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Impact of CO₂ concentration in gas phase on foam behavior in carbonate rocks

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Foam-assisted water alternate gas injection (FAWAG injection) could be a promising technology to assist gas mobility control, consequently gas management in surface facilities of ultra-deepwater fields in the Brazilian offshore (Vieira et al., 2020). In these fields carbon dioxide (CO₂) concentration in the gas stream varies, which can negatively impact foam stability, accelerating its destruction (Abdelaal et al., 2020). However, the impact of CO₂ concentration in the gas phase on foam generation and foam strength (apparent viscosity) in porous media. To this end, we conducted coreflood experiments where gas phase and surfactant solution were co-injected through Indiana limestone under relevant conditions (temperature –65°C, pressure –10 MPa and superficial velocity –3.5 x 10⁻⁶ m s⁻¹). Four different gas compositions were used for the tests, namely nitrogen (N₂), CO₂ and two CO₂-N₂ mixtures (10 mol%, 50 mol%). Two commercial zwitterionic surfactants (CAHS –co-camidopropyl hydroxysultaine and CB –cetyl betaine) were used at 0.5 wt.% concentration (active matter) as foaming agents. The experiments were carried out with the core mounted in vertical position and the injection direction was bottom-to-top.

Our results have shown that increase in CO₂ concentration in the gas phase decreased overall apparent viscosity (μ_{foam}), but no linear correlation has been found. Maximum μ_{foam} values for CB ranging from 30 mPa s⁻¹ for CO₂-foam to 170 mPa s⁻¹ for N₂-foam. For CAHS, maximum μ_{foam} values ranged between 70 mPa s⁻¹ and 170 mPa s⁻¹ for the same conditions. Gas composition also impacted transition foam quality (fg), however, the changes in foam behavior as a function of gas fraction seemed to be dependent of the structure of zwitterionic surfactant. For CB surfactant, increased CO₂ concentration in gas phase (10 mol% and 50 mol% CO₂-N₂) shifted foam transition quality to the lower gas fractions (from 0.6 to 0.4), indicating that coalescence was favored under these conditions. The apparent viscosity of the foam formed between CO₂ and CB surfactant solution did not present a clear transition, and it remained constant as a function of foam quality. Under the same conditions, fg for CAHS was shifted to the right (0.5 to 0.7), indicating that resistance to coalescence increased as a function of CO₂ concentration on the gas phase for this surfactant. Another important observation was that from a gas fraction of 0.9, foam apparent viscosity was independent of gas composition. That meant that N₂-, gas mixture- or CO₂-foam had the same foam apparent viscosity (CAHS ~ 20 mPa s⁻¹, CB ~ 10 mPa s⁻¹), indicating that this regime was dominated by limiting capillary pressure.

These findings suggest that for FAWAG project gas stream has considerable variation in CO₂ concentration, the surfactant chosen not only needs to tolerate salinity and temperature of the reservoir, but also needs to maintain a high fg^* under these changing gas composition conditions.

Participation

In-Person

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Primary author: Dr DA FONSECA FAÇANHA, Juliana Maria (Shell Bazil Technology)

Co-authors: Prof. PÉREZ, Aurora; Dr FREITAS LOPES, Leandro

Presenter: Dr DA FONSECA FAÇANHA, Juliana Maria (Shell Bazil Technology)

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