geoconvention
Calgary • Canada • May 11-13 2026

Experimental Evaluation of Heavy Oil Recovery from the Sparky Formation Using Solvent-Surfactant Systems in Cyclic Solvent Injection

Saman Mohammadi[1], Ke Xu[1], George Couch Herman[2], Russell Giesbrecht[3] and Hassan Dehghanpour[1]*

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

[2]BASF Corporation

[3]BASF Canada Inc.

Summary

Field production data obtained from over 300 wells completed in the Sparky Formation (Figure 1) illustrates that surfactant application enhances normalized cumulative oil recovery after six months. In parallel, cyclic solvent injection (CSI) has been recognized as an environmentally-friendly alternative to thermal methods for improving heavy oil recovery [1]. Accordingly, the objective of this study is to incorporate a hydrophobic surfactant into a liquid solvent and evaluate its performance in CSI, an approach that remains unexplored in the published literature. We hypothesize that surfactant-aided CSI enhances heavy oil recovery by combining solvent-driven mechanisms (e.g., viscosity reduction [2], solvent diffusion [3], and oil swelling [4]) and surfactant-driven mechanisms (e.g., interfacial tension reduction [5], and emulsification [6]).

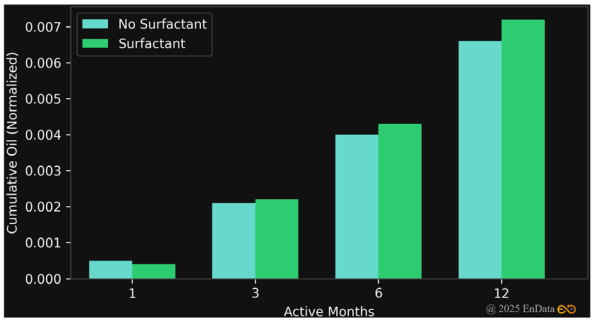


Figure 1- Normalized cumulative oil production for 310 wells in the Sparky Formation obtained from the Benchmarking Analysis module of the EnData platform [7]. We normalize cumulative oil production based on petrophysical properties and completion design. The results demonstrate improved normalized oil productivity for the wells treated with surfactant.

We follow a systematic protocol using in-situ rock and fluid samples to restore reservoir conditions. Furthermore, we use a state-of-the-art system to visualize and quantify oil recovery during CSI using solvent with and without surfactant. The experimental results demonstrate that adding 0.5 wt.% surfactant to pentane (i.e., solvent) increases heavy oil recovery from 32% to 45% primarily by enhancing the diffusivity and solubility of the solvent.

Theory / Method / Workflow

We use a custom-designed core flooding system to restore the Sparky plugs for the visualization experiments through the following workflow:

1) We select a set of twin plugs with relatively similar petrophysical properties.
2) We put a dry core in the Hassler core holder and apply an overburden pressure of ~ 600 psi (representing reservoir pressure).

3) We inject filtered brine to the plug at the rate of 1 ft/day and continue injection until it is fully saturated with brine.
4) We inject heavy oil into the brine-saturated samples under constant-pressure mode and continue injection for 2 PV after oil breakthrough.
5) We coat the lateral and the bottom surface of the plugs with epoxy to better represent a reservoir undergoing a CSI process such that injection and production occurs from one direction.

We use a visualization setup to conduct the CSI experiments designed for this study. We continuously record pressure and snapshots from the interactions between solvent and oil-saturated rock samples throughout the CSI experiments. We conduct CSI experiments on the heavy-oil saturated samples partly coated with epoxy. Each CSI experiment (as illustrated in Figure 2) includes injection (up to 600 psi, corresponding to reservoir pressure), soaking (until the pressure profile stabilizes) and depletion stages. We conduct one CSI experiment on one plug using solvent as the base case, while we use the other plug to test with solvent and surfactant. It is expected that the difference in the oil recovery factors is related to the presence of surfactant. Both experiments are conducted in a single cycle at the reservoir temperature (i.e., 21 °C).

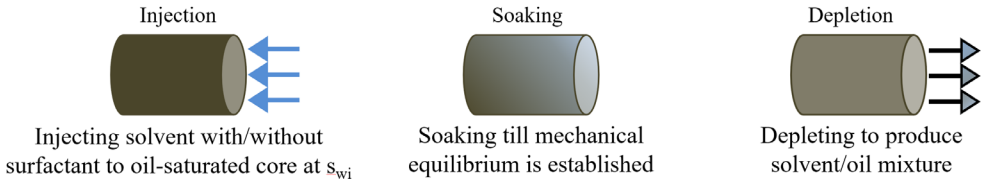


Figure 2- Schematic of the CSI experiments designed for this study. Each CSI experiment includes injection, soaking and depletion stages. One heavy oil-saturated plug is used for CSI using solvent and another plug is used for CSI using solvent+surfactant.

Results, Observations, Conclusions

The results obtained from the CSI experiments indicate that solvent recovers 32% of the initial oil in place, while adding 0.5 wt.% of surfactant increases oil recovery by an additional 13% (from 32% to 45%). Figure 3 indicates the snapshots from the core surface during the CSI experiment using solvent, and solvent+surfactant, respectively. The snapshots are recorded at different times, and are highlighted by letters from “a” to “e” for the plug tested using solvent, and “f” to “j” for the plug tested using solvent+surfactant. The snapshots are taken at 40 frames/second in order to properly monitor the solvent-heavy oil interactions.

