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Formulation of a synthetic nanofluid for enhanced oil recovery from oil reservoirs

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1. ABSTRACT

Synergistic compounds have shown effective results in improving oil production from oil reservoirs due to their high surface properties. In this experimental study, a novel nanofluid was prepared to alter the wettability and increase oil recovery. In this regard, the nanoparticle was first synthesized and then surface-modified with effective compounds. The structural characteristics of the surface-modified synthetic nanoparticle were analyzed using SEM, FTIR and XRD. The stability of the nanofluid was investigated using zeta potential analysis. Additionally, interfacial tension, contact angle and core flooding tests were done. The results showed that the nanofluid reduced the contact angle and surface tension from the baseline values to 29° and 3.20 mN/m, respectively. The core flooding results indicated that the maximum oil recovery using the synthetic nanofluid was 15%.

Keywords: Nanofluid, Interfacial tension, Wettability alteration, Core flooding, Enhanced oil recovery.

2. INTRODUCTION

In general, the investigation of physical processes at the pore scale through laboratory approaches is very important for the development of enhanced oil recovery techniques. Chemical enhanced oil recovery significantly increases oil production by increasing the macroscopic displacement efficiency of various crude oil types [1,2]. In addition, the emergence of nanotechnology plays an important role in oil recovery performance due to their unique properties and capabilities [3]. Recently, it has been shown that the use of low-salinity water in a synergistic manner [4,5] can reduce the interfacial tension and change the wettability of the rock from oil-wet to water-wet conditions. A review of previous studies showed that, due to factors such as narrow pores, reservoir heterogeneity and other factors, the wettability alteration and the average recovery rate from low-permeability reservoirs using water flooding and other synthetic nanoparticles is much lower. In this regard, to increase the oil recovery rate, it is necessary to implement innovative and efficient methods of chemical enhanced oil recovery. Therefore, in this study, for the first time, a new synthetic nanofluid has been formulated for enhanced oil recovery. In this regard, the existence of an optimal and cost-effective concentration has been used in the experiments. The tests that have been investigated in this study include interfacial tension, stability, contact angle and core flooding.

3. MATERIALS AND METHODS

The materials used in the synthesis process include titanium isopropoxide, isopropanol, potassium laurate salt, ethanol, acetic acid, Triton X-100 and deionized water. Also, the materials used to prepare the engineered low-salinity water include sodium chloride (12.788 wt%), potassium chloride (0.559 wt%), calcium chloride dihydrate (0.882 wt%), magnesium chloride hexahydrate (5.997 wt%), sodium sulfate (3.409 wt%) and sodium hydrogen carbonate (0.168 wt%).

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3.1. Nanofluid synthesis and preparation process

The general process of synthesis and preparation of nanofluid is as follows: first titanium dioxide was synthesized. Generally, an acidic agent (acetic acid) was used in the process. In this regard, 2.5 ml of titanium isopropoxide was added to 225 ml of isopropanol and stirred at 30 °C for 20 minutes. A solution of 2.5 ml of ethanol and 1.2 ml of acetic acid was then added, and the mixture was stirred for an hour to form a gel. Next, in order to synthesize the surface-modified nanoparticle composition, 1.8 ml of surfactant and the amount of potassium laurate salt were added to the mixture of titanium isopropoxide and isopropanol, and the solution was stirred for 1 hour to form a dense gel-like solution. This mixture was dried in an oven at 80 °C for one hour, which was subsequently calcined at 300 °C for one hour to obtain the functionalized synthetic blend. In this regard, SEM, FTIR, and XRD analyses were performed to determine the structural properties of the surface-modified nanoparticles. Generally, for nanofluid preparation, the surface-modified nanoparticles were combined with engineered low-salinity water, and an ultrasonic device was used to homogenize the mixture at varying concentrations (50, 100, 150, 200, 250, and 300 ppm). The stability of the resulting nanofluids was evaluated over a period of 30 hours. After preparing the novel nanofluid, the stability, interfacial tension, contact angle, and core flooding tests were performed.

4. RESULTS AND DISCUSSION

4.1. Structural and morphological characteristics of the synthetic compound

In this section, the results of Fourier transform infrared, X-ray diffraction, and Scanning electron microscopy analyses are reported. The results of the analyses showed that the nanoparticles were well surface modified.

4.2. Stability and electrical conductivity analysis

The results of electrical conductivity and zeta potential (figure 2) were reported. In this regard, among the prepared nanofluids, the 150 ppm nanofluid was identified as the most stable concentration.

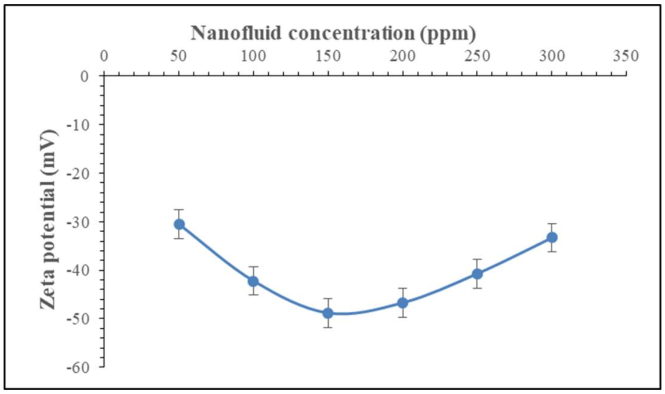

Figure 1. Zeta potential test for nanofluids at different concentrations.

4.3. Interfacial tension test

Figure 2 shows the interfacial tension graph of nanofluid at different concentrations. The results showed that the reduction in interfacial tension at a concentration of 150 ppm was greater than at other concentrations.

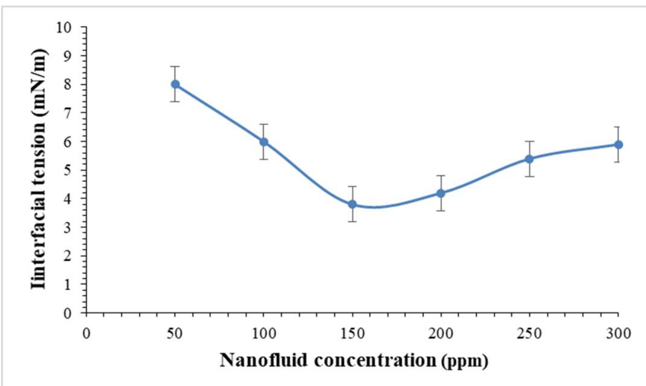

Figure 2. Interfacial tension between oil and synthetic nanofluid at different concentrations.

4.4. Contact angle test

The contact angle was measured at concentrations of 50, 100, 150, 200, 250 and 300 ppm. So that at a concentration of 150 ppm, the contact angle between the oil droplet and the rock reached its maximum and in a way caused the separation of oil from the core rock. Therefore, at a concentration of 150 ppm, a significant change in the wettability of the core rock from oil-wet to water-wet conditions was created with a change in the contact angle to 29°.

5. CONCLUSION

In this laboratory study, the effect of a new synthetic nanofluid on oil recovery was studied. Then, the optimal concentration was selected by electrical conductivity and zeta potential tests. In this study, experiments including interfacial tension, contact angle and core flooding were performed. The results showed that the nanofluid reduced the contact angle and interfacial tension from the baseline to 29° and 3.20 mN/m, respectively. The core flooding results showed that the nanofluid was able to increase oil recovery by 15%.

6. REFERENCES

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