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Investigation of species transport in fractured porous media using 3D-printed micromodels

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Understanding flow and transport through fractured porous media is vital for optimising large-scale hydrological and geological processes such as carbon capture and storage, geothermal energy production, and contaminant transport. Direct Numerical Simulations (DNS) solving the Navier-Stokes equations can accurately describe species transport through relatively small volumes of porous media. However, the use of DNS to investigate large geometries with multiscale features, such as fractures, pores and micro-pores, is limited due to the significant computational costs. An alternative can be offered by the Multiscale Darcy-Brinkman-Stokes (DBS) simulations, for which under-resolved small-scale features are represented through their effective permeability and porosity values. Multiscale DBS models have been extensively benchmarked for single-phase flow through multiscale porous media. However, relatively little knowledge exists of their applicability to model species transport. Recent advances in three-dimensional (3D) printing allow for fast and cheap manufacturing of multiscale models with complex porosity distributions, which has enabled the investigation of specific flow processes. In this work, we present an experimental and numerical study of species transport through 3D-printed geometries containing both fracture and matrix. First, we conduct single-phase flow species transport experiments in order to develop a benchmark experimental dataset. Then, we compare the experimental results with the species transport obtained with DNS simulations and with multiscale DBS simulations. Our results show an accurate match between the DNS and DBS solvers. Moreover, we show that our multiscale DBS model can be used to extract the transfer function for flow and species transport at the interface between fracture and matrix, which can be used as an input for dual continuum models. Finally, we show how our model can be applied to estimate the transfer coefficients as a function of flow rate and species diffusion using a micro-CT image of a real fracture.

Participation

In-Person

References

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