Contribution ID: **293** Type: **Oral Presentation**

The Transition from Connected to Disconnected Pathway Flow Regime : Understanding the Combined Effects of Wettability and Flowrate

Thursday, 2 June 2022 14:45 (15 minutes)

The contribution of pore-scale properties is often neglected in large scale (macro-scale) models describing subsurface fluid processes (1). Pore-scale flow properties, such as wettability have a significant impact on macro-scale flow functions, such as relative permeability, capillary pressure, saturation distribution and displacement efficiency (2). Upscaling multiphase flow from Pore-to-Darcy scale is one of the largest unresolved problems in the field of porous media research that has attracted the interest of many researchers for decades (3). One of the key challenges is addressing connected and disconnected fluid fractions (4)(5).
In this work, the combined effects of wettability and fluid flowrate on dynamic fluid connectivity and the saturation function are investigated. Direct numerical simulations involving immiscible displacement of decane by water were performed in a 2D digital model of a Berea sandstone rock. In all simulations performed, the Berea sandstone model was initially saturated with decane and then water was injected to displace it from the pore spaces. Invading fluid Darcy velocities investigated ranged from 0.03m/s (Ca= 5.45x10-4; Reynold's number (Re) = 0.36) to 30m/s (Ca= 5.45x10-1; Re = 360). Wetting conditions investigated were for contact angles 45° (water-wet), 90° (neutrally-wet) and 150° (oil-wet).
Connected pathway flow (CPF) and two disconnected flow regimes were observed. The first disconnected flow regime was classified as ganglion dynamics (GD), where the invading fluid propagated through the pore network in the form of large, disconnected ganglia. The second disconnected flow regime was a drop traffic flow (DTF), where the invading fluid propagated throught the pore network as very small fluidic elements (droplets).
At the lowest capillary number (Ca= 5.45x10-4), the CPF regime dominated under the neutrally wet state whilst the GD flow regime dominated for the oil- and water-wet cases. A connectivity index (Λ) derived from the Euler characteristic (χ), a fluid topological descriptor, was used to track the temporal evolution of fluid connectivity as the simulations progressed. For all wetting conditions investigated, ganglia of the defending fluid became smaller and more disconnected with increasing flow rate. At the highest capillary number (Ca= 5.45x10-1), the DTF flow regime dominated for all wetting states. In cases where the GD regime dominated, low flow cohesion was observed between discrete ganglia whilst high flow cohesion was observed where the CPF regime was dominant. Although more discrete fluid elements were present in the DTF regime in comparison to the GD regime, higher flow cohesion was observed in DTF dominant cases. The transition from low cohesion to high cohesion flows was found to have a consequential effect on the kinetics of the displacement process and the shape of the saturation function. Displacement efficiency increased by up to 35% for highly cohesive flows in comparison to flows with low ganglion cohesion.
Acknowledgements
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (MILEPOST, Grant agreement no.: 695070). This paper reflects only the authors'view and ERC is not responsible for any use that may be made of the information it contains.

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Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Unsure

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Session Classification: MS06-A

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