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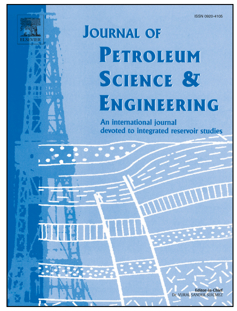

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Improving Oil Recovery in the Wolfcamp Unconventional Liquid Reservoir Using Surfactants in Completion Fluids

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Abstract

Well performance after stimulation in unconventional liquid reservoirs (ULR) can be enhanced by altering rock wettability, and by moderately reducing interfacial tension (IFT) using surfactants in completion fluids. However, ULR lithology plays a major role in surfactant selection due to rock-fluid interactions having direct impact on oil recovery. This experimental study evaluates and compares the efficiency of different groups and blends of surfactants on recovering liquid hydrocarbons from siliceous and carbonate Wolfcamp shale cores by analyzing the effects of lithology, oil and surfactant type on wettability and IFT alteration, and their impact on imbibition and oil recovery.

ULR wettability was determined by contact angle (CA) experiments, and its alteration was evidenced when adding surfactants to completion fluids. The results showed that at field-used concentrations, all tested surfactants altered wettability from oil and intermediate-wet to water-wet. These findings were consistent with zeta potential results when assessing surfactant solution film stability on siliceous and carbonate shale rock surfaces as an indication of water wetness. In addition, IFT between crude oil and completion fluids was measured to gauge IFT reduction by surfactants, showing higher reductions by anionic surfactants compared to nonionic and blended surfactants. Finally, imbibition potential for completion fluids with and without surfactants was tested in spontaneous imbibition experiments. Oil recovery from Wolfcamp shale cores was tracked in real time, and CT scan technology was simultaneously used to monitor frac fluid penetration in ULR cores. The results showed that cores submerged in completion fluids with surfactant additives have higher hydrocarbon recovery and better fluid imbibition than those in frac fluids without surfactants. In addition, siliceous shale cores had higher oil recovery and fluid penetration when anionic surfactants were used. Conversely, carbonate shale cores showed better hydrocarbon recovery and penetration when submerged in nonionic-cationic surfactants. Hence, it can be concluded that the addition of surfactants to completion fluids improved oil recovery by wettability alteration and IFT reduction, and core lithology, oil and surfactant type impacted fluid imbibition and oil recovery and should play a major role on surfactant selection. These findings give important understanding for designing completion fluid treatments and flowback schedules for these ULR.

1. Introduction

Oil production from unconventional liquid reservoirs (ULR) has become one of the most important sources of energy for United States, positioning it as one the world's greatest liquid hydrocarbon producer (Doman 2015). Commercial hydrocarbon recovery from ULR mainly depends on multistage fracture treatments, where induced fractures create a flow path for hydrocarbons to move towards the wellbore. The effectiveness of hydraulic fracture treatments in increasing oil recovery can be improved by adding surfactant additives to completion fluids to alter wettability and improve frac-water imbibition. Wettability controls fluid distribution in the reservoir and, consequently, flow behavior becomes especially relevant for improved oil recovery (IOR) in conventional reservoirs and lately in ULR.

In petroleum systems composed of brine, oil and rock, wettability is defined as the affinity of an immiscible fluid for the rock surface in the presence of another immiscible fluid (Anderson 1986a, Craig 1971). Wettability can be measured by quantitative methods such as contact angle (CA), Amott-Harvey index and US Bureau of Mines (USBM), and by qualitative methods like nuclear magnetic resonance (NMR), relative permeability determination, and zeta potential (Wang et al. 2012, Anderson 1986b). However, due to liquid rich shale petrophysical characteristics of ultralow permeability and low porosity, many of these methods are experimentally not practical and CA, NMR and zeta potential methods are the most appropriate ways to estimate ULR wettability. In this study, wettability was determined through CA measurements. We also used zeta potential experiments to determine double layer stability and wettability alteration when surfactants are added to completion fluids based on the premise that aqueous solution film stability on the rock surface is also an indication of wetting state and it is driven by rock-brine-oil charges (Hirasaki 1991).

Wettability alteration can be chemically achieved by the use of surfactants. Surfactants are amphiphilic compounds with both hydrophobic and hydrophilic groups. Based on their polar head group, they are commonly classified by anionic (negative charge), cationic (positive charge), nonionic (no charge), and zwitterionic or amphoteric (positive and negative charge). Depending on surfactant and oil type as well as rock lithology, surfactant solutions flow and/or diffuse into the rock matrix differently, and altering wettability and reducing interfacial tension (IFT) at the brine-oil interface. Wettability alteration by surfactants has been extensively studied in conventional reservoirs. Therefore, three main mechanisms responsible for shifting wettability were proposed by the literature: ion-pair formation driven by electrostatic interaction (Standnes and Austad 2000), surfactant adsorption driven by hydrophobic interaction (Standnes and Austad 2000, Austad and Milter 1997) and micellar solubilization driven initially by IFT reduction and then by surfactant miscibility (Kumar, Dao, and Mohanty 2008). These