Contribution ID: **665** Type: **Oral Presentation**

Two-phase non-linear flow in Pore Network Model

Monday, 22 May 2023 12:20 (15 minutes)

Immiscible displacements in porous media have been extensively explored, both experimentally and numerically, in the last decades, and, for two-phase Newtonian flows, it was shown that the competition between the characteristic forces involved, like viscous and capillary forces, determines the structure of the invasion pattern [1]. In this work, we try to extend these studies taking into account some non-linear behaviors, namely the presence of yield stress and the formation of compact displacement regions. If the displaced fluid consist in a non-Newtonian Bingham liquid, flowing like a Newtonian fluid only above a finite stress, a yield stress dominant pattern emerges, characterized by needle-like paths of low dimensionality [2]. On the other hand, compact invasion regions, in which every pore is invaded by both fluids in a rapid succession, emerge when imposing a constant pressure drop throughout the medium, as recently shown experimentally in a porous Hele-Shaw cell [3]. We perform numerical simulations of a two-dimensional porous medium, in the framework of the dynamical Pore-Network model [4]. An algorithm, part of the Augmented Lagrangian methods class and already implied successfully for the study of non-Newtonian flow, was adopted for solving the non-linear relation between the flow rate and the pressure at the pore level [5]. We then characterize the structure of the invasion patterns related to these non-linear effects, measuring quantities like the saturation of the invading phase and the fractal dimension of the corresponding paths, and comparing these values with the ones present in literature for the two-phase fully-Newtonian flow. The domains of validity of these patterns are finally mapped onto a plane with axes the ratio between the different forces into play, obtaining a 'phase-diagram' for these immiscible invasion displacements.

Participation

In-Person

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Session Classification: MS06-A

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