A Pore-Level Analysis on Residual Oil Structure post Secondary and Tertiary Displacements

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Abstract. The use of micromodels in displacement experiments is becoming an established methodology to study oil sweep and mobilization. Enhanced oil recovery (EOR) processes reduce the remaining oil. Yet, the evolution of this remaining oil in terms of structure and conformations has not been well described. Gaining such understanding can offer an opportunity to better optimize EOR processes. Accordingly, we perform micromodel displacements and assess the microscopic changes in remaining oil.

We use a 2D micromodel mimicking the topology of a sandstone. We establish connate brine saturation. Then, we conduct oil displacements where waterflooding is followed by a tertiary surfactant-flood. After each stage, we collect 25 microscopic images across the micromodel. We then use an in-house Matlab code to analyze the images. Based on the analyzed images, we quantify remaining-oil saturations after each stage. More importantly, we delineate the remaining-oil structures in terms of size (pore-bodies spanned), conformation (degree of roundness), and connectivity (coordination number).

In this sandstone-based micromodel, the remaining oil saturation dropped from 35% after waterflooding to 15% after surfactant injection. Initial oil saturation was 87%. Image analyses allowed in-depth characterization of the remaining oil. The size-distribution of remaining oil globules was obtained after both stages. Significant reduction of the globules size was realized post surfactant-flooding. In addition, a narrower distribution was observed. In general, most remaining globules spanned multiple pore-bodies post waterflooding while almost all were reduced to occupying a portion of single pore-bodies post surfactant-flooding. As such, the conformation of the remaining oil after waterflooding was irregular as it was dictated by the underlying topology. After surfactant-flooding, most globules were circular. Accordingly, the main trapping mechanism post surfactant-flooding is snap-off. To the contrary, the remaining oil post waterflooding was largely trapped due to bypassing (pore-doublet effects)—yet, snap-off was still observed. Obviously, globules post waterflooding exhibited higher coordination numbers as they spanned multiple-pore bodies. Surfactant-flooding enabled mobilization of these globules as the interfacial tension (IFT) was reduced, which allowed viscous forces to overcome the capillary forces required to access and deform these globules. With that, we correlate IFT reduction and the narrowest coordination path (connected pore-throat).

In summary, the evolution of remaining oil has been delineated. Differences between the remaining oil before and after surfactant-flooding is clearly outlined with respect to changes in the oil globules size, connectivity, and conformation. Such understanding might offer an opportunity to better optimize EOR processes.