An Experimental Investigation into the Pore-Scale Mechanisms during Cyclic Gaseous Solvent Injection (CGSI) for Enhanced Oil Recovery (EOR) in the Bakken Formation

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Abstract

The Bakken formation contains enormous volumes of oil and gas. However, primary recovery from this formation accounts for less than 10% recovery factor. Cyclic gaseous solvent injection (CGSI) has been identified as a promising method for improving hydrocarbon recovery. However, for industry-wide adoption, there is a need to understand the underlying multiscale recovery mechanisms better. The macroscopic performance during CGSI is a culmination of the pore-level mechanisms. Thus, understanding the pore-level displacement mechanisms under various operating conditions may hold the key to better design of CGSI in the field. To this end, we aim to comprehend the pore-level displacement efficiency of two powerful gaseous solvents, CO_2 and ethane, in middle Bakken unconventional core samples. Our method begins with measuring the initial pore size distribution (PSD) of the selected core samples using NMR relaxometry at 100% fluid saturation. Then, CGSI is simulated with the core samples in the laboratory, after which post-injection PSD measurements were performed. By comparing the PSD prior to and after CGSI, the pore-level displacement mechanisms in various pore-size groups were determined and discussed. We discuss the impact of gas composition, miscibility condition, soak period, production period, rock-surface-to-volume ratio, and their variable interactions. Our results show that when CGSI is performed below miscibility (BM) conditions, at the base case soak and production periods, fluid is swept in the small pores (and above), but both solvents barely access the micropores. Above miscibility (AM) conditions, displacement in the micropores was significantly enhanced using ethane but was less remarkable when CO_2 was used. With a longer soaking time, the displacement by CO_2 and ethane in the micropores was increased considerably but had no effect in the micropores under BM conditions. Prolonging the production period improved the sweep efficiency in the micropores only under AM conditions for both gases. Overall, ethane outperformed CO_2 in displacing fluids from pores, with free fluid indices (FFI) ranging from 30 - 87% versus 19-75% for CO_2. Although the influence of cyclic CO_2 injection design parameters on pore-level sweep efficiency has been discussed for other formations, studies in the Bakken are limited. In addition, variable interactions, such as those discussed, have rarely been addressed in current literature. Therefore, we believe that the results of this research will aid in the comprehension and development of CGSI EOR design in unconventional plays around the world.