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Tortuosity-governed droplet transport in a microfluidic porous network

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Multiphase flow in porous media is widely studied and impacts countless applications in many natural and industrial processes, such as geologic CO2 sequestration, water infiltration into soil, and particle filtration. However, many questions remain, particularly with regard to the effect of the confinement and the geometry of the porous medium on the transport of dispersions.

We address these issues experimentally using controlled porous media: micromodels. We designed polydimethylsiloxane (PDMS) micromodels consisting of regular networks of vertical cylindrical posts, at the centres of which we injected water droplets in a continuous oil phase. A priori, no preferential paths are expected, except in a stochastic manner. However, we show that the radial alignment of the posts, i.e. the geometric tortuosity of the network, varies angularly in a periodic manner and plays a key role in droplet transport by generating reproducible preferential paths. By systematically varying the geometrical configuration of the posts, injection capillary number, droplet size, and droplet concentration, we characterise the droplet transport and the conditions for droplet breakup. At low capillary numbers, radial droplet transport is homogeneous. By increasing the capillary number, droplets initially follow the least tortuous paths before transitioning to a stable flow regime whereby droplets flow primarily in the most tortuous paths. Through large-scale droplet tracking, we demonstrate the influence of the geometric tortuosity of the media on the resulting droplet flow patterns and the counter-intuitive responses that can arise. Through this analysis, we emphasise the role of local geometrical configuration and propose a new metric for droplet transport which is the tortuosity of the porous media.

Participation

In-Person

References

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