Characterization of Enhanced Oil Bank Build Up through Relative Permeability Analysis

Al Saadi, Faisal; Wolf, Karl-Heinz; Wijsman, Melanie; van Kruijsdijk, C.

DOI
10.3997/2214-4609.201801117

Publication date
2018

Document Version
Final published version

Published in
80th EAGE Conference and Exhibition 2018

We F 06

Characterization of Enhanced Oil Bank Build Up through Relative Permeability Analysis

F. Al Saadi (Shell Global Solutions International B.V), M. Wijsman* (Delft University of Technology), K. Wolf (Delft University of Technology), C. van Kruijsdijk (Shell Global Solutions International B.V)

Summary

In this research, we investigate and characterize the oil bank mobilization on a single-mineral porous medial "Fontainebleau sandstone" (Al Saadi, 2017). Chemicals (surfactant and polymer) are used to mobilize the trapped/residual oil and build up the oil bank. The understanding of favorable physical, chemical and spatial conditions of when and how an oil bank is formed is very limited. It is more applicable when coreflow experiments are upscaled from core scale to field scale

Coreflow experiments were carrried out in high end setup which provide us with the robust, accurate and repeatable experimental data for oil mobilization process from 7 cm to one meter scale core samples. Data integrity of coreflow experiments are insured by two ways: repeating the experiments and reproducing the experimental results; improving the precesion and accuracy. Additionally, some of the coreflow experiments were carried out under CT scanner where the mobilization process of oil bank is visualized, monitored and characterized.

For experimental data Interpretation; we used analytical (JBN Method) and in house numerical simulator to produce accurate relative permeability curves for various core lengths. This experimental relative permeability interpretation provides us insight into the mechanisms and dynamics of the oil mobilization process in natural porous media.

Introduction

The dynamics and physics of fluids flow in bulk porous medium are complex and challenging to predict, simulate and model. It becomes more complicated when the researchers start to deal with chemical Enhanced Oil Recovery (EOR) processes. Additional fluids (i.e. the chemicals) are introduced with more physical and chemical rock-fluid-fluid interactions (Interfacial tension, micro-emulsions, ..etc) (Stegemeier, 1977). It is therefore essential to produce representative, high resolution, accurate and repeatable experimental data to evaluate the behavior of multiphase fluids in porous media for the design of oil field applications.

At field scale the principles work. However, there is little understanding about the processes happening under in-situ conditions. The lack of understanding is on the mechanisms of reconnecting the remaining trapped oil (i.e. oil bank build up) and transport it in the porous media. The challenge is mainly related to poor connection of trapped oil after waterflooding.

In this research, we experimentally demonstrated the process of oil bank build up where experimental results provided a high degree of data integrity. In addition, results give direct evidence for the mechanism of oil bank build up and upscaling procedure. We ensured the repeatability, reproducibility and integrity of the experimental data. We visualized and explored semi-quantitatively the entire process from mobilizing residual oil to dispersed flow to oil bank formation using a core flow tests using cores of different lengths (7 – 100 cm) by evaluating the changes in the oil Relative Permeability.

Method

We built a coreflow laboratory setup which is upgraded with density and conductivity meters at the inlet and the outlet of the coreholder. They provide us with accurate and continuous data of production rates and fluid types for mass balance. A porous plate is built in the coreholder to ensure good and representative distribution of the oil phase during the fluid initialization process. Pressure sensors have been installed along the core to monitor the oil mobilization process and chemical injected slug. The coreflow setup operates automatically and remotely via labview™. This gives us minimal manual intervention to ensure repeatability of the experimental steps. The setup is flexible and can be moved into a CT scanner to visualize and monitor oil bank construction and mobilization.

