Contribution ID: **876** Type: **Oral Presentation**

Capillary entry pressure in soft porous media

Monday, 22 May 2023 17:45 (15 minutes)

The capillary entry pressure is a fundamental quantitative parameter in two phase flows in porous media. The entry pressure is set primarily by the interfacial tension between the invading and defending fluids, the relative wetting properties of the fluids on the solid skeleton, and the length scale of the pore throats. In rigid porous media, all of these quantities are typically fixed, meaning the entry pressure is a constant for a particular choice of medium or fluids.

Here, we consider entry pressure for very soft porous media: specifically, those with elastic moduli comparable to the characteristic capillary pressure scale of the system. In such media, the pore geometry may undergo significant deformations due to the injection of an invading phase. As a consequence, the size of the pore throats and, hence, the entry pressure may evolve dynamically. We investigate how entry pressure is impacted by deformation using an idealised model experimental system comprising a quasi-2D column of water-saturated hydrogel beads, which we compress using a "capillary piston": a pressure-controlled bubble of non-wetting gas that squashes the column along its length, driving liquid from the far end of the column via a permeable barrier. These experiments are complemented with simple analytical models of analogous systems.

We begin by considering quasistatic loading and then extend our study to rapid dynamical loading. The latter scenario introduces a viscous pore pressure, which further opposes the entry of gas into the pore space. We discuss how the transient consolidation flow driven by the capillary piston introduces a spatial distribution of pore and solid stresses and, hence, a spatially-distributed capillary entry pressure within the system. We consider how we may decouple the different forces at work to extract quantitative knowledge of deformation-dependent entry pressure from experimental observations of percolation in soft porous media.

Participation

In-Person

References

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Session Classification: MS06-A

Track Classification: (MS06-A) Physics of multiphase flow in diverse porous media