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The impact of silica nanoparticles on the performance of polymer solution in presence of salts in polymer flooding for heavy oil recovery

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HIGHLIGHTS

- Effect of silica nanoparticles on polymer viscosity and oil recovery was evaluated.
- Oil recovery has a direct relation with injectant viscosity.
- Pore displacement efficiency increased with increase in nanoparticles concentration.
- Silica interacts with cations to decrease degradation of the polymer.

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ABSTRACT

Due to role of polymer in increasing sweep efficiency during oil recovery, much attention has been paid to the using polymer solutions in enhanced oil recovery methods. In spite of the existence of the great researches in this area, the role of nanoparticles in modification of the polymer performance in the presence of salts has not been examined before. Furthermore, there is no information about how the dispersed silica nanoparticles affect the heavy oil recovery during the polymer flooding in the presence of divalent cations. In this study, a series of polymer flooding experiments are performed in a quarter five-spot glass micromodel saturated with heavy oil. Solutions of polyacrylamide and dispersed silica nanoparticles in polyacrylamide (DSNP) with different salinities are used as the injectants to examine the effect of silica nanoparticles on the polyacrylamide performance in the presence of salts during polymer flooding of heavy oil, the oil recovery values were measured in different salinities. Furthermore, viscosity measurements are performed to help analyzing the results of polymer flooding tests. The oil recovery is measured via analysis of the continuously captured images during the displacement. Also, microscopic monitoring is used to analyze the distribution of residual heavy oil and polymer solution at the pore level. The results showed that the oil recovery decreases by increasing the salt concentration during the polyacrylamide flooding whereas in case of flooding with suspension of silica nanoparticles in polyacrylamide, decreasing rate in oil recovery is lower. The results of viscosity measurements showed that increasing the salt concentration lowers the viscosity of polyacrylamide solution to a minimum value which at higher values salts had a reverse effect and increased solution viscosity. Moreover, viscosity of silica nanosuspension in polyacrylamide was higher than that of polyacrylamide solution at the same salinity. This increase in viscosity becomes more noticeable by increasing the silica nanoparticles concentration. Finally oil recovery values versus injectant viscosity were plotted for different condition of salinity which confirmed the previous results, it means oil recovery was increased wherever injectant viscosity has been increased.

1. Introduction

Enhanced oil recovery (EOR) methods are applied to increase the oil recovery in oil fields [1–4]. Polymer ability to increase the sweep efficiency of water phase in the oil reservoirs has developed the use of polymer solutions in EOR methods. By using polymer solutions, water mobility decreases thereby oil recovery increases [5]. Besides petroleum industry, polyacrylamide has wide applications as water purification flocculants, soil conditioning agents, hydro gels in biomedicine, gels and membranes in protein separation, etc. [6].

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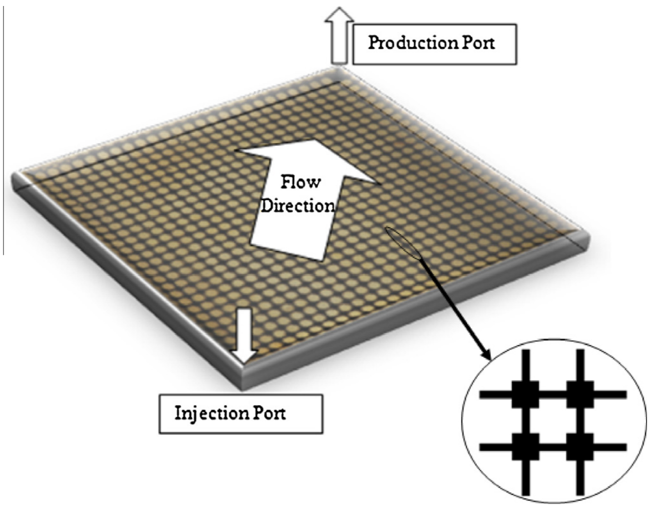

Fig. 1. A schematic of the glass micromodel saturated with heavy oil.

The existence of harsh conditions in an oil reservoir (e.g., high temperature, high pressure, chemical substances and bacteria in oil reservoirs) affects the polymer solutions function [7,8]. These factors cause degradation of the polymer due to which the polymer viscosity decreases [9–11]. One of the most important types of polymer degradation is chemical degradation due to the presence of different types of salts in formation water in the oil reservoirs. There are some papers to describe different effects of nanoparticles on polymer solution like rheology improvement or thermal property improvement [12–16]. The role of nanoparticles in modification of the polymer performance in the presence of salts has remained a topic of debate in the literature. Furthermore, there is a little information of how the dispersed silica nanoparticles affect the oil recovery efficiency during polymer flooding in the presence of divalent cations, especially when heavy oil is being displaced.

In this study, the effect of silica nanoparticles on the polyacrylamide performance in EOR in the presence of salt is evaluated by conducting a number of polymer flooding tests. These experiments is conducted (in the presence and absence of silica nanoparticles in the polyacrylamide solution) in a quarter five-spot glass micromodel. To investigate the effect of different concentrations of salts on the polyacrylamide performance, different brines (Each brine sample with a different salt concentration) are used as the aqueous phase for the preparation of polymer (polyacrylamide) solution. Polyacrylamide solution with three different concentrations is used to examine the effect of polymer concentration on the heavy oil recovery. Additionally, in order to examine the effect of nanoparticles concentration on the performance of polyacrylamide solution in the presence of salts, first, oil recovery and viscosity of injected solution at a constant concentration of nanoparticle (i.e., 0.1 wt.%) is tested in every polymer flooding tests. Then, in each polymer concentration the salt concentration which the minimum oil recovery is occurred in this salt concentration is chosen. To compare oil recovery variation with solution viscosity, oil recovery variation trend with solution viscosity was plotted for all condition and finally, in every polymer concentration and the salt

Table 1
Physical and hydraulic properties of the glass micromodel.

Pore diameter (μm)	Throat diameter (μm)	Coordination number	Aspect ratio	Permeability (mD)	Porosity (%)	Etched thickness (μm)
610	200	4	3.05	2.5	33	34

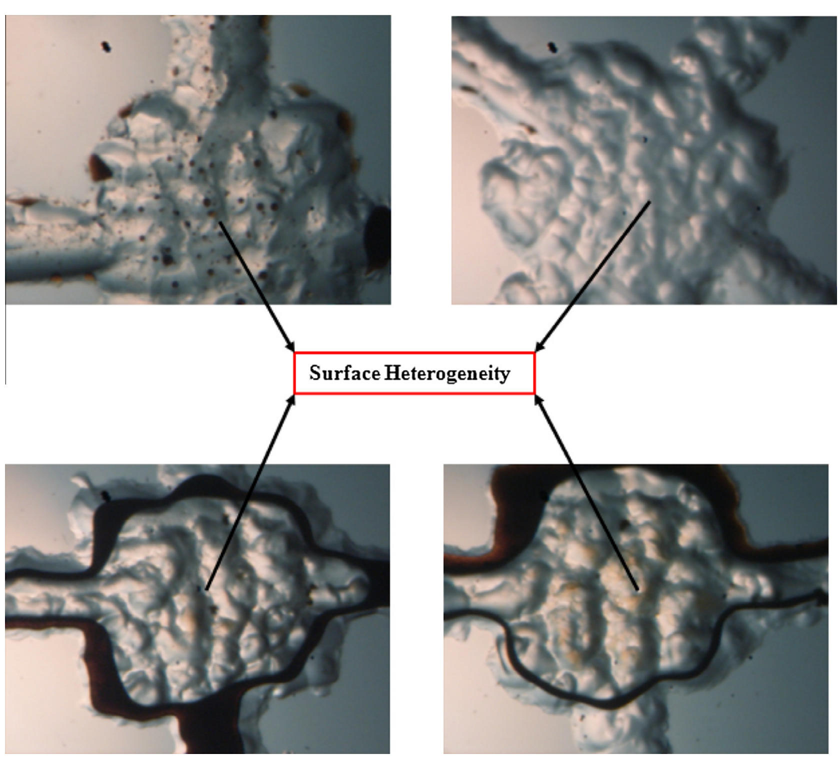

Fig. 2. Examples of pore-scale distribution in rough surfaces constructed by laser method.