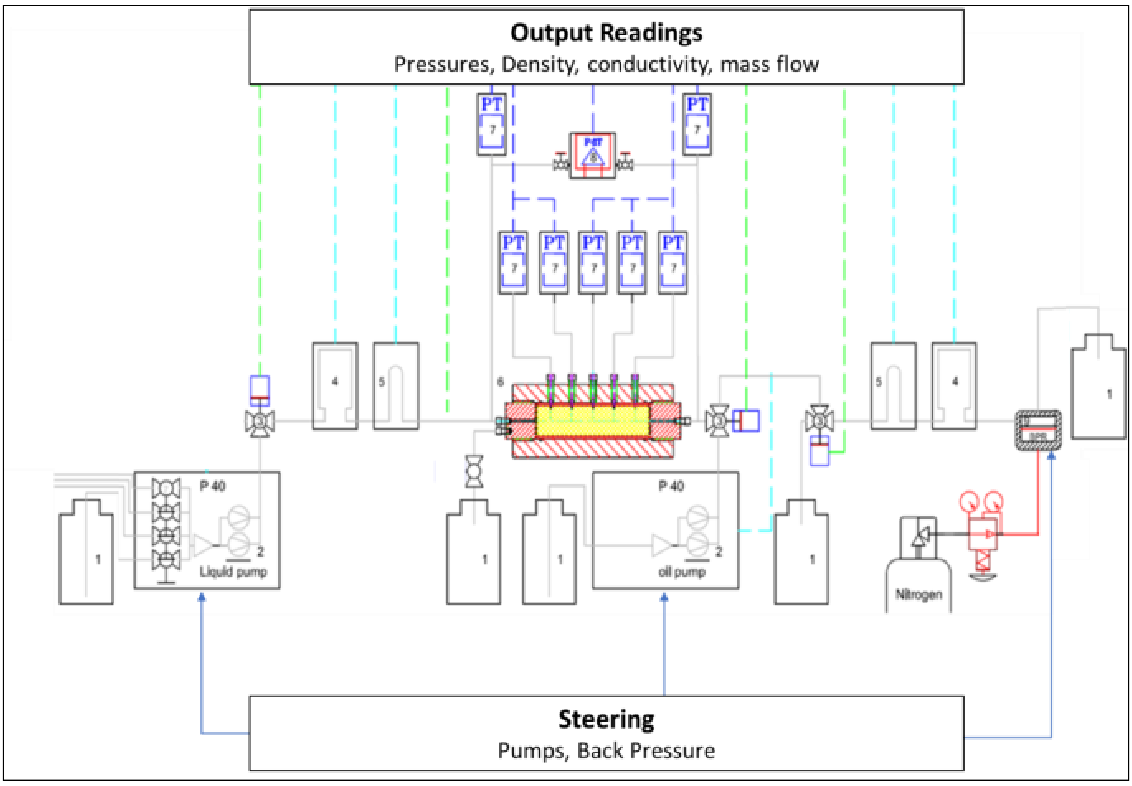

***Figure 1** Schematic design of the core flow setup. The numbers correspond with the set-up description here below.*

Legend of the set-up parts

1	**Bottles**:	with the fluids to be injected, i.e. brine, oil and chemical solutions.
2	**Pump, BlueShadow 40P™**:	for oil, brine and chemical solutions.
3	**Electrical 3 way Valves**:	for fluid direction control across the fluid transport system.
4	**Mini CORI-FLOW™ :**	Flow rate control with the Mass Flow Meters (MFMs).
5	**Conductivity monitors:**	effluent Bulk conductivity measurements.
6	**Coreholder:**	various sizes. Length 0.07 to 1.00 m, diameter constant at 0.039 m.
7	**Pressure transducers:**	Pressure variation 0 – 100 bar.
8	**Pressure difference transducers:**	Pressure difference variation 0 – 100 bar.
9	**Dome-loaded back pressure regulator**:	Up to 50 bar maximum.

We monitor slug movements across the core and study fluid flow and distributions during the chemical coreflood experiments via X-ray computerized tomography (Vinegar and Wellington, 1987). In the CT scanner (Figure 2). The X-ray tube rotates vertically around the core in the center, with a helical path and creates through imaging 2-D density images of the X-ray attenuation in tomographic slices parallel to the core-axis. They are rendered to 3-D saturation profiles, where the X-Y resolution in the plane is 250 µm x 250 µm. All imagingwas done by usingAVIZO™ and in-house Avizo codes developed by the authors.

