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A NOVEL DISPERSED PARTICLE GEL STRENGTHENED ALKALI/SURFACTANT/POLYMER COMBINATION FLOODING SYSTEM FOR ENHANCED OIL RECOVERY.

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RESUME

Au cours des ces dernières années, un nouveau gel des particules dispersées (DPG) a attiré beaucoup d'attention en raison de ses excellentes propriétés et de ses bonnes perspectives d'application dans un processus de récupération assistée du pétrole. La méthode de préparation est pratique et facile à mettre à l'échelle pour l'application sur le terrain. Le gel des particules dispersées, dont la taille varie du submicron au micron, peut bloquer les couches à haute perméabilité en s'accumulant dans les grands espaces de pores ou en bouchant directement les petites gorges des pores dans un réservoir. En outre, les gels des particules dispersées peuvent permettre un contrôle du profil en profondeur grâce à la déformation élastique et à la migration dans le milieu poreux du réservoir. Ces caractéristiques ont démontrés le grand potentiel des gels de particules dispersées pour renforcer le système d'injection combiné des alcalins/surfactants/polymères.

Mots-clés : *Agglomérat de fines particules, analyse des photographies hémisphériques, géométrie algorithmique, convexité, enveloppement convexe, méthode de Monte-Carlo, morphologie, compacité, porosité.*

ABSTRACT

In recent years, a newly developed dispersed particle gel (DPG) has attracted significant attention because of its excellent properties and a good application prospect in an enhanced oil recovery process. The preparation method is convenient and easy to scale up for the field application. The dispersed particle gel with sizes ranging from submicron to micron can block the high permeability layers by accumulating in large pore spaces or directly plugging small pore throats. Furthermore, the dispersed particle gels can achieve in-depth profile control due to the elastic deformation and migration into the reservoir's porous media. These characteristics have demonstrated great potential for the dispersed particle gels to strengthen the alkali/surfactant/polymer combination flooding system.

Keywords : *Chromatography separation; novel dispersed particle gel; interfacial tension (IFT); displacement mechanism; enhanced oil recovery; interaction; Adsorption.*

INTRODUCTION

With rising energy consumption in the world, it is essential to improve oil recovery production. Depending on reservoir behavior, the oil recovery operation has been subdivided into three phases [1]. However, during the long-term water flooding stage, oil recovery maintenance becomes more difficult due to the reservoirs' permeability, which increases considerably during the oil field development process. In general, due to the oil/water viscosity proportion, this leads to lower the water injection phase ratio, which permits an easier channeling of water injected into the injection to production wells. The swept volume of water injected can be reduced by the reservoir's homogeneity and the change in water/oil ratio. However, in oil fields, the reduction in heterogeneity formation and the water/oil ratio improvement become a significant problem for oil recovery [2-3]. Therefore, to improve the enhanced oil recovery conditions, the displacement efficiency and sweep efficiency of the displacement agents need to be improved. So far, the chemical ASP combination is a practical method for enhanced oil recovery [4-7]. The chemical flooding technology with polymer, surfactant, and alkali as the principal agent can improve oil recovery by 8% - 15%; it plays an essential role in the efficient development of conventional reservoirs [8-11]. There are two methods to enhance oil recovery: the sweep efficiency improvement and the displacement efficiency improvement. The basic method is to transform the displacement agent's mobility and (or) oil to enhance the sweep efficiency. The mobility measures the capability of fluid to flow through the porous media. The fundamental method to enhanced oil recovery is to modify the rock surfaces wettability and decrease the capillary effect contrary impact. The chemical displacement flooding technology can be divided into Polymer flooding, Surfactant flooding, Alkali flooding, and the alkali/surfactant/polymer (ASP) combination flooding system. Chemical combination flooding system is one of the main most commonly used for EOR processes, which have joined in many kinds of research and pilot testing techniques for the mature oilfield's high water cut. China is one of the countries in the world, which develops chemical EOR technology vigorously. ASP flooding pilot tests have achieved good oil recovery results in Daqing, Xinjiang, Shengli oilfield. In the chemical flooding system, the polymer plays a prominent role because of a viscoelastic characteristic to improve the mobility ratio. When the polymer system flows in a porous medium, the injection pressure decrease, which leads to a low-profile control due to the low water-oil ratio, and makes the system challenging to obtain a good yield for an extended period of enhanced oil recovery. The surfactant reduces the interfacial tension, the remaining oil saturation and increases the displacement efficiency. The alkali forms the in-situ surfactant by reacting with the crude oil; this reaction significantly affects the system's viscosity and the IFT of the system. However, in porous medium, the dilution effect and shear deterioration affected the alkaline-surfactant-polymer combination flooding system's viscosity. With the increase of reservoir temperature and salinity, the temperature and salt tolerance of polymer, surfactant, and alkali are facing significant challenges, which has become technical difficult for the application in medium-high temperature and medium-high salt reservoirs. Some problems have been exposed in the pilot field experiments in medium-high temperature and medium-high salt reservoirs. When the reservoir temperature and salinity are higher than 80˚C, and 5×104mg/L salinity, polymer thermal viscosity reduction and salt sensitivity are significant, and the viscosity reduction rate can reach more than 60%. The alkali has poor salt tolerance and large consumption. The ASP combination flooding system's effect is reduced, so applying the chemical combination flooding system containing polymer and alkali in high temperature and high salt reservoirs is severely restricted.

2 Experimental procedures.

2.1 Materials

The polymer partial hydrolysis polyacrylamide used in the experiment was bought fro Gaoyuan Co. Ltd. Dongying. China with 18,000,000 molecular weight average and 30% hydrolysis degree. The alkylbenzene sulfonate used has abbreviated Haitai with 50% active content, and the sodium carbonate used with 98% active content was bought from Beijing chemistry. The viscosity of the simulated crude oil used in the tests was 25mPa.s at 60°C with a density of 0.91g/cm3 and an acid value of 0.45mg/g bought from China Daqing oilfield. The simulated water used has a salinity of 4000mg/L. The average temperature used was 60°C for all experiments.

2.2. PREPARATION METHODE OF THE DISPERSED PARTICLE GELS (DPG).

In general, there are two methods to prepare the DPG particles after the preparation of the bulk gel: the shearing cross-linking and the highspeed shearing method. Despite the difference, both methods implicate shearing forces in the preparation mechanism. For this experiment, we diluted first the concentration mass of 0.3% polymer in 400 mg/L of brine salinity; then, we dropped 0.9% phenolic resin cross-linking agent to form the uniform gelation solution placed in the oven at 90°C for 6 hours. After, a colloid mill with the rotation speed of 45 Hz was used for 15min to milling 200g of water and 200g of bulk gel simultaneously. Finally, the DPG products were obtained, as shown in Fig 1-1. It can be seen that the particle size of the dispersion is different depending on the shear rate, and the particle size is distributed between nm ~ mm. The higher the shear rate, the greater the shear force exerted by the colloid mill on the bulk gel, and the easier it is to break the bulk gel into smaller DPG particles. Fig 1-2 further shows that the particle size distribution curve of the DPG particles formed under high shear rate conditions is narrow, indicating that the DPG particles prepared by the mechanical method are relatively uniform. The particles are mainly spherical; the SEM technique was used to characterize the particles' size distribution about 2µm Fig 1-3. The viscosity of DPG particles was measured using a viscometer (Brookfield DV−2 Pro, Middleboro, MA, USA) was 6.4mPa·s with a shear rate of 71s−1.

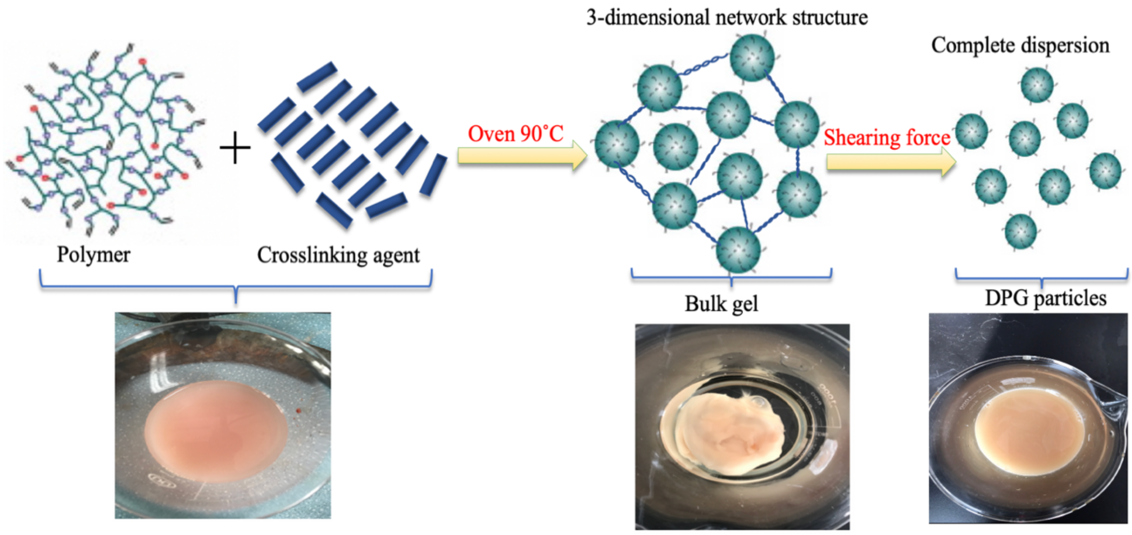

Fig.1-1 The Formation Mechanism of DPG Particles.

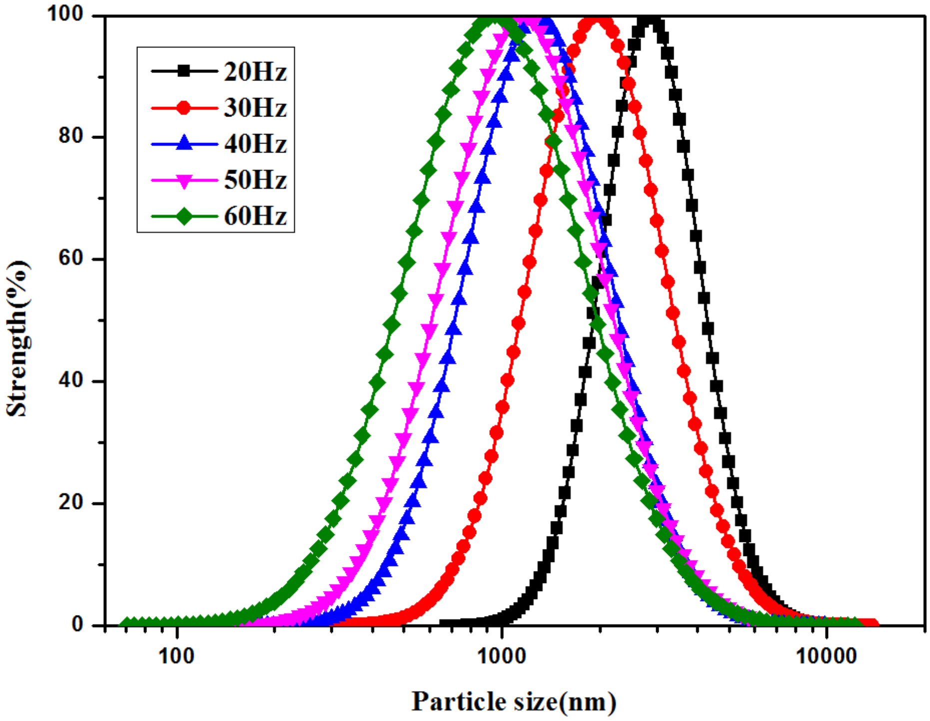

Fig.1-2 Effect of Shearing Rate on the Size Distribution of the DPG Particles

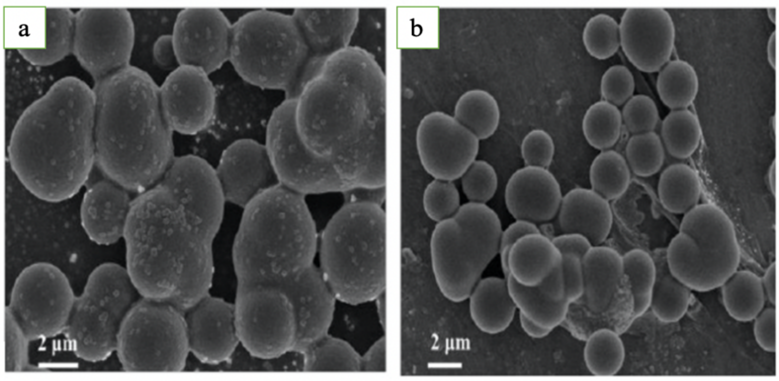

Fig 1-3. DPG Particles Morphology and Size Distribution.

Conclusion

In this paper, the dispersed particle gel strengthened alkali/surfactant/polymer combination flooding system has been prepared successfully as a novel combination flooding system for the enhanced oil recovery process. The major conclusions are summarized as follows. A small number of hydrophobic groups of DPG particles absorbed the surfactant on the interface, reduced the diffusion rate, and improved the surfactant's fluidity ratio. The alkali reacts with the crude oil acidity to form the in-situ surfactant. Therefore, the action mechanism of the system's synergistic effect makes the remaining oil emulsification ability enhanced until it broke into small oil droplets. Thus, action improves the DASP combination profile control capacity for enhanced oil recovery processes.

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