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Research Article

Study on Blocking Performance of DCA Microspheres with low Permeability Reservoir Pores

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Abstract:

For improving sweep efficiency and decreasing water production in high temperature and low permeability reservoir, divinylbenzene-co-acrylamide microspheres (DCA) were synthesized by dispersion polymerization using acrylamide crosslinked with azobisisobutyronitrile. Scanning electron microscopy (SEM) and dynamic lighting scattering (DLS) were adopted to investigate the shape, size and structure properties of DCA microspheres . The results demonstrated that original shape of the nanoscale polymer microspheres were typical spherical, ranging in size from 5μm to 60μm. DCA microspheres can tolerate high temperature of 100℃. Good dispersion of DCA microspheres in salinity water also can be pumped into artificial core at any rate. When the microspheres were dispersed in salinity water for hours, their size was increased due to swelling and a poly-dispersed system appeared but the spherical form was remained. The microspheres can plug porous medium and there is certain matching relation between the size of microspheres and the size of reservoir pore, and they can be adsorbed, accumulated and bridged in the pore-throat to play a role of plugging. The heterogeneous core displacement experiment shows that DAC microspheres mainly plug high permeability layer and the permeability of low-permeability layer is changed little. Due to these properties, DAC microspheres will become a selection for deep profile for low permeability, heterogeneous and high temperature reservoir.

1. Introduction

Low permeability and ultra-low permeability reservoirs are widely distributed in China. Compared with medium and high permeability reservoirs, the heterogeneity of low permeability reservoirs is serious. The injected water is easily channelling and difficult to affect the dense oil matrix. For fractured low permeability reservoirs, the water plugging agent need good injection, and can effectively plug and ensure long effective period.

Many chemical profile agents have been widely adopted to control water content. Polymer microsphere is a new potential profile control technology developed rapidly in recent years. According to the diameter of reservoir rock throat, the polymer microspheres matching the throat diameter are prepared by nano-micron material synthesis method, which is polymerized by polymer monomer, crosslinking agent, initiator and activator. The mechanism of profile control is that the microspheres can move freely in the porous media after entering the reservoir with injected water. The polymer microspheres accumulate in the throat to block up and cause resistance to the flow, so that the subsequent flow will turn around and flow around. Because the microspheres have the certain degree of viscoelasticity, the microspheres will be elastic deformation as the plugging pressure difference increases to a certain extent. Then the polymer microspheres continue to migrate deeply through the throat, so as to achieve step-by-step deep profile control and flooding. The profile control agent should have such properties: The profile control agent could migrate in reservoirs which is near injection wells. During the migration process, the profile control agent gradually forms the plugging of water channel. Microspheres with specific functions and properties are a kind of plugging agent which may realize this technical idea. DCA microspheres can realize this. At the beginning of injection, the diameter of DCA microspheres is much smaller than the pore throat diameter of reservoir. In the process of migrating to the deep reservoir, the microspheres gradually self-assemble into clusters, thus realizing deep plugging of water channel. In this article, divinylbenzene-co-acrylamide microspheres (DCAMs) with different particle size were firstly prepared by using dispersion polymerization. Then their physical properties such as chemical structure, micromorphology, particle size and size distribution, swelling property and stability were reseached. The core displacement experiment under the simulated reservoir conditions was designed to analyze the recovery and profile modification performance of DCAMs.

2. Experimental Methods and Results

Preparation of PCPMs

In this study, acrylamide (AM), N, N'-methylene bisacrylamide, Span 80 , Sodium Alcohol Ether Sulphate (AES), Divinylbenzene (DVB), 2-methylpropionitrile，deionized water and plant oil were used to prepare the samples of micron-size divinylbenzene-co-acrylamide microspheres (DCAMs) through dispersion polymerization . The micromorphology of DCAMs was observed by Axiostar plus optical microscope and FEI Quanta 200 scanning electron microscope. The particle size and size distribution of DCAMs was measured by Malvern laser particle size analyzer.

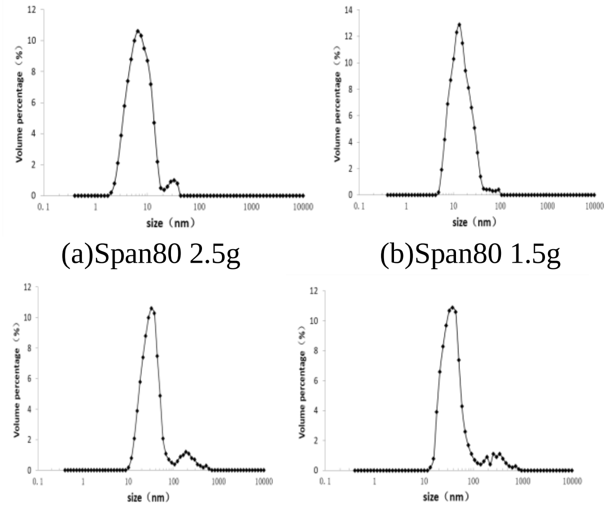
Particle size evaluation of DCAMs

SEM and laser particle sizer were used to evaluate the original size and swollen size of divinylbenzene-co-acrylamide microspheres.

（1） Original size

As shown in figure 1(a)~(d), particle size of four microspheres production has single peak characteristic and distribution is narrow. The particle size of DCAMs were well controlled by changing Span80. According to different design requirements, specified particle size of DCAMs could be produced. The average size of microspheres decreased with the increasing Span80. The particle size distribution range were from 5μm to 60μm.

（2） Swelling size of DCAMs



(a)Span80 2.5g (b)Span80 1.5g

(c)Span80 0.8g (d)Span80 0.4g

Figure 1. *The particle size distribution of DCA microspher*es

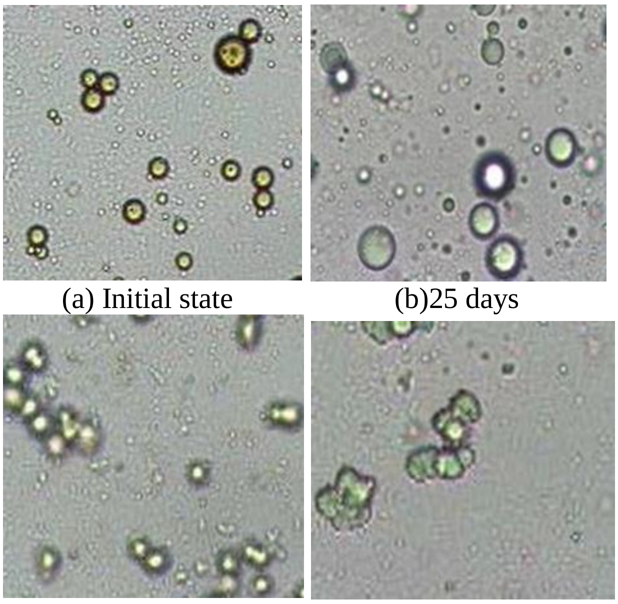
DCAMs were scattered in simulated formation water and configured solution of 2000 mg/L. Preparing microspheres solution with the concentration of 2000 mg/L, and scattering microspheres in simulated formation water. Place the solution at 100℃ for 100 days. The changes of microsphe-res sizes were observed by Axiostar plus optical microscope, shown in fig 2.

The particle size of microspheres increased as the time grew at the 100℃; the growth chiefly occurred in the first 2-4 days, and then declined until it tend to balance. Analysing reasons on the physical structure, DCAMs are three-dimensional networks with low crosslinking degree. Water could intrude into these networks. These results illustrate that DCAMs have excellent swollen property. That property could be beneficial for DCAMs to be injected into formation.

(3) Using TEM to measure the initial form of microspheres

SEM was adopted to measure the sizes variation of microspheres at 100℃ for 100 days and the results are shown in fig 4. As analysing from the SEM photos, there were visible holes at microsphere surface. As the microspheres stayed longer in the simulated water, the hydration degree of the microspheres enhanced. As the microspheres bulged totally, they could blend into net structure, which is benefit to plug high permeability channel and big pore throat. DCA microspheres are synthesized by copolymerization of divinylbenzene and acrylamide. The particle size and distribution could be controlled by changing the reaction conditions.

Experiments in porous medium of microspheres suitable for reservoir condition



(a) Initial state (b)25 days

(c)50 days (d)75 days

Figure 2. *Photomicrographs of DCA microspheres at different days*

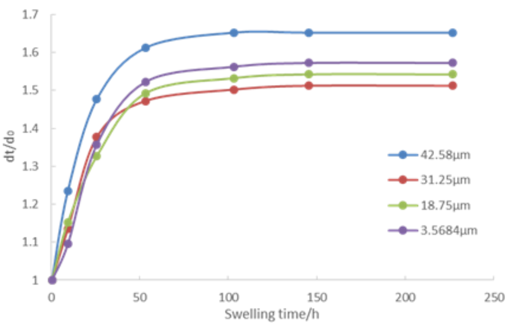


Figure 3. *Water swelling property of DCAMs*

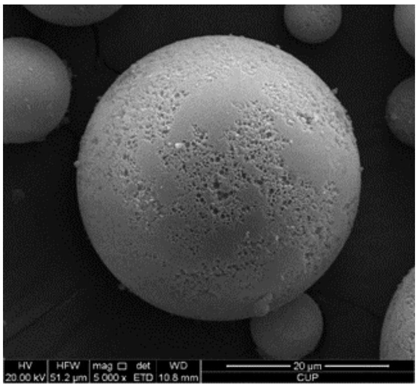


Figure 4. *SEM photos of microspheres swelling at 100℃for 20 days（2000mg/L）*

(1)Blockage property of DCA microspheres

The experiments were done in multifunctional core displacement equipment which is shown in Fig5. The artificial core was 30cm long, and the diameter was 2.5cm. The core permeability was 25*10-3μm. The microspheres solution with the concentration of 2000mg/L was injected into the artificial core which was placed at 100℃ and the entire volume was 0.3PV. The injection sequence was water-flooding, microsphe-res solution and follow up water flooding. The manometric points configured at different core's position monitored pressure variations throughout injection process. As shown in Fig6, the microspheres could block the formation obviously. The pressure increasing of the core's end indicated that microspheres could migrate into the deep reservoir and have good deep profile control ability. As the injection of DCA microspheres solutions, the pressure points are increased. When the 0.3PV of solutions are injected, the pressure rise trend is slowed down, and a small range of fluctuation occurs. During the subsequent water flooding process, the pressure at each pressure point is increased. This phenomenon indicates that the DCA microspheres can effectively enter the depth of formation and form a certain blocking effect.

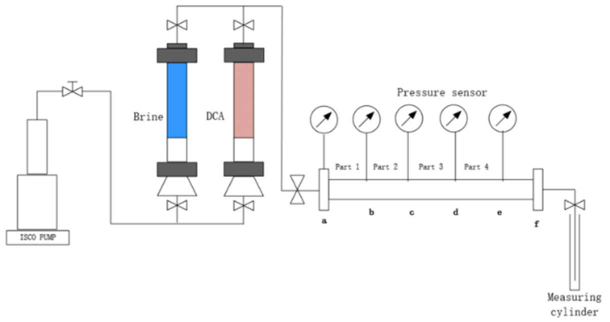


Figure 5. *Multi-measuring point pressure device.*

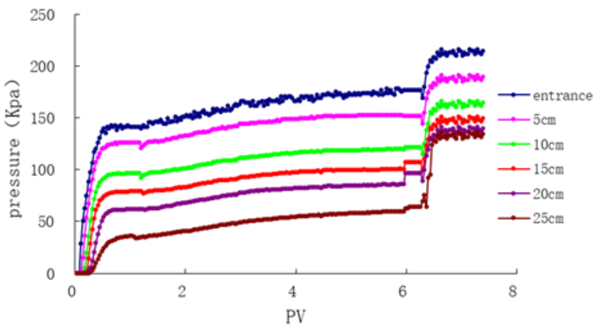


Figure 6. *Residual resistance coefficient of microspheres at different positions*

(2) Recovery ratio and Profile Modification Performance of DCAMs

Heterogeneous core flow apparatus was adopted in this research to access profile modification performance of DCAMs. The length of the core holders is 30cm and the inner diameter is 4.5cm. Heterogeneous core is shown in Fig7. The permeability of heterogeneous core is 5 *10-3μm and 25*10-3μm, repectively. The experiment was conducted at 100 °C and the injecting velocity was 0.2 mL/min. The mineralization of simulated water is 7843 mg/L. The simulated water was firstly injected until water content arrived at 98% ,then 2000 mg/L DCAMs was injected; at end, water was injected again. The pressure of different positions of heterogeneous core was measured by high procession pressure sensor. Fig 8 shows the displacement performance curves in heterogeneous core. It can be seen that DCAMs can block heterogeneous core selectively. The water-flooding recovery was 30.52%. The rate of enhanced oil recovery increased by 41.6% after injecting DCA microspheres. In the process of injecting DCA microspheres , the water content decreased by 76%. In the water flooding stage, the water-free recovery rate rose faster and reached 16.5%. However, once the production well produced water, the water content increased rapidly, and The rising trend of the recovery curve has become gentle. The pressure of injection end dropped and gradually stabilized. The final recovery factor in the water flooding stage was 29.2%. The strong heterogeneity of the model makes the injected water quickly break through the high permeability layer, which reduced the sweep efficiency and limited the water flooding recovery. The change in pressure data confirmed the inefficient circulation of injected water, and the recovery rate in the water flooding stage was very low and the water content of the oil well rose quickly. 0.3PV polymer microspheres were injected after the end of water flooding. The water content decreased rapidly and the water ratio declined to 79.5%. At the same time, the pressure increased. The overall recovery rate after the subsequent water flooding increased to 40.1%. This result shows that DCAMs have a good enhanced oil recovery ability and profile modification performance

Figure 7. *The photo of heterogeneous core*

3. Conclusions

DCAMs are regular spherical particles with a narrow unimodal particle size distribution. DCAMs have good swollen property, high thermal stability and good resistance to high temperature of 100 °C. Though changing the particle size of microspheres, DCAMs has the fine flexibility for different reservoirs. There are four stages for microspheres migrating though porous media. They are smooth

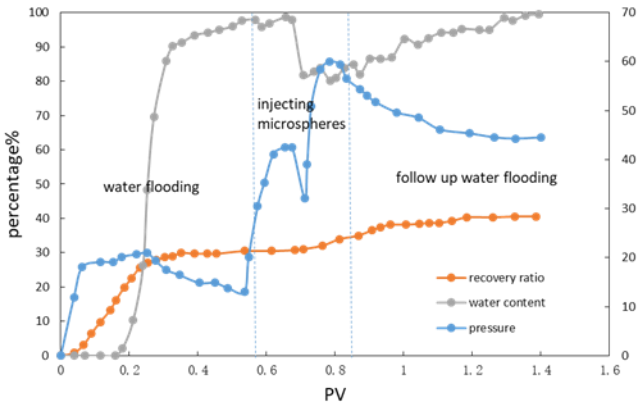


Figure 8. *Effect of decreasing water and increasing oil by injecting DCAMs*

passing, elastic plugging, bridge plugging and complete plugging respectively. The microspheres have good injection and can migrate to the deep core. The residual resistance coefficient is high and beneficial for subsequent fluid turning around. The core displacement experiment results shows DCAMs could can be enhance effectively oil recovery in high temperature and low permeability reservoir.

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