Contribution ID: **606** Type: **Poster Presentation**

Evaluation of phase and inter-phase fractal dimensions during two-phase primary drainage in a microfluidic cell

Wednesday, 24 May 2023 10:30 (1h 30m)

It has been four decades since Wilkinson and Willemsen [1] introduced a new, at the time, theory of percolation, the invasion-percolation theory, as they named it. The concept was based on the fact that a displacement process between two immiscible fluids is capillarity-driven, but can be applied also in cases where the path of lowest resistance is followed. It involves the use of the fractal dimension of the bulk invading phase in the expression of the fraction of saturation of the relevant phase, as soon as this phase becomes connected, meaning is percolating.
In this work we quantify the bulk fractal dimension of the non-wetting phase during a primary drainage process, in a microfluidic cell with the box-counting method. Twelve combinations for boundary flux conditions and viscosity ratios were experimentally investigated, in terms of the evolution of the fractal dimension of the bulk invading phase, and all the corresponding interfaces between all phases involved, namely wetting, non-wetting and solid. Based on the images acquired during the displacement processes, plots related to the corresponding fractal dimensions for all entities with saturation, capillary number and viscosity ratio were produced, as soon as percolation was established for the non-wetting phase.
Our results showed that we could reproduce the Lenormand [2] diagram in terms of capillary and viscous fingering regimes in the capillary number - viscosity ratio space. We could also identify the relative significance of each fractal dimension with respect to the flow regime. Some of them could be used, either as stand-alone information or in a complementary manner, to identify the flow regime in the space defined by the capillary number and viscosity ratio. Finally, we speculated the reasons behind the change of the corresponding fractal dimensions with respect to saturation, as a morphological information of the corresponding bulk phases and their interfaces.

Participation

In-Person

References

1. D. Wilkinson and J. F. Willemsen 1983 J. Phys. A: Math. Gen. 16 3365
2. Lenormand, R., Touboul, E. and Zarcone, C., 1988. Numerical models and experiments on immiscible displacements in porous media. Journal of fluid mechanics, 189, pp.165-187.

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Session Classification: Poster

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