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3D X-ray velocimetry for pore-scale flows in geological and industrial porous media

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Fluid dynamics in porous materials plays an important role in nature and in industry, e.g. groundwater flow in aquifers or the performance of filtration devices and porous catalysts. The intricate confining pore geometries in such materials can lead to complex flow phenomena, particularly during e.g. multiphase and non-Newtonian flows, which are difficult to reproduce in numerical or experimental model systems. A crucial impediment to investigate such phenomena is the current lack of methods to measure 3D, unsteady, pore-scale flow fields in most materials –despite advances in micro-particle velocimetry for optically transparent porous media (Roman et al. 2015, Datta et al. 2013) and MRI-based velocimetry for steady flows (De Kort et al. 2019). Here, we present new 3D micro-particle velocimetry results on flows in optically opaque porous media, based on time-resolved X-ray micro-computed tomography (micro-CT). We imaged the movement of X-ray tracing micro-particles suspended in single-phase flow, using laboratory-based fast micro-CT at frame rates on the order of tens of seconds and voxel sizes on the order of 10 μm. A Langrangian particle tracking algorithm was then used to determine individual micro-particle paths through the pores, from which the 3D, 3-component velocity field in the pore space could be interpolated. The experimental methodology was validated by testing the workflow on simulated micro-CT datasets based on ground-truth particle tracks, and by comparing the experimental results to computational fluid dynamics results. The new method is readily extendable to even higher spatial and temporal resolutions, enabling its application to complex, unsteady flows in a wide range of porous materials of scientific and industrial relevance. It thus has the potential of causing a breakthrough in the study of flow in porous media.

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

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