UNIVERSITI TEKNOLOGI MARA

GRAPHENE OXIDE-ASSISTED-SCALE INHIBITOR IN MITIGATING SILICATE SCALES FORMATION

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ABSTRACT

The incompatibilities mixing of high pH alkaline flooding with the neutral pH connate water during alkaline-surfactant-polymer (ASP) flooding triggers the formation of silicate scales. Scale inhibitors (SI) are being injected downhole but even so, studies reported that silicate scales still could not be mitigated even at high doses of SIs and that one-third of the injected SI would return to the production line due to poor adsorption of SI onto rock formation. Since nanoparticles (NPs) have tuneable properties and morphologies, they are to be incorporated with the carboxylate-sulphonate copolymer, TH5000 SI to improve the adsorption as well as prolong squeeze treatment lifetime with a much lower minimum inhibitor concentration (MIC). This study aims to investigate the adsorption of SI onto NP and rock formation along with the performance of the newly modified SI/NP in inhibiting silicate scale formation. There are four major parts of the experimental procedure involved which are; i) dispersion test, ii) static adsorption capacity test, iii) static inhibition efficiency (IE) test, and iv) sand pack test (dynamic inhibition efficiency (IE) test). An experimental methodology has been developed in this work to produce a well-defined silicate scale in the laboratory. This has then been used in silicate IE experiments in order to study potential silicate inhibitors. The performance of the modified SI/NP and the silicate scales produced in the experiments are measured and characterised by UV – vis, ZetaSizer Nano, XRD, SEM/ EDX, FTIR, and ICP – OES, accordingly. Dispersion test of NPs revealed that the presence of SDS surfactant in the synthetic brine enhanced the stability and dispersion of all the NPs and GO attained the most stable zeta potential value, – 107 mV compared to MWCNT, Fe_3O_4, and SiO_2. Adsorption capacity test also has proven that by incorporating GO and SI, at least 0.5 mg/g of SI/NP was adsorbed onto rock formation instead of just 0.395 mg/g when no NP is present. In the IE test, the newly modified SI/NP successfully inhibited 87.87% of Si ions and 88.37% of Mg ions from reacting, a 57.42% improvement over SI-only solutions. Characterization by SEM, FTIR, and XRD further corroborated these static inhibition findings. Dynamic sandpack tests simulated reservoir conditions, showing the modified SI/NP significantly reduced scale formation during the 24-hour shut-in period, corroborated by FTIR and XRD. However, post-flush effluent analysis yielded inconsistent results, indicating a need for further optimization studies in dynamic conditions. While the static IE test successfully established a MIC of 100 ppm for effective silicate scale inhibition (achieving 87.87% for Si ions and 88.37% for Mg ions), the MIC for dynamic conditions could not be reliably determined due to inconsistent results from the sand pack dynamic IE test. Overall, this study confirms that modifying polymeric SIs with GO NPs, alongside SDS surfactant, substantially enhances SI adsorption onto the rock formation and significantly improves silicate scale inhibition, offering a high potential for prolonging squeeze treatment lifetimes and reducing maintenance costs in oilfield production lines. Further dynamic studies are recommended for full field implementation.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Petroleum, or also known as crude oil is a fossil fuel that accumulated beneath the land or the ocean floor. This crude oil is conventionally extracted from subsurface reservoirs using drilling rigs for well construction, followed by primary production methods, which often involve artificial lift systems like pumping units. Modern advancements in drilling and production technologies have significantly streamlined the extraction process. However, even after the conventional hydrocarbon recovery, there are still residual oil remains within the reservoir. There is approximately 60-70% of original oil in place (OOIP) left in the reservoir, where 40-50% is trapped in the rock formation while another 20-30% is in lower permeability areas [1]. This residual oil cannot be recovered by using the conventional oil extraction method. This is precisely where Enhanced Oil Recovery (EOR) methods become critical. EOR, also known as tertiary recovery, encompasses a range of advanced techniques designed to mobilize and extract oil that has not been retrieved through primary or secondary methods. Primary recovery, which relies on natural reservoir energy, often supplemented by artificial lift, typically yields only about 10% of a reservoir's OOIP. Secondary recovery commonly involves injecting water or gas into the reservoir to displace and sweep oil towards production wells, achieving an additional 20% to 40% of oil recovery from the formation.

EOR is the tertiary technique that is implemented intentionally to improve the mobility of the oil in between the rock formations, making it easier to flow to a well for extraction. This technique is now common in the oilfield industry due to the fact that the suitability of a specific EOR process is highly sensitive to the reservoir. Generally, there are three primary techniques that are used in EOR. This includes gas injection, thermal injection, and chemical injection. Gas injection, which includes immiscible and miscible processes, commonly uses natural gas, nitrogen, or carbon dioxide (CO_2) and is injected downhole into the reservoir. In this application, the gases will decrease the viscosity of the oil while increasing the fluidity. These gases expand and facilitate the oil through the formation, or mix with or dissolve within the oil. In thermal injection,