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Mathematical Modeling of Carbonated Waterflooding: Analytical Solutions for Low-Carbon Enhanced Oil Recovery

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The transition to a low-carbon economy emphasizes innovations that reduce greenhouse gas emissions while enhancing energy and production efficiency. Among the strategies adopted by oil and gas (O&G) companies is carbonated waterflooding, a method of enhanced oil recovery (EOR-CO2) that involves injecting carbonated water into reservoirs. This technique not only improves oil recovery but also contributes to carbon sequestration by storing CO2 in subsurface formations.

Although carbonated waterflooding has been studied since the mid-20th century, the process introduces complex interactions between CO2, reservoir rocks, and fluids (oil and water) that require detailed evaluation. Key mechanisms include oil swelling, viscosity reduction, miscibility effects, and geochemical interactions. A comprehensive understanding of these processes is critical for optimizing recovery and aligning with low-carbon economy objectives.

This work presents an analytical model for carbonated waterflooding in porous media saturated with oil and water. The study evaluates the interactions between CO2, reservoir rocks, and reservoir fluids, focusing on a three-component system (oil, water, and CO2) in two phases (aqueous and oleic). The model is derived using mass conservation equations in a one-dimensional, homogeneous, incompressible, and isothermal system. Simplifying assumptions include constant porosity and permeability, negligible dispersion, capillary, and gravitational effects, and the absence of chemical reactions. However, interphase mass transfer between oil, water, and CO2 is incorporated, along with CO2 adsorption onto the solid phase.

The findings offer insights into the dynamics of carbonated waterflooding and its potential to enhance oil recovery while contributing to carbon sequestration goals.

By providing an analytical framework, this work advances the understanding of carbonated waterflooding as an EOR technique, offering a basis for optimizing field applications and supporting the development of sustainable oil recovery strategies aligned with global low-carbon goals.

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References

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