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Forecasting Oil Production and Economics of a Foam Pilot Including Quantitative Uncertainty Assessment

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This paper investigates through reservoir simulations the set-up of a foam EOR process in a real sector of a low permeability reservoir produced by waterflooding. The objectives are: to demonstrate our capability to simulate foam injection at field scale; to investigate the technical feasibility of foam injection in terms of injectivity, foam stability and improved oil recovery; and to analyze its economic feasibility as a function of technical uncertainties and market prices variations.

The study is conducted using a reservoir simulator combined with uncertainty and optimization capabilities. Our foam model modifies the gas relative permeability according to a multi-parameter mobility reduction function. Several sensitivity analyses and optimizations were performed to design the injection sequence that optimizes the foam displacement and the resulting sweep efficiency, and to determine the influence on the oil recovery and the net present value of the foam quality, its maximum gas mobility reduction, its stability and the surfactant adsorption. By applying Monte-Carlo methods on surface responses, the process robustness against surfactant adsorption and hydrocarbon prices uncertainties was assessed.

The optimization of foam injection at pilot scale requires a specific study because that process is driven by many parameters with opposite effects. Specifically we found that foam viscosity may hinder injectivity, potentially leading to a decrease in the oil production, while foam may greatly enhance displacement profiles at the same time. Moreover numerical simulations show that early gas breakthrough can occur even for highly viscous foams because the apparent foam viscosity decreases in the near wellbore due to higher velocities. This can be mitigated by performing a 3-4 months surfactant water injection pre-flush. It is then possible to find an optimal foam injection sequence that generates a high financial profit for realistic foam parameters. The foam quality turns out to be a key parameter to control the foam EOR process, with quite different values found to maximize either oil production or net present value. For the case under consideration that involves a surfactant adsorption of 250 µg/g and an optimized 5-year injection of a foam of quality 0.45 following a surfactant aqueous pre-flush, we show that the foam process is profitable and robust with respect to market prices variations and technical uncertainties.

This innovative optimization methodology shows that foam processes could be eligible for this pilot. After designing properly the injection sequence, including a surfactant pre-flush prior to foam injection, reservoir simulations predict that this EOR process may highly improve the exploitation profitability. Moreover profitability is robust to economic uncertainties, with a breakeven price of 30 $ per barrel, as well as technical uncertainties, of which adsorption up to 600 µg/g.

References

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