Visualizing flow interactions between fracture and matrix using a temporo-ensemble PIV method

Mehrdad Ahkami[a], Thomas Roesgen[b], Martin O. Saar[a], Xiang-Zhao Kong[a]

a. Geothermal Energy and Geofluids, Institute of Geophyscs, ETH Zurich, CH-8092, Zurich, Switzerland

b. Institute of Fluid Dynamics, ETH Zurich, CH-8092, Zurich, Switzerland

mahkami@ethz.ch , xkong@ethz.ch

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ABSTRACT

In the Earth Sciences, a fractured medium is often considered to be an interacting double-continuum medium with varying transport properties. Understanding transport processes in such a double-continuum medium is crucial for understanding and optimizing mass and energy transport in various industrial and scientific applications, such as hydrogeology, geothermal energy, and geochemistry. In Engineered Geothermal Systems (EGS), fluids mainly flow through fracture networks, where the heat exchange between the matrix (i.e., heat reservoir) and fractures governs the efficiency and life time of the EGS. There, flow interactions between fracture and matrix likely govern the heat exchange rate. Several physical models (e.g., the flow transfer function (Kazemi et al., 1976; Lu et al., 2008; Abushaikha and Gosselin, 2008)) have been proposed in order to describe the fluid flow interactions between fractures and rock matrix. However, validation of these models requires laboratory experimental observations.

In the presented study, Particle Image Velocimetry (PIV) methods are used to delineate a two-dimensional (2D) fluid flow field in a well-characterized fractured porous medium that is produced using 3D printing technology. This medium consists of two matrices with two different pore sizes, each matrix containing one dead-end fracture and one flow-through fracture. This configuration allows us to quantify the effect of pore-space heterogeneity on flow behaviour at the interface between the porous rock matrices and both the dead-end and the flow-through fractures.

The utilized PIV method is capable of reducing the size of the interrogation window (and velocity vector resolution) down to a single pixel. Such small interrogation windows enable the characterization of pore-scale flow features in a large Field of View (FOV) which involves various hydraulic property heterogeneities. The results of this study illustrate the effect the fracture geometry and the permeability of the surrounding matrices have on fluid flow interactions between different regions and can be used to calibrate future numerical simulations in fractured porous media.

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