Optimal Zwitterionic Surfactant Slug for an Improved Oil Recovery in Oil Wet Carbonate Rocks

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1. Introduction

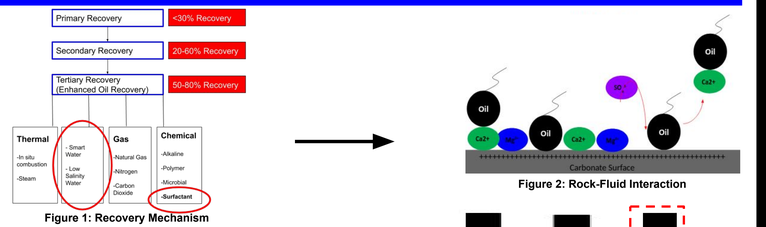


Figure 1: Recovery Mechanism

Figure 2: Rock-Fluid Interaction

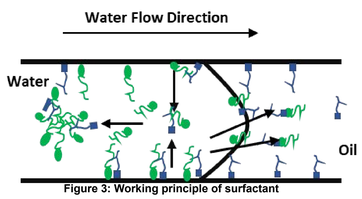


Figure 3: Working principle of surfactant

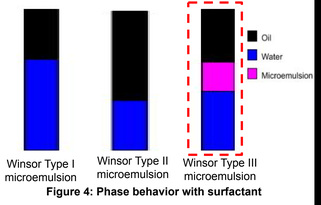


Figure 4: Phase behavior with surfactant

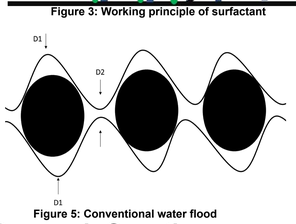


Figure 5: Conventional water flood

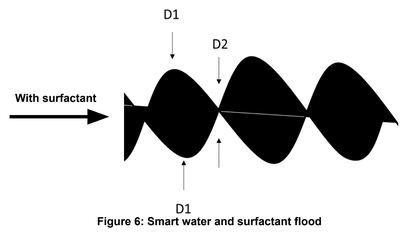
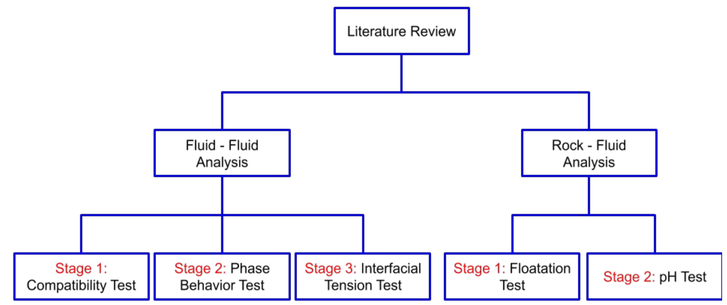


Figure 6: Smart water and surfactant flood

Research Question:

- What is the optimum zwitterionic surfactant slug required for an improved oil recovery in Silurian Dolomite?

2. Materials and Methods



Surfactant: 0.5% Chembetaine zwitterionic surfactant

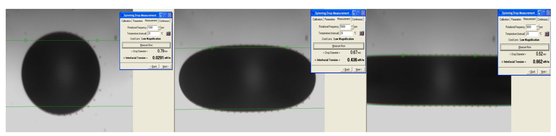


Figure 7: Interfacial Tension measurement

Salt	% Concentration
NaCl	62
$CaCl_2.2H_2O$	19.63
$MgCl_2.6H_2O$	16.3
Na_2SO_4	1.95
$NaHCO_3$	0.12

Table 1: Composition of the synthetic formation brine

3. Results and Discussion

Fluid - Fluid Analysis

Stage 1: Compatibility Test

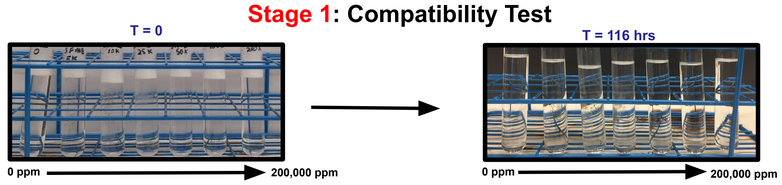


Figure 8: Compatibility Tests

Stage 2: Phase Behavior Test

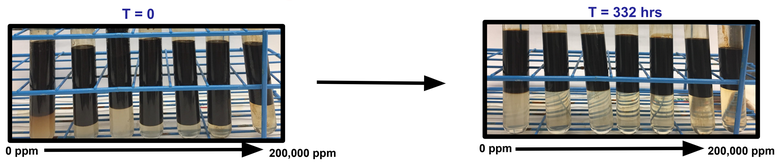


Figure 9: Phase Behavior Test

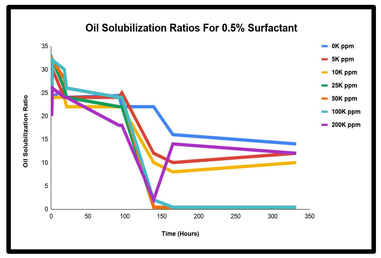


Figure 10: Oil solubilization ratio vs Time

- **Figure 10** shows a decrease in the oil solubilization ratio 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 after 332 hours is 50,000 ppm and 100,000 ppm and the highest is at 5,000 ppm and 10,000 ppm.

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

Stage 3: Interfacial Tension Measurements

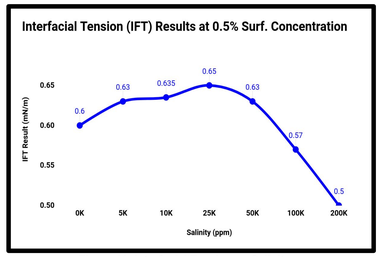


Figure 11: Interfacial Tension vs Salinity

- **Figure 11** shows a change in IFT with salinity
- There is a non-monotonous behavior of IFT with salinity
- Competition for solubilization between high salinity brine and surfactant results in a low IFT.

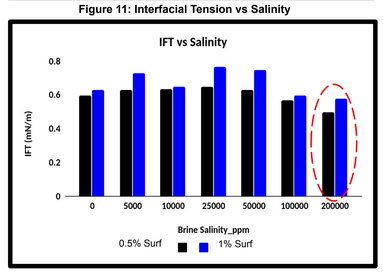


Figure 12: Effect of surfactant concentration on IFT

- **Figure 12** shows the effect of surfactant concentration on IFT
- An increase is surfactant concentration results in an increase in the Interfacial tension
- IFT values are still not ultra low (between 10^{-2} and 10^{-3} mN/m)

Rock - Fluid Analysis

Stage 1: Floatation Test

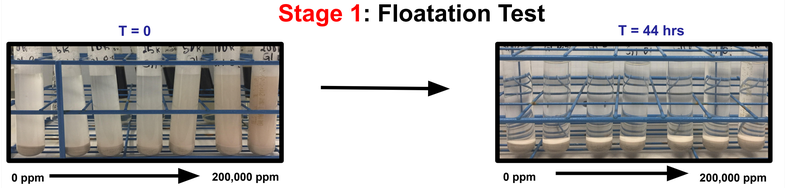


Figure 13: Floatation Test for wettability

Stage 2: pH Test

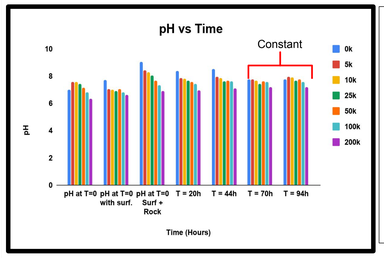


Figure 14: pH vs Time

- **Figure 14** shows the results for pH measurements with time
- With rock addition, there is an increase in the pH
- The pH remains does not change after 70 hours
- The alkaline pH environment increases the chances of insitu surfactant generation in the reservoir.

4. Conclusions and Recommendations

- The surfactant used cannot alter wettability or reduce the Interfacial tension to ultra low values at the concentrations used.
- pH results remains at alkaline levels which could promote saponification
- Saponification reaction reduces the possibility for in situ surfactant generation
- From these analyses, the optimal surfactant slug for improved oil recovery in the carbonate rock studied would be at 10,000 ppm brine at 0.5% surfactant concentration
- It is recommended that a lower surfactant concentrations should be tested
- The zwitterionic surfactant could also be mixed with other ionic surfactants at optimal salinity for a synergetic effect of wettability alteration and interfacial tension reduction.

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-Jawfi, 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

- Dr. Japan Trivedi
- Benedicta Nwani
- Mr. Fitz Caluttung
- Mrs. Vesna MacKenzie

Supported By: