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Contribution ID: **889** Type: **Oral 20 Minutes**

Using Surfactants to Induce Viscosity Driven Crossflow in Oil-Wet Fractured Micromodels

Thursday, 17 May 2018 11:41 (15 minutes)

The objective of this work is to use micromodels to investigate the feasibility of using viscous microemulsions to mobilize oil in fractured, oil-wet porous media by inducing crossflow. Production by water flooding from fractured oil-wet media, such as carbonates, is challenging because capillary forces prevent water imbibition into the matrix. Recently, experimental core floods (Parra et al., 2016) and numerical simulation (Abbasi et al., 2010) have demonstrated extremely high recoveries in carbonates even with fracture/matrix permeability ratios above 10,000 by using surfactants to reduce the interfacial tension and create in-situ viscous microemulsions to create transverse pressure gradients. Here, we conducted low IFT floods in oil-wet, fractured glass micromodels to show that the recovery is due to crossflow, the recovery is significant (30-40% OOIP after flooding for 1 pore volumes), microemulsions are formed and visible, and a cone-shaped sweep pattern is consistent with reservoir simulation studies. We also show that the rate of crossflow is dependent on the viscosity of the microemulsion.

A glass micromodel was fabricated using conventional photolithography procedures. The micromodel has a fracture with permeability 1000 times greater than the matrix. To make the micromodel oil-wet, the glass surface was activated with sulfuric acid, silylated with an alkylsilane, and aged in oil.

The micromodels were saturated with low viscosity (13 cp) light oil and water flooded for several pore volumes until no reduction in oil saturation was observed. Immediately following the water flood a surfactant solution with low IFT was injected continuously. Surfactant slugs of different salinities, but all at low IFT, were injected to investigate the role of microemulsion viscosity on oil recovery. Image sequences of the floods were captured and analyzed using ImageJ for changes in saturation versus time.

Waterflooding the micromodel only resulted in production in the fracture because large capillary forces prevent water imbibition into the matrix. However, we observed significant crossflow and production from the matrix when surfactant solution was injected for 0.5 pore volumes. The micromodels were flat, so buoyant forces were negligible and all the crossflow was from transverse, viscous pressure gradients. The in-situ microemulsion viscosity was controlled by salinity and we show that higher viscosities (e.g. 50 cp versus 13 cp) result in higher recoveries. The sweep pattern is approximately “cone shaped” as predicted in numerical simulation.

The following was observed from the experiment:
• Crossflow in 2D and 2.5D fractured, oil-wet micromodels was observed when viscous microemulsions were formed in-situ to create transverse pressure gradients.
• Production from the matrix occurred in the same cone-shaped patterns as predicted by reservoir simulation.
• Higher recoveries were achieved using higher viscosity microemulsions, created by varying salinity.

References

Parra, J. E., Pope, G. A., Mejia, M., & Balhoff, M. T. (2016, September 26). New Approach for Using Surfactants to Enhance Oil Recovery from Naturally Fractured Oil-Wet Carbonate Reservoirs. Society of Petroleum Engineers. doi:10.2118/181713-MS
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Session Classification: Parallel 10-D

Track Classification: MS 3.06: Microfluidics and Micromodels in Porous Media Research