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Optimal Zwitterionic Surfactant Slug for an Improved OilRecovery in Oil Wet Carbonate Rocks - Silurian Dolomite

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Abstract

The increase in energy demand has led to extensive research and development on economically, environmentally and technically feasible ways of improving the ever-growing energy demand. A common derivative of energy is from hydrocarbons, specifically oil. The process of oil recovery can be divided into primary, secondary, and tertiary recovery (also known as enhanced oil recovery). Once the internal pressure of a reservoir has depleted enough during primary and secondary recovery, more advanced techniques in enhanced oil recovery mechanisms are used to recover 50-80% of oil in the reservoir. Tertiary recovery includes the use of surfactants to reduce interfacial tension (IFT) or alter wettability. In this work, a zwitter ionic surfactant at two different concentrations is evaluated for its ability to reduce the interfacial tension between oil and water, as well as altering wettability in silurian dolomite. To achieve this, fluid-fluid analysis was done by a compatibility test, phase behavior test and interfacial tension measurements. Rock-fluid analysis was also completed by means of floatation test, carried out with carbonate rock particles to analyze the surfactant's ability to alter wettability. Solution pH measurements were taken to validate the qualitative floatation test results. Results show that the surfactant, chembetaine C surfactant, is compatible with all ranges of salinities investigated, though was not able to produce a winsor type III micro-emulsion. The results of the interfacial tension measurements are in line with the phase behavior test, as none of the measurements were at ultra-low values. Surfactant retention is likely to occur with the analyzed zwitterionic surfactant based on the fluid-fluid analysis. Qualitative results from the floatation test show that the wettability of the carbonate rock particles cannot be significantly altered to more water-wet conditions. The pH of the solution remains at alkaline values, which can be beneficial in enhanced oil recovery in producing soap in situ, also known as saponification. Overall, tests conclude that this zwitterionic surfactant at 1% concentration would be most effective at 10,000 ppm salinity brine, though overall is not suitable for chemically enhanced oil recovery.

Key words:
zwitterionic surfactant, enhanced oil recovery, compatibility test, phase behavior test, interfacial tension, wettability, tertiary oil recovery

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1. Introduction

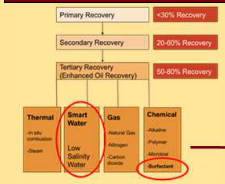


Figure 1 : Recovery Mechanism

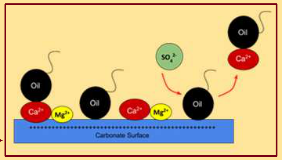


Figure 2 : Rock-fluid interaction

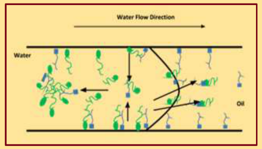


Figure 3: Working mechanism of a surfactant

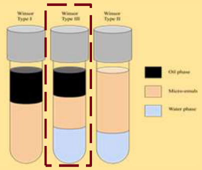


Figure 4 : Microemulsion phase behavior

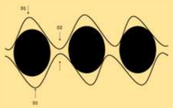


Figure 5: Conventional water flooding

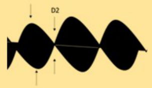
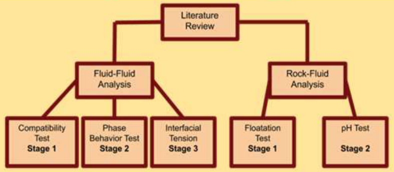


Figure 6: Smart water and surfactant flooding

Research Question:
What is the optimal surfactant slug that is required for an improved oil recovery in Silurian Dolomite rock?

2. Experimental Approach



Salts	% Composition
NaCl	62
CaCl2.2H2O	19.63
Na2SO4	1.95
MgCl2.6H2O	16.3
NaHCO3	0.12

Table 1: Synthetic Formation Brine composition

Surfactant:
1% Chembetaine zwitterionic surfactant

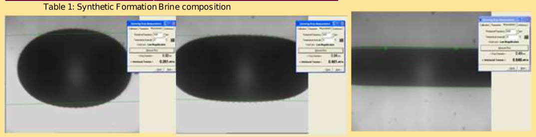


Figure 7: Interfacial Tension measurement

3. Results and Discussion

Phase 1: Fluid-Fluid Analysis

Stage 1: Compatibility Test

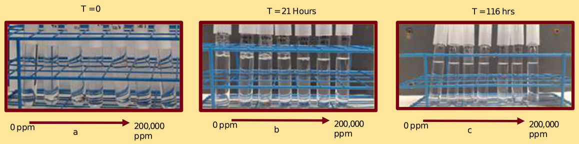


Figure 8: Compatibility Test

Stage 2: Phase Behavior Test

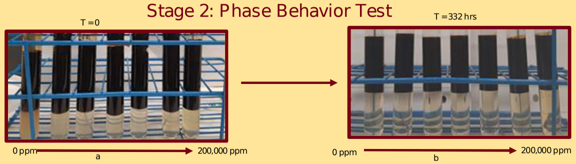


Figure 9: Phase behavior Test

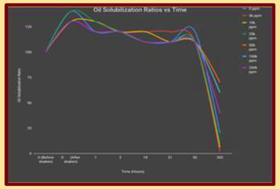


Figure 10: Oil Solubilization ratio vs Time

$$\text{Oil Solubilization ratio} = \frac{V_{\text{oil in the microemulsion phase}}}{V_{\text{active surfactant}}}$$

- Figure 10: A decrease in the oil solubilization ratio is observed with time.
- The decrease in the oil solubilization ratio is an indication of the reduced activity of the surfactant over time.
- The salinity with the lowest oil solubilization ratio at time 332 hours was 5,000 ppm and the highest for 50,000 ppm.

Stage 3: Interfacial Tension Measurements

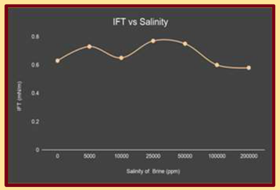


Figure 11: Effect of Salinity on IFT

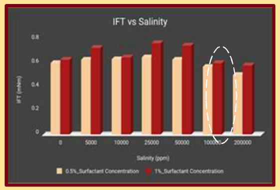


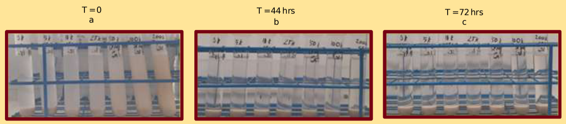
Figure 12: Effect of Surfactant concentration on IFT

- Figure 11 shows the changes in IFT with salinity.
- There is a non-monotonous behavior of IFT with salinity.
- IFT is lowest at 200,000 ppm brine salinity since there is a competition for solubilization between brine and surfactant.
- Due to the presence of excess ions at high salinity, the surfactant is pushed further towards the oil-brine interface which results in a lower IFT.
- Figure 12 shows the changes in IFT with surfactant concentration.
- A decrease in surfactant concentration from 1% to 0.5% results in a decrease in the IFT.
- Non of the concentrations yields ultra-low IFT values (10^{-2} and 10^{-3} mN/m).

Phase 2: Rock-Fluid Analysis

Stage 1: Floatation Test

Figure 13 (Below): Floatation Test



Stage 2: pH Measurements

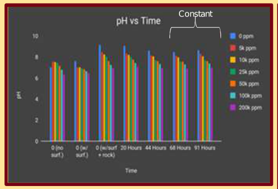


Figure 14: Change in pH with Time

- Figure 14 shows the results for pH measurements over time.
- With the addition of carbonate rock, there is an increase in the pH
- No change in is seen from 68 hours
- The alkaline pH environment increases the chances of in situ surfactant generation in the reservoir.

4. Conclusions and Recommendations

- Based on the fluid- fluid analysis, surfactant retention is likely to occur with the zwitterionic surfactant analyzed.
- Based on the rock-fluid analysis, the zwitterionic surfactant cannot alter the wettability of oil wet carbonate rocks significantly towards more water wet conditions
- The pH of the solution reduces over time but remains at alkaline conditions which could be beneficial in oil recovery
- The concentration of the surfactant used should be further reduced to analyze the concentration and salinity in which the middle phase (Winsor type III) micro-emulsion will occur.
- Optimal surfactant slug in this case is at 10,000 ppm at 1% surfactant concentration

5. References

- Zhang, P., Tweheyo, M. T., & Austad, T. (2006). Wettability alteration and improved oil recovery in chalk: The effect of calcium in the presence of sulfate. Energy & Fuels, 20(5), 2056-2062.
- Yousef, A. A., Al-Saleh, S., & Al-J awfi, M. S. (2012). Improved/enhanced oil recovery from carbonate reservoirs by tuning injection water salinity and ionic content. Paper presented at the SPE Improved Oil Recovery Symposium.

6. Acknowledgements

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