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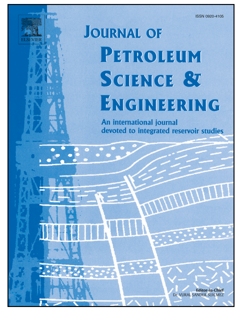

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Visualization of Fracturing Fluid Dynamics in a Nanofluidic Chip

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Abstract

Hydraulic fracturing is responsible for remarkable production from shale and tight formations, albeit at the cost of significant water usage. The flow dynamics of oil and fracturing fluid in nanopores remains largely uncharacterized, in part due to the challenge of conducting experiments at nanoscales. In this paper, we demonstrate a nanofluidic-based approach to visualize the fluid displacement during hydraulic fracturing. Nanoporous silicon-glass chips with circular and square grain shapes and identical depth of 175 nm were fabricated using reactive-ion etching (RIE) and ionic bonding. Leveraging the inherent fluorescence property of the oil, the fluorescence microscopy was used to record the dynamics of the fluid displacement inside the chip. Performance of three different fracturing fluids - deionized water, potassium chloride (KCl) solution, and slick water - were evaluated based on the volumetric infiltration in the nanoporous network, entrapment of fracturing fluid in the porous media, and total production during drawdown. The KCl solution had the highest infiltration rate (fill factor of 0.68) and the lowest entrapment factor (0.39), resulting in the highest fracturing fluid recovery representing 43% in the square grain geometry with similar results for circular grains. With the fast quantification and ease of operation here, the nanofluidic approach enables a rapid screening of different fracturing fluids to inform shale oil operators.

Keywords: Fracturing fluid; infiltration; entrapment; recovery; nanofluidic

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