Contribution ID: **824**

Type: **Oral Presentation**

Clogging and particle accumulation during the flow of suspensions of solid particles in model 2D porous media.

Wednesday, 24 May 2023 15:00 (15 minutes)

We are interested in the transport of solid particle suspensions in porous media, which are important in many applications, in soil mechanics, in filtering operations… etc. . The accumulation of these particles is indeed often undesirable because it leads to a reduction of the permeability and sometimes to a complete clogging of the medium. Different types of clogging (geometrical, bridging, aggregation…) have been described at the pore scale, upscaling is a real issue for these phenomena.

We have designed model experiments in 2D micromodels made with standard microfluidic techniques (PDMS and glass), at an intermediate scale consisting of about 100 x 100 pores, but keeping the resolution at the pore scale. The pore geometries consist of irregular pillars, with pore diameters of 50 micrometers, i.e. a few particle diameters. Using direct fluorescence imaging, we calculate the dynamics of the local volume fraction of particles after injection of a suspension at a controlled pressure or flow rate. Importantly, we used particles with matching index and density, which not only allows good imaging but also neglects colloidal interactions.

We systematically varied particle size, concentration, and flow rate (or pressure), and observed, in agreement with single-pore studies, that the ratio of particle diameter to pore throat diameter is most important. Below 0.2, only a few pores are clogged, whereas all experiments lead to complete clogging above 0.4. In this intermediate regime where clogging is mainly initiated by geometric bridging of some pores, we observe the formation of clusters of arrested particles. The size of these clusters increases very slowly with time until reaching either a steady state or percolation. It also depends strictly on the volume fraction of the particles. Remarkably, the size of the clusters correlates well with the total fraction of the medium occupied by the arrested particles, suggesting that the percolation theory could adequately describe the clogging. In contrast, flow rate (or pressure) has only a weak effect on the observations, which we interpret as a consequence of weak particle-to-particle and particle-to-wall interactions.

Despite its weak effect in steady state, the pressure drop has a striking influence when varied over time. Periodic experiments under similar conditions lead to the conclusion that the probability of clogging is significantly reduced in the presence of flow oscillations. In regimes where clogging does not occur in the steady state, these oscillations also reduce the particle accumulation and mean cluster size. Pressure oscillations must be of sufficiently high amplitude (typically 20% of the mean value) and of sufficiently low frequency to be used to prevent clogging of the device.

Participation

In-Person

References

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Session Classification: MS11

Track Classification: (MS11) Microfluidics and nanofluidics in porous systems