CHAPTER

3

NANOPARTICLES AS A HYDROCARBON RECOVERY ENHANCER

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3.1 INTRODUCTION

In 2013, Mousavi et al. (2013) conducted pioneering research work on the utilisation of nanoparticles for enhancing the wettability of a gas condensate reservoir. The researchers conducted an experiment involving the manipulation and examination of fluorinated silica nanoparticles. Their objective was to enhance the wettability of a limestone rock specimen, hence facilitating the efficient extraction of gas condensate from a reservoir located in close proximity to the wellbore.

Fluorinated silica nanoparticles were synthesised using a co-hydrolysis reaction involving the combination of ethanol and ammonia with tetraethoxysilane (TEOS) and nonafluorohydroxyltriethoxysilane (FAS9). Due to its high electronegativity, fluorine exhibits a pronounced affinity for bonding with carbon atoms, leading to the formation of robust carbon-fluorine bonds. Consequently, the resulting fluorinated compounds possess a moderate level of reactivity and demonstrate exceptional liquid-repellent properties. Due to their large surface-area-to-volume ratio and enhanced chemical reactivity, nanoparticles have attracted increasing interest among researchers in the upstream petroleum industry for enhanced oil recovery (EOR) applications (Li et al., 2021).

Aminnaji et al. (2015) and Sharifzadeh et al. (2015) employed the utilisation of a nanofluid in order to enhance the wettability characteristics of limestone and sandstone specimens. In their study, Sharifzadeh et al. (2015) synthesised fluorinated nanosilica through the use of sol-gel coating solutions including tetraethyl orthosilicate (TEOS), fluoroalkylsilane (FAS9), and ethanol with the addition of acid (hydrochloric acid) and base (ammonia) catalysts. The experimental investigations of contact angle, spontaneous imbibition, and core flooding collectively indicate that the relative permeability of the gas exhibits a decline when it undergoes a transition from a liquid-wet state to a gas-wet one. The scope of chemical treatments that altered wettability was likewise constrained.

The research work conducted by Franco-Aguirre et al. (2018) provides further support for this theoretical framework. It has been observed that the irreducible saturation of condensate is decreased and the endpoint of condensate relative permeability is enhanced, resulting in improved condensate mobility. The study conducted by Brassard et al. (2011) is particularly relevant in this context. Silica nanoparticles were prepared using the widely employed Stober method, followed by the addition of fluoroalkylsilane (FAS17) to the ethanolic solution, resulting in the production of fluorinated silica nanoparticles.

In the last step, a solution comprising fluorinated silica nanoparticles was applied onto aluminium alloy substrates using a spin-coating technique, resulting in the formation of thin films with superhydrophobic properties. The absence of wettability screening tests or wettability modification studies conducted by Brassard et al. (2011) precluded the determination of the superhydrophobicity of the fluorinated silica nanoparticles in question.

Esmaeilzadeh et al. (2015) made the observation that nanoparticles such as titanium oxide and carbon nanotubes exhibit features that are analogous to those of nanosilica. This study is also supported by Sircar et al. (2022) and Al-Asadi et al. (2022), which show that chemical nanoparticles such as silica and titanium oxide have great potential in hydrocarbon recovery.

While conducting molecular dynamics simulations, Riascos (2017) and Sepehrinia (2017) explored the characteristics of fluorinated silica nanoparticles in terms of alterations in wettability. However, it is important to note that their findings lack validation or corroboration through experimental evidence. Additional recent investigations have been conducted by Franco-Aguirre et al. (2018) and Jin et al. (2016). Jin et al. (2016) exclusively present the alterations in relative permeability of water and condensate in their study, without including gas. This omission is noteworthy because their research primarily investigates the influence of wettability modification on the relative permeabilities of gas and condensate.

Additionally, due to the unavailability of the procedure for synthesising fluorochemically modified nanosilica, both studies had to rely on commercially available products. The investigation of nanoparticle-induced wettability alteration on rocky surfaces has predominantly been conducted using contact angle measurements and spontaneous imbibition tests (Franco-Aguirre et al., 2018; Jin et al., 2016).

This research work presents a novel approach in which fluorinated silica nanoparticles are synthesised by employing 1H, 1H, 2H, 2H-perfluorodecyltriethoxysilane (FAS17) and tetraethoxysilane (TEOS) at different molar ratios. The objective is to develop a surface that exhibits superhydrophobic and oleophobic qualities, along with the ability to self-clean. The surface-modified silica nanoparticles were subjected to a comprehensive analysis using several techniques, including FTIR, DLS particle sizer, zeta potential, thermogravimetric analysis (TGA), and field emission scanning electron microscopy. In order to assess the capability of fluorinated silica nanoparticles to alter surface wetting, a set of wettability screening experiments was conducted.