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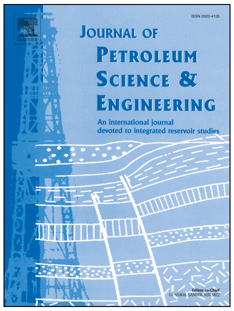

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Modeling and Optimization of Alkaline-Surfactant-Polymer Flooding and Hybrid Enhanced Oil Recovery Processes

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Abstract

This paper presents recent advances in the subject of modeling and optimization of ASP (Alkaline, Surfactant and Polymer) flooding. We used an approach that models the behavior of the surfactant-oil-water-microemulsion system based on solubility data. In Type III systems, the emulsion is distributed judiciously between the oil and water phases without the need to introduce a third liquid phase. This model captures the most important physical and chemical phenomena in the ASP process. The model is validated with numerous corefloođing experiments conducted by different research institutes as well as with a specialized chemical flood simulator. Agreements between the model and the experiments in terms of oil recovery and pressure drop were achieved for all core floods. In addition, the model is consistent with both UTCHEM-EQBATCH and UTCHEM-IPHREEQC. This model has also been successfully applied to match the recovery of Alkaline-CoSolvent-Polymer flooding, which is a promising recovery approach.

We investigated the potential of hybrid low salinity ASP flooding in which Low Salinity Waterflooding (LSW) was implemented in secondary production and followed by ASP flooding. This approach can provide a superior performance compared to the conventional chemical flooding because it provides better oil recovery in the secondary stage and promotes the synergy between a low salinity environment and ASP slugs. Finally, the proposed robust optimization workflow helps to increase a project NPV and significantly reduces the uncertainty range associated with geology.

1. Principles of ASP Flooding for Enhanced Oil Recovery

Oil recovery operations have traditionally been subdivided into three stages: primary, secondary, and tertiary (Green and Willhite, 1998). In the initial production stage (primary recovery), oil is mainly produced using energy that exists naturally in a reservoir. Conventional waterflooding is the secondary recovery stage in which water is injected into a reservoir to sweep additional oil recovery and to supplement the natural energy. Even though waterflooding normally results in a higher oil-recovery factor than primary recovery, a high residual oil saturation is generally still left behind, typically 50-60% of the original oil in place (OOIP). Tertiary recovery (the third stage of production) is very important for maximizing the ultimate recovery factor. In this stage, Enhanced Oil Recovery (EOR) is achieved by injecting materials that are not normally present in a petroleum reservoir (Chen et al., 2006) such as gas, heat, or chemicals. An important approach in EOR is chemical flooding, for example, alkaline, surfactant, or polymer, and their various combinations (Alkaline/Polymer - AP flooding, Surfactant/Polymer - SP Flooding, and Alkaline/Surfactant/Polymer - ASP flooding). Among these methods, ASP flooding has been proven as one of the most effective approaches for EOR with an excellent recovery factor up to 98% OOIP in laboratory tests (Fortenberry, 2013). ASP flooding has been implemented for pilot tests in different countries, mainly in Canada, USA, China, South America, and India, and most of these field tests showed significant improvement in recovery efficiencies over the past several decades with up to an increase of 25% OOIP (Sheng, 2013a). With global energy demand and consumption forecast continuously growing, along with the significant depletion of conventional resources and high costs and high uncertainties of offshore projects, chemical EOR, particularly ASP flooding, has the potential to play an important role in unlocking the hydrocarbon resources left behind after primary and secondary recovery stages in mature reservoirs.