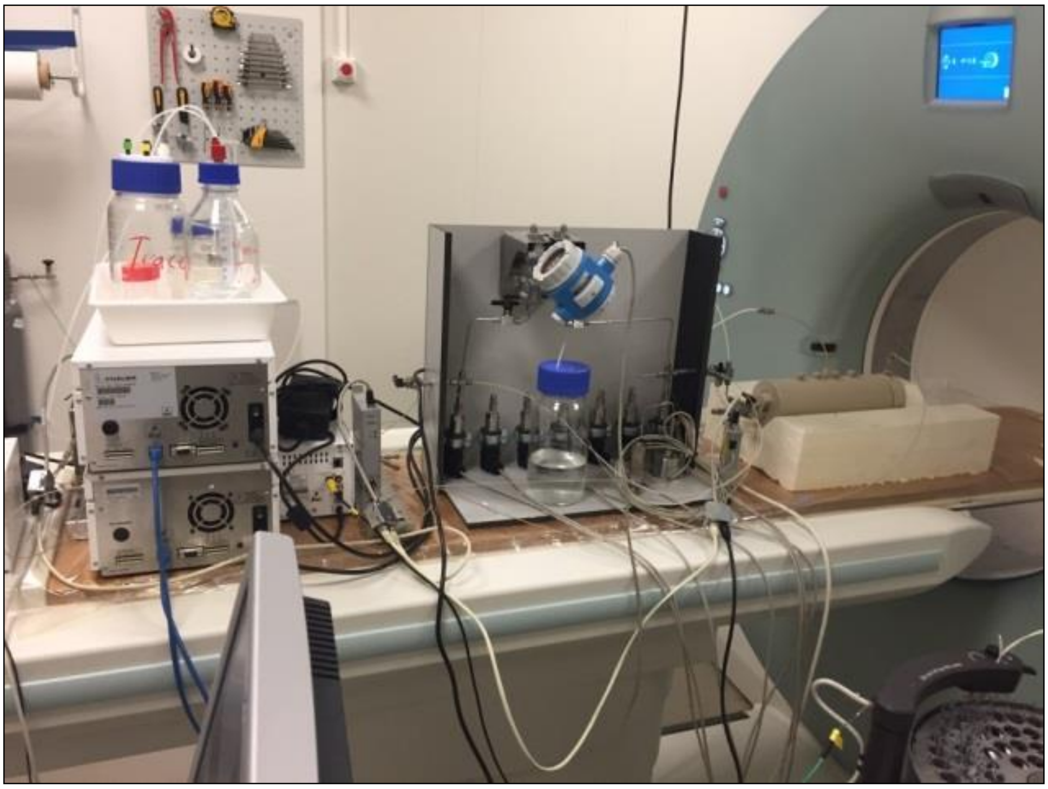

Figure 2 *The setup under the CT scanner.*

Example (Visualization of Oil Bank build up)

After waterflooding, only the oil fraction originally in the core is displaced. This leaves the residual oil in the form of discontinuous oil blobs in the pore framework, named ganglia (Avraam and Payatakes, 1995). We inject a surfactant-polymer flood to reduce the interfacial tension and mobilize these ganglia. They tend to move faster than the chemical flood, i.e. at the beginning, as disperse and discontinuous ganglia (Figure 3B), and later it starts to coalescence and collide with other ganglia.

Consequently, a zone of dense concentration of moving ganglia is expected to form near the advancing flood front of mostly connected oil (Figure 3C). The oil bank in turn, supports to increase the sweep efficiency on other ganglia encountered downstream (Figure 3D).

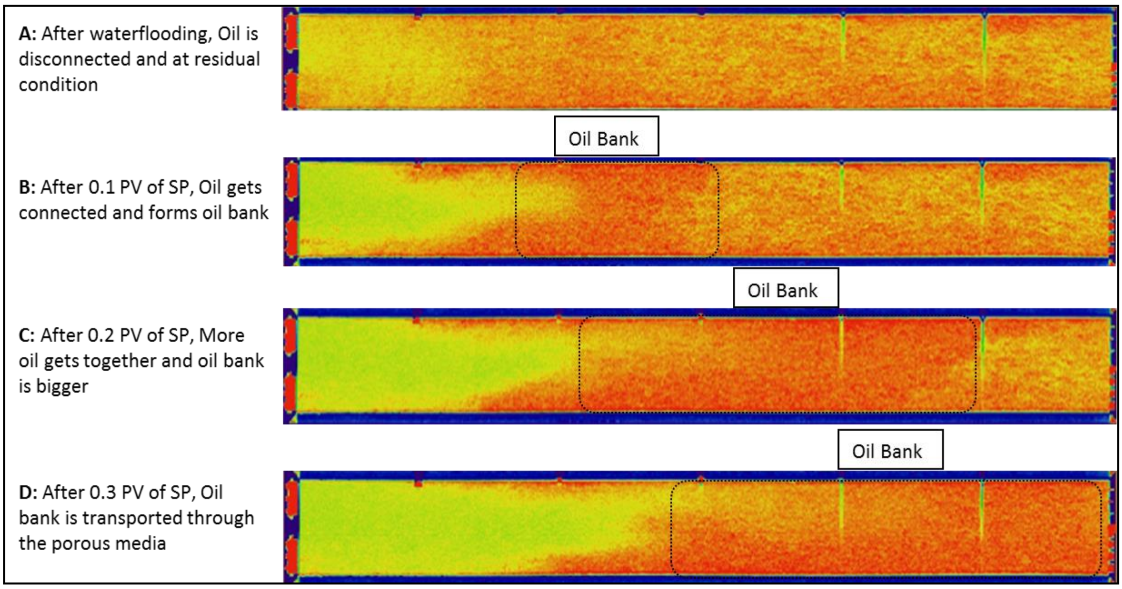

Figure 3 *Oil Bank build up process in the core (Core Length is 38 cm, core diameter is 3.8 cm, Red color indicates oil, green is the surfactant polymer.*

Example (Changes in Relative Permeability for different core lengths)

Analytical and simulation analysis were done on the coreflow experimental data to investigate the changes in relative permeability at different core lengths. Our analysis involves matching pressure and production data. The results from the analytical JBN method (1959) were compared to results using in-house numerical simulator. As shown in figure 4, RelPerms show a larger increase in oil relative permeability; showing that at longer core lengths trapped oil is more easily mobilised. However, we saw other parameters influence the oil bank build up like core hetrogeniety and amount of residual oil saturation.

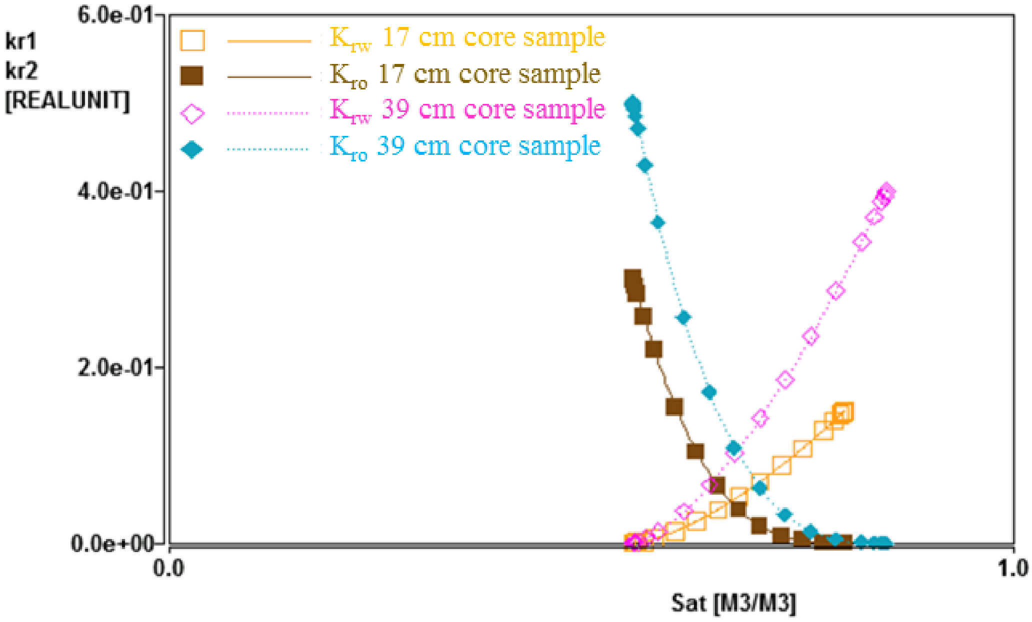

Figure 4 *Comparison of relative permeability at two different cores (17 cm vs 39 cm) during chemical flooding.*

Conclusions

- In chemical EOR, Oil Bank build up is a function of:
  - Core properties like length, pore volume and hetrogeiniety.
  - Amount of residual oil left after waterflood.
  - Chemical slug properties like size and salinity
- Building up a sucessful oil bank by means of Chemical EOR, accelerates the oil production but not necessary increases the ultimate recovery.

Acknowledgments

The authors want to thank the TU Delft technical team (Michiel Slob, Karel Heller, Joost van Meel, Ellen de Koning and Jens van den Berg) for their contributions to the sample preparation, experimental work, CT scanning and image analysis discussions.

References

Al Saadi F, Wolf KH and Kruijsdijk C.V. (2017) Characterization of Fontainebleau Sandstone: Quartz Overgrowth and its Impact on Pore-Throat Framework. J Pet Environ Biotechnol 7: 328. doi: 10.4172/2157-7463.1000328

Stegemeier, G. L (1977) "Mechanisms of Entrapment and Mobilization of Oil in Porous Media", in Improved oil Recovery by Surfactant and Polymer Flooding, Shah, D. O. and Schechter, R. S. ed., Academic Press, New York.

Johnson, E.F., Bossler D.P., and Naumann V.O, (1959), Calculation of Relative Permeability from Displacement Experiments, Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers. Vol. 216, 370-372

Vinegar, H.J., and Wellington, S.L., (1987). Tomographic imaging of three-phase flow experiments. Review of Scientific Instruments 58 (1), 96–107

Avraam, D. G., and Payatakes A. C., (1995). Generalized Relative Permeability Coefficients during Steady-State Two-Phase Flow in Porous Media, and Correlation with the Flow Mechanisms. Transport in Porous Media 20: 135-168, 1995. 135