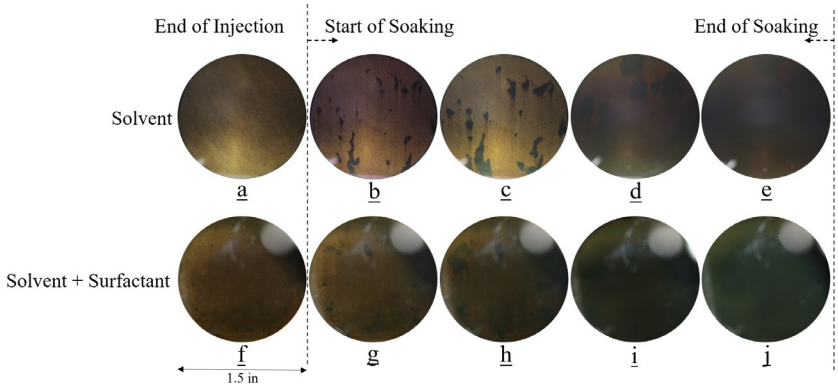


Figure 3- Snapshots taken from the core surface during the CSI using solvent with and without surfactant. The snapshots are recorded at different times and are highlighted from “a” to “e” for the solvent, and from “f” to “j” for the solvent+surfactant.

The results indicate that a certain amount of discontinuous heavy oil in the form of small droplets is produced due to the compression of the rock sample during injection (snapshots a and f in Figure 3). By further injection of solvent into the visualization cell and compression of the oil-saturated plug, more oil is extracted (snapshots b and g in Figure 3). Oil can approach first-contact miscibility with hydrocarbon solvents at elevated pressures [8]. During the soaking stage, the cell darkens due to continued extraction of oil components. Once the mechanical equilibrium is established, the cell is dark such that the rock surface cannot be observed (snapshots e and j in Figure 3). The pressure profile during the soaking stage using solvent stabilizes at 499 psi after 44 hours, while that using solvent+surfactant stabilizes at 468 psi after 69 hours. Therefore, adding surfactant to solvent results in a lower equilibrium pressure and a longer time to reach equilibrium (i.e., increased diffusion). The analysis of the effluents indicates that adding surfactant to solvent increases heavy oil recovery by further extraction of the intermediate to heavy components of the heavy oil. This finding explains why in solvent+surfactant systems, lower equilibrium pressure and longer equilibrium time are observed. Additionally, the results indicate that adding surfactant enhances solvent diffusivity and solubility, contributing to an additional 13% oil recovery.

Novel/Additive Information

This study proposes a novel non-thermal process for improving heavy-oil recovery by integrating surfactants with a liquid solvent. The results demonstrate that adding surfactant can enhance solvent diffusivity and solubility, improving the extraction of intermediate-to-heavy oil fractions, thereby enhancing heavy oil recovery. These findings show that surfactant addition can shift the solvent-oil equilibrium behavior and increase recovery by improving extraction of intermediate-to-heavy fractions in a single-cycle CSI test.

Acknowledgements

We acknowledge BASF Corporation for their financial support and formulating the surfactants, Teine Energy for providing the rock and fluid samples, Dr. Tamer Moussa for analyzing the field data using EnData and geoLOGIC systems Ltd. We also acknowledge Natural Sciences and Engineering Research Council (NSERC) of Canada and Future Energy Systems for their financial support.

References

[1] Lin L, Ma H, Zeng F, Gu Y. A critical review of the solvent-based heavy oil recovery methods. Soc. Pet. Eng. - SPE Heavy Oil Conf. Canada 2014, vol. 2, OnePetro; 2014, p. 1079–98. https://doi.org/10.2118/170098-ms.

[2] Ahadi A, Torabi F. Insight into heavy oil recovery of cyclic solvent injection (CSI) utilizing C3H8/CH4 and C3H8/CH4/CO2. Petroleum 2018;4:337–46. https://doi.org/10.1016/j.petlm.2018.04.001.

[3] Ivory J, Chang J, Coates R, Forshner K. Investigation of cyclic solvent injection process for heavy oil recovery. Can Int Pet Conf 2009, CIPC 2009 2009;49:22–33. https://doi.org/10.2118/2009-161.

[4] Athar KS, Yassin MR, Dehghanpour H. Visualizing Interactions between Liquid Propane and Heavy Oil. J. Energy Resour. Technol. Trans. ASME, vol. 142, OnePetro; 2020. https://doi.org/10.1115/1.4047318.

[5] Zhao J, Torabi F, Yang J. The role of emulsification and IFT reduction in recovering heavy oil during alkaline-surfactant-assisted CO2 foam flooding: an experimental study. Fuel 2022;313:122942.

[6] Chen P, Mohanty KK. Surfactant-mediated spontaneous imbibition in carbonate rocks at harsh reservoir conditions. SPE J 2013;18:124–33.

[7] EnData. Benchmarking Analysis 2025.

[8] Stalkup FI. Status of Miscible Displacement. JPT, J Pet Technol 1983;35:815–26. https://doi.org/10.2118/9992-PA.