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Flow characterization in fractured porous media using the temporo-ensemble PIV method

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In reservoir applications, such as groundwater management, geological waste disposal, and hydrogeology, a reservoir is often a heterogeneous fractured porous medium. In such a medium, mass and energy transport are considered to be strongly influenced by the fracture networks. For flow and transport simulations, the Darcy-scale approach is often used, however, its continuum-scale upscaling assumptions are questionable. Unfortunately, very few experimental observations have shed light on these questions.
Here we present an experimental framework for 2D analyses of flow in a 3D-printed fractured porous medium. The 3D-printed medium consists of well-defined heterogeneities, i.e. two porous matrices with two different pore sizes, each matrix with one dead-end and one flow-through fracture. We demonstrate the capability of a temporo-ensemble Particle Image Velocimetry (PIV) method to maximize the spatial resolution of velocity vectors (ultimately at the single-pixel resolution) using an inexpensive, in-line illumination setup. Our approach is advantageous in terms of minimizing the pixel usage for velocity determination, thus yielding high spatial resolution of velocity vectors while capturing a large field of view. Our study provides a novel experimental velocimetry framework to delineate flow in fractured porous media in order to extend the physical understanding of flow properties in such configurations. In addition, we quantify the effect of background matrices on flow velocity in fractures using the longitudinal and lateral components of flow velocities in fractures. Our results indicate that the background matrices have a significant effect on fracture-matrix flow interactions, which can dominate over the effect of fracture geometry.

References

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