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Original Paper

Polymer efficiency and sulfate concentration for hybrid EOR application to an acidic carbonate reservoir

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ABSTRACT

Polymers play an important role in hybrid enhanced oil recovery (EOR), which involves both a polymer and low-salinity water. Because the polymer commonly used for low-salinity polymer flooding (LSPF) is strongly sensitive to brine pH, its efficiency can deteriorate in carbonate reservoirs containing highly acidic formation water. In this study, polymer efficiency in an acidic carbonate reservoir was investigated experimentally for different salinity levels and SO_4^{2-} concentrations. Results indicated that lowering salinity improved polymer stability, resulting in less polymer adsorption, greater wettability alteration, and ultimately, higher oil recovery. However, low salinity may not be desirable for LSPF if the injected fluid does not contain a sufficient number of sulfate (SO_4^{2-}) ions. Analysis of polymer efficiency showed that more oil can be produced with the same polymer concentration by adjusting the SO_4^{2-} content. Therefore, when river water, which is relatively easily available in onshore fields, is designed to be injected into an acidic carbonate reservoir, the LSPF method proposed in this study can be a reliable and environmentally friendly method with addition of a sufficient number of SO_4^{2-} ions to river water.

1. Introduction

Polymers have been employed in various fields and industries to improve the efficiency of energy storage and production. In terms of energy storage, polymers are utilized for development of solar cells and batteries as an emerging technology (Qian et al., 2021; Bella et al., 2020). Polymer-based batteries have several advantages: high power densities can be achieved, flexible batteries can be developed, and recycling is possible as they are metal-free (Hager et al., 2020). In the oil and gas industry, polymers are commonly used to enhance the production of hydrocarbon fuels (Khalil et al., 2017). Adding polymers into the injection fluid increases the fluid viscosity and decreases the fluid permeability, ultimately improving the mobility of oil (Sheng, 2011).

Polymer flooding has been adopted as a mature enhanced oil recovery (EOR) method with successful outcomes in the field (Sorbie, 1991; Standnes and Skjevrak, 2014). For the injected polymer, 92% of the reported projects used partially hydrolyzed polyacrylamide (HPAM) due to its high water solubility (Standnes and Skjevrak, 2014; Sheng et al., 2015). Because the rheological properties of the HPAM strongly depend on brine salinity, low-salinity polymer flooding (LSPF) was recently proposed to improve polymer stability (Shiran and Skauge, 2013). The LSPF method has received great attention due to the synergistic effects of polymer flooding and low-salinity waterflooding (LSWF) (Vermolen et al., 2014). Lowering the salinity of the injection fluid not only prevents polymer retention (Unsal et al., 2018), but also alters the wettability of the rock surface from oil-wet to water-wet (Khorsandi et al., 2016). When low-salinity water is used as the injection fluid, it requires a smaller amount of polymer to obtain the target viscosity, which may reduce the injected polymer volume and the cost for the produced water treatment (Shiran and Skauge, 2013; Vermolen et al., 2014).

The LSPF application has practical limitations, especially for carbonate reservoirs. Most polymer flooding projects have been carried out in sandstone reservoirs due to the harsh conditions of carbonate reservoirs such as heterogeneity and low permeability (Sheng et al., 2015). In particular, the LSPF process in the United Arab Emirates (UAE) is more challenging as the carbonate oil fields have high temperature, high salinity, and high concentrations of divalent ions (Masalmeh et al., 2019). In addition, some reservoir

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