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Effect of Non-Newtonian Foam on SAG Foam EOR

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Objectives/Scope:
Foam can improve sweep efficiency in gas-injection enhanced oil recovery. Surfactant-alternating-gas (SAG) is a favored method of foam injection due to injectivity and operational considerations. Laboratory data indicate that foam can be non-Newtonian in the high-quality regime, and therefore during gas injection in a SAG process. We investigate the implications of this finding for mobility control and injectivity, by extending fractional-flow theory to gas injection in a non-Newtonian SAG process in radial flow.
Methods, Procedures, Process:
Non-Newtonian behavior in the high-quality regime means the limiting water saturation for foam stability varies as superficial velocity decreases with radial distance from the well. We discretize the domain radially and perform Buckley-Leverett analysis on each ring; solution characteristics are of constant foam quality. For the first time, we show the implications of this behavior for mobility control at the displacement front as well as injectivity. We base the foam-model parameters and the extent of non-Newtonian behavior on laboratory data in the absence of oil. We compare results to mobilities determined by conventional simulation, where grid resolution is limited.
Results, Observations, Conclusions:
For shear-thinning foam, mobility control improves as the foam front propagates from the well, but injectivity declines somewhat with time. The change of mobility ratio at the front can be considerable, given the huge velocity difference between the wellbore and further out. This change is not simply that measured at steady state at fixed foam quality in the laboratory, however, because the foam front in a non-Newtonian SAG process does not propagate at fixed foam quality. Injectivity benefits from the increased mobility of shear-thinning foam near the well. The foam front, which maintains a constant dimensionless velocity for Newtonian foam, decelerates somewhat with time for shear-thinning foam. For shear-thickening foam, mobility control deteriorates as the foam front advances, though injectivity improves somewhat with time. Overall, however, injectivity suffers from reduced foam mobility at high superficial velocity near the well. The foam front accelerates somewhat with time. Overall, injectivity is a complex result of changing saturations and varying superficial velocities very near the well. Conventional simulators cannot adequately represent these effects, or estimate injectivity accurately, in the absence of exceptional grid resolution near the injection well.
Novel/Additive Information:
For the first time we extrapolate laboratory steady-state foam data for non-Newtonian foam to investigate the implications for injectivity and mobility control in gas injection in SAG in the field.

References

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