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Pattern transition during immiscible displacement of non-Newtonian fluids in a rough fracture

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Two-phase flow in fractured media involving non-Newtonian fluids is of vital importance in many subsurface engineering applications. However, the impact of non-Newtonian rheology on the displacement dynamics remains unclear. In this work, we perform primary drainage experiments in which a Xanthan gum solution displaces a silicone oil in a transparent rough fracture for a wide range of shear-thinning property (controlled by polymer concentration) and flow rates. Based on qualitative and quantitative analyses of the observed fluid morphologies, we present an experimental phase diagram of the obtained displacement patterns. We present an experimental phase diagram of the obtained displacement patterns. We characterize a novel displacement pattern where the fluid-fluid interface changes from stable (plug flow) to unstable (fingering). We further propose a theoretical model elucidating the mechanisms behind the flow regime transitions. The interface stability criterion predicted by this model is in good agreement with the experimental measurements, and stresses the important role of fluid rheology, coupled to aperture variability, in immiscible displacements in rough fractures.

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References

Zhang et al. (2023). Displacement patterns of a Newtonian fluid by a shear-thinning fluid in a rough fracture. Water Resources Research, 59, e2023WR034958.

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Primary author: YANG, Zhibing (Wuhan University)

Co-authors: ZHANG, Le (Wuhan University); Prof. MÉHEUST, Yves (Geosciences Rennes, CNRS SCTD, 2 rue Jean Zay, 54519 Vandoeuvre les Nancy); NEUWEILER, Insa (Leibnitz Universitat Hannover); HU, Ran (Wuhan University); CHEN, Yi-Feng (Wuhan University)

Presenter: YANG, Zhibing (Wuhan University)

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