based on deriving a Poisson equation for pressure and adapted for the unique idiosyncrasies of the RDFF equations. We explore the convergence behaviour of the method and demonstrate novel flow phenomena in planar and axisymmetric fractures which cannot be captured by Poiseuille flow simulations.