SPE 116754

ASP Chemical Flooding Without the Need for Soft Water

Adam K. Flaaten, SPE, Quoc P. Nguyen, SPE, Jieyuan Zhang, SPE, Hourshad Mohammadi, SPE, and Gary A. Pope, SPE, The University of Texas at Austin

This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 21–24 September 2008.

Abstract

Alkaline-surfactant-polymer (ASP) flooding using conventional alkali requires soft water. However, soft water is not always available, and softening hard brines may be very costly or infeasible in many cases depending on the location, the brine composition and other factors. For instance, conventional ASP uses sodium carbonate to reduce the adsorption of the surfactant and generate soap in-situ by reacting with acidic crude oils; however, calcium carbonate precipitates unless the brine is soft. A form of borax known as metaborate has been found to sequester divalent cations such as Ca^{++} and prevent precipitation. This approach has been combined with the screening and selection of surfactant formulations that will perform well with brines with high salinity and hardness. We demonstrate this approach in this paper by combining high performance, low cost surfactants with co-surfactants that increase salinity and hardness tolerance with metaborate. Chemical formulations containing surfactants and alkali in hard brine were screened for performance and tolerance using microemulsion phase behavior experiments and crude at reservoir temperature. A formulation was found that with an optimum salinity of 120,000 ppm TDS (with 6600 ppm divalent cations) that performed well in core floods with high oil recovery and almost zero final chemical flood residual oil saturation. Additionally, chemical formulations containing sodium metaborate and hard brine gave nearly 100% oil recovery, with no indication of precipitate formation. Metaborate chemistry was incorporated into the mechanistic UTCHEM simulator and the simulator was then used to model the core floods. Overall, novel ASP with metaborate performed comparable to conventional ASP using sodium carbonate in soft water, demonstrating advancements in ASP adaptation to hard, saline reservoirs without the need for soft brine, which increases the number of oil reservoirs that are candidates for enhanced oil recovery using ASP flooding.

Introduction

This paper describes a laboratory and modeling approach to ASP flooding in reservoirs containing very hard, saline brines without the need for soft brine. Our target reservoir is a low temperature (50 °C), light oil (API 45) sandstone reservoir containing hard, saline formation brine with 157,000 mg/L TDS salinity of which 8600 mg/L are Ca^{++} and Mg^{++}. Our objective was to design an ASP slug to use as much of the formation brine as possible and eliminate the need for soft water. We show that a novel alkali, sodium metaborate, can provide tolerance to high divalent cation concentrations, which the conventional alkali sodium carbonate cannot. Our laboratory approach uses quick, inexpensive microemulsion phase behavior experiments to screen chemical formulations for both performance and tolerance to salinity and hardness. Well performing formulations are validated for good oil recovery and other criteria using prepared Berea sandstone cores saturated with very hard, saline brine at residual oil saturation.

Experimental data containing metaborate were modeled using UTCHEM, a chemical flooding compositional simulator developed by The University of Texas at Austin. UTCHEM is a three-dimensional multiphase, multicomponent, mechanistic simulator that can considers three liquid phases (aqueous, oleic, and microemulsion) formed from a number of chemical species (such as water, oil, surfactant, polymer, alkali, electrolytes). Metaborate chemistry was added to UTCHEM to model chemical reactions such as precipitation, dissolution, consumption, sequestration and ion exchange reactions of the metaborate components during ASP flooding with hard brine. UTCHEM is capable of modeling soap generation from alkali reaction with acidic components in crude oil; however, this crude oil was found to be non-reactive with alkali. Experimental phase behavior data were matched to obtain critical model parameters used in the chemical flood simulations and needed to explain performance changes with salinity. The simulations were useful for understanding changes in pH, electrolyte concentrations and other important details within the cores during the chemical floods.