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Quantifying pressure fluctuations in fractured porous media using velocimetry methods

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In-depth understanding of pressure fluctuations during fluid flow in complex porous media is of significant importance in various reservoir engineering applications. Large-scale behaviours of fluid and solute transport in the subsurface are determined by pore-scale features. Therefore, it is crucial to determine pore-scale transport properties and then upscale these properties to larger scales. Numerical modelling is employed routinely to simulate fluid and solute transport as well as pressure fluctuations in fractured porous media. In contrast, only a limited number of experimental methods have been developed to determine fluid flow and pressure fields in experimental porous media investigations with sufficient spatial resolution to test or verify numerical results.

Optical flow visualization methods, for example, Particle Shadow Velocimetry (PSV), have been widely used for flow characterization. However, due to the lack of transparency of natural rocks, it is challenging, or impossible, to characterize flow inside rocks using PSV. In this study, 3D-printing technology is employed to manufacture a transparent fractured porous medium to resemble dual-permeability and dual-porosity subsurface formations. The medium consists of two flow-through and two dead-end fractures, symmetrically embedded into two matrices with different pore sizes. Using an LED light source for back illumination and a monochrome camera for image registration, fluid velocity fields can be determined, using a modified single-pixel Particle Image Velocimetry (PIV) method to determine cross-correlations of seeding particle patterns in time. We calculate pressure fluctuations in the two matrices, the two flow-through fractures, and two dead-end fractures by solving the Navier-Stokes equations with respect to the measured velocities. Our results demonstrate the potential of using flow visualization techniques to characterize flow and to determine pressure fields in complex porous media experiments.