Optimal zwitterionic surfactant slug for an improved oil recovery in oil-wet carbonate rocks

Madison Barth[1], Japan Trivedi[1], Benedicta Nwani[1], Yosamin Esanullah[1]

[1]Department of Civil and Environmental Engineering, University of Alberta

Page 7/ WISEST Special Issue / Volume 2 / DOI: 10.29173/aar45

Abstract

Of recent, there has been research and development in the technologies/techniques required to meet the ever-growing energy demand in the world. Oil is a major source of energy which is contained in over 50% of carbonate reservoirs. The oil/mixed wettability of carbonate rocks makes it technically challenging to recover the needed oil. The process of crude oil recovery has three different stages primary, secondary and tertiary recovery. Tertiary recovery is also known as enhanced oil recovery or EOR. EOR includes the use of surfactants to reduce the interfacial tension between a hydrocarbon and brine, thus suspending them both in a microemulsion. Surfactant performance can be affected by multiple variables, including brine salinity, surfactant concentration, and type of hydrocarbon. A petroleum engineer must take all variables into consideration when selecting a surfactant to make sure that its efficiency is as high as possible, especially because the use of surfactants is costly.

In this work, a chembetaine zwitter ionic surfactant of two different concentrations are evaluated at various synthetic formation brine salinities for their favourable wettability alteration and interfacial tension reduction in oil-wet carbonate- Silurian Dolomite. For the evaluation, fluid-fluid and rock-fluid analysis are carried out to select the optimal surfactant concentration and brine salinity with the greatest improved oil recovery potential.

Results are indicative that the surfactant at the two concentrations studied is compatible at the ranges of salinities evaluated. However, from the fluid-fluid analysis, there was no ultra-low interfacial tension that is needed for oil mobilization. More so, the rock-fluid analysis shows that the surfactant is not able to alter the wettability of oil-wet rocks favourably. The optimal surfactant slug for the greatest oil recovery, in this case, would be expected at 0.5% surfactant concentration in 10,000 ppm synthetic formation brine salinity. This study, therefore, serves as a guide for the design of optimal surfactant slug in oil-wet carbonate cores requires to reduce non-productive time, prevent reservoir damage and therefore improve recovery.

Key words:
surfactant, zwitterionic, enhanced oil recovery, oil -wet, silurian dolomite

Cite as: Barth M., Trived J., Nwani B., Esanullah Y. 2019. Optimal zwitterionic surfactant slug for an improved oil recovery in oil-wet carbonate rocks. Alberta Academic Review, Vol 2 (2) 7-8, WISEST Special Issue (not peer-reviewed), DOI: 10.29173/aar45.

albertaacademicreview.com

ISSN 2561-5327 (print)
ISSN 2561-5335 (online)

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

Madison Barth, Yosamin Esanullah, Benedicta Nwani (MSc), and Japan Trivedi (PhD)

Department of Civil and Environmental Engineering, University of Alberta

1. Introduction

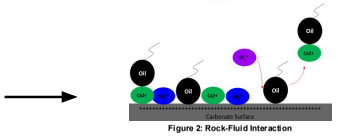

Figure 1: Recovery Mechanism

Figure 2: Rock-Fluid Interaction

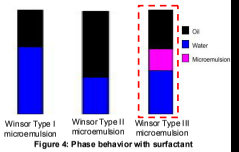

Figure 4: Phase behavior with surfactant

Figure 3: Working principle of surfactant

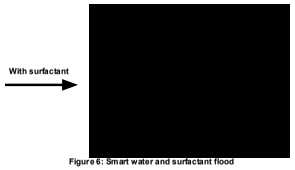

Figure 5: Conventional water flood

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

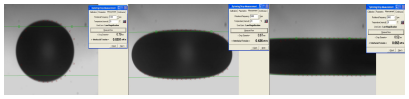

Figure 7: Interfacial Tension measurement

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

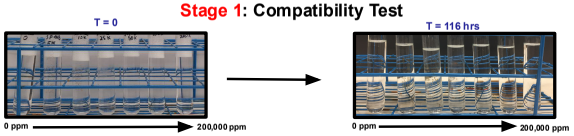

Figure 8: Compatibility Tests

Stage 2: Phase Behavior Test

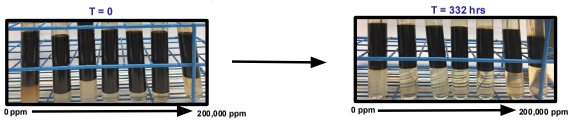

Figure 9: Phase Behavior Test

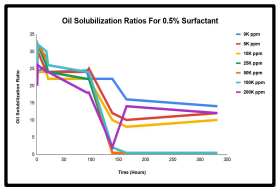

Figure 10: Oil solubilization ratio vs Time

- **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.

Stage 3: Interfacial Tension Measurements

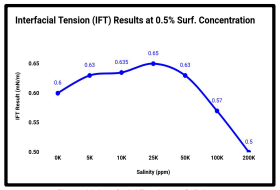

Figure 11: Interfacial Tension vs Salinity

- **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.

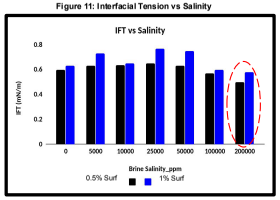

Figure 12: Effect of surfactant concentration on IFT

- **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

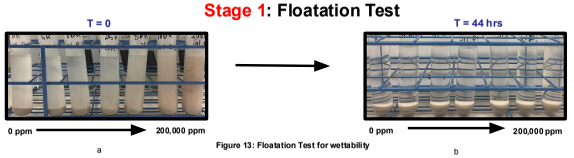

Figure 13: Floatation Test for wettability

Stage 2: pH Test

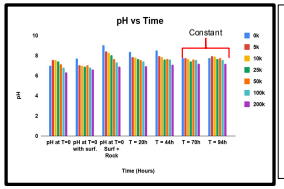

Figure 14: pH vs Time

- **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:

Canada

SPE Canadian Educational Foundation

MOTOROLA