Selective Water Blocking Mechanism Analysis of Double Crosslinked Gel Plugging Agent

Hao Guo, Qingwang Liu, Zhenzhong Fan, Jigang Wang, Jianjun Xu*
Department of Petroleum Engineering, Northeast Petroleum University, DaQing City Heilongjiang Province 163318, China

*Corresponding Author e-mail: 123939274@qq.com

Abstract. The microscopic morphology of the plugging agent was observed by scanning electron microscope. Double crosslinking system has dense pores and full structure. The outer network in the double crosslinked gel is filled into the voids of the network. This mainly forms a secondary network in the form of filling, which can greatly improve the water retention and viscoelasticity of the gel. Based on microscopic morphology, the principle of high efficiency plugging was analyzed. The water plugging in the well is simulated by visual model, and the selective plugging effect of double crosslinked gel is observed more intuitively.

Keywords. double crosslinking; selective plugging agent; water plugging mechanism; visual simulation

1. Introduction
The gelation process of double crosslinked gel can be divided into two stages: the primary crosslinking gel formed at the ground temperature and the double crosslinked gel formed at the reservoir temperature [1, 2]. The advantage of double crosslinked gel is that it can be used as a new plugging control technique to improve profile control and water plugging in existing low permeable fractured reservoirs [3-5]. It can also be used as a new technique to improve the injection of water wave and coefficient. Macromolecules in double crosslinked gels are water soluble linear polymers with large molecular weights and many repeating links [6]. There are hydrophilic groups on each link, such as -COONa, -CONH₂, -COOH, etc. [7]. After cross-linking, double crosslinked gel forms a three-dimensional structure with high strength gel system in the water, and the adhesive ability is stronger. [8]

2. Microstructure of plugging agent and its efficient sealing principle
A double crosslinked gel based plugging agent was synthesized by using hyperbranched polyacrylamide as an internal network polymer and cationic polyacrylamide as an outer network polymer [9, 10]. Structure determines performance. The microstructure of the gel system was analyzed by scanning electron microscopy. From the microstructure analysis, double crosslinked gel reduces the filtration mechanism and strengthens the micromechanism of toughening.
2.1. Microform of plugging agent

(1) Using the scanning electron microscope, the external network gel was magnified 400 times, 800 times and 1600 times as shown in figure 1.

![Figure 1. External network gel scanning electron microscopy display](image1)

The single crosslinking system is characterized by large aggregation of molecular wires, large pore size, loose structure and uneven three-dimensional network skeletons. The binding ability of water is poor.

(2) The double cross-linked network gels were enlarged 400 times, 800 times and 1600 times respectively by scanning electron microscope, as shown in figure 2.

![Figure 2. Double crosslinked network gel scanning electron microscope display](image2)

The molecular chain of the double cross-linked system is stretched, the thickness of the chain is uniform and the mesh pores are denser. The small molecule of the polymer is filled in the pores of the new polymer macromolecule, forming a film, and the level is plump. It has a strong ability to bind water and produce large deformation resistance. When the concentration is increased, the polymer is flocculent and the grid structure is uniform. The main chain is clear, the branched chain is well developed, and the membrane between the chains is formed. According to previous research experience, this effect mainly comes from the properties of the polymer's anti-salt properties.

2.2. High efficiency plugging principle

The inner network is rapidly gelled at ground temperature. The initial crosslinking gel was used to reduce the filtration loss of the plugging agent in the crack and improve the water retention property of the gel.

Double cross-linked gel is a gel that combines two separate polymer cross-linked networks. The outer network of double crosslinked gel is filled into the voids of the network, and the water retention
and viscoelasticity of the gel can be greatly improved. The mechanical properties of gels can be greatly improved by double cross-linking gel compared with the corresponding dual crosslinked gel, which is a non-linear enhancement.

3. Visualization simulation of water shutoff in oil well
The main problem of water discharge in most oil wells is the problem of bottom water ridge. We simulate the formation of the reservoir with a certain permeability gradient by visual model, and make a physical simulation of water plugging in the well. The simulation of water plugging in the well can increase the selectivity of water shutoff and reduce the damage to the reservoir. The selective plugging effect of double crosslinked gel can be observed more intuitively. By analyzing the mechanism of plugging agent into the high permeable layer in the low permeability layer, the effect of selective water plugging is evaluated.

3.1. Establishment of visual model
The model uses two square glass plates with a length of 200mm and a thickness of 5mm. The interior is filled with 100-200 purpose sand grains, surrounded by epoxy resin and 6%-10% ethylenediamine and phosphoric acid ester, and the glue is fully cemented. The reservoir model formed between the two glass plates has a high permeability zone and a low permeability zone in one reservoir.

![Figure 3. Visualization panel model](image)

Fig.4 sketch map of visual test device 1- Computer; 2- micro pump; 3- model; 4- camera; 5- monitor

There are several high permeable zones in the middle of the model. The visual flat model, shown in Figure 3, is a visual experimental device, as shown in figure 4.
3.2. **Visualization model experiment step**

The visualization model is taken to vacuum and saturate the simulated formation water in Daqing oilfield, as shown on the left of figure 5.

The visualization model is saturated crude oil, as shown in the middle of figure 5.

The visualization model simulates water injection to bottom water breakthrough, as shown on the right of figure 5.

![Figure 5. Saturated formation water saturated crude oil and bottom water injection](image)

A double crosslinked gel is injected at the end of the simulated horizontal segment of the visualization model, as shown on the left of figure 6.

Constant temperature under 70 °C, after 48 h the visualization model is taken out and injected into the bottom water to carry out water flooding, as shown on the right side of figure 6.

![Fig. 6 Water flooding after the first injection of plugging agent](image)

A double crosslinked gel is injected from the