CHAPTER

5

WETTABILITY ALTERATION USING NANOPARTICLES FOR THE ENHANCEMENT OF OIL PRODUCTION

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5.1 INTRODUCTION

Wettability modification is regarded as one of the fundamental mechanisms that contributes to the enhancement of residual oil recovery during low-saline waterflooding. Modifications in wettability have a considerable impact on the petrophysical properties of the reservoir and provide insights into the spatial distribution of fluids and various reservoir fluids within the pore system. The wettability of surfaces can be classified as either hydrophilic or hydrophobic depending on the specific application. In the realm of enhanced oil recovery (EOR) applications, it is observed that nanoparticles (NPs) exhibit advantageous attributes in contrast to alternative injection fluids employed in conventional EOR techniques, including gas, polymer, alkali, steam, and other chemical agents. The injection of nanoparticles and ions with low saline water for enhanced oil recovery is commonly referred to as low salinity water flooding with nanoparticle assistance (Nwidee et al., 2017).

Low salinity water (LSW) injection has emerged as a growing practice in EOR owing to its capacity to increase oil and gas production in both sandstone and carbonate reservoirs. The utilisation of LSW injection techniques offers various benefits, encompassing the availability and affordability of water, reduced operational expenses when compared to alternative EOR methods, and its environmentally friendly nature, thereby presenting a propitious avenue for oil production improvement (Songolzadeh & Moghadasi, 2017).

The utilisation of NPs in LSW has been discovered in EOR through the alteration of wettability towards the water-wet phase and the reduction of interfacial tension, as NPs serve as the modifier of interfacial tension (IFT). By increasing the salinity of water, it becomes possible to achieve a greater incremental oil recovery. Nonetheless, once the salinity reaches the critical threshold, the NPs become more unstable, which can be evidenced by the aggregation of particles within the fluid (Keykhosravi et al., 2021).

Silica nanoparticles (SiNPs) are the most common NPs employed in EOR. Sandstone contains silicon dioxide, which is the predominant component and constitutes about 99.8% of the SiNPs. Additionally, SiNPs are more eco-friendly compared to other nanomaterials, cost-effective and offer the convenience of facile surface modification to regulate their chemical reactivity (Youssif et al., 2018). The utilisation of SiNPs could potentially enhance the production of oil through displacement mechanisms. The initial mechanism in this process is the disjoining pressure mechanism. In the presence of SiNPs within the dispersion media, these nanoparticles have a tendency to undergo reorganisation and form a film that has a wedge-like shape in direct contact with the oil phase that is discontinuous, thereby culminating in the aforementioned process (Wasan et al., 2011). The other mechanism is the wettability alteration; SiNPs modify the wettability of rocks, leading to a reduction in the interfacial tension and contact angle between two immiscible fluids (Dahle, 2014).

Laboratory research carried out by Olayiwola and Dejam (2020b) has demonstrated the significance of salinity in nanofluids pertaining to its influence on wettability and IFT. At the laboratory level, the utilisation of NPs in reservoirs for EOR has been effectively implemented, demonstrating its potential as a prospective contender for EOR, alongside surfactants and polymers. Monfared et al. (2016) have conducted a laboratory experiment to investigate the efficacy of SiNPs in the presence or absence of salt, including investigations on oil-wet calcite substrates, the dispersion of NPs in formation brine, oil-wet limestone, and IFT.

Surfactants are employed in the context of nanofluid injection to stabilise the NPs and alter their surface characteristics, transitioning them from a hydrophilic to a hydrophobic state. Injected NPs and surfactants can modify wettability and interfacial energy through their adsorption at both solid-liquid and liquid-liquid interfaces. Surfactant adsorption is reduced by NPs on the walls of the pores, subsequently leading to a reduction in the IFT (Olayiwola & Dejam, 2020a). It has been discovered by Hendraningrat and Torsæter (2016) that the presence of salinity positively impacts the degree of wettability alteration caused by nanofluids. In the investigations conducted on IFT and contact angle, numerous extensive experiments successfully determined the optimal salinity level and nanoparticle concentration. Additionally, research on the influence of water salinity and hardness cations on the efficacy of silica-based nanoparticles in EOR processes indicated that higher salinity levels contribute to improved oil recovery.

This chapter explains the effectiveness of hybrid SiNPs within surfactant and low saline water on wettability, IFT and zeta potential. In this research, these variables were assessed under various concentrations of brine salinities in order to modulate the surface charge of SiNPs and regulate the repulsion between SiNPs and surfactant molecules.

5.2 EFFECTS OF NANOPARTICLES ON WETTABILITY, INTERFACIAL TENSION, AND ZETA POTENTIAL

Nanoparticles modify the wettability of the rock surface by substituting the carboxylic particles that are currently situated on the rock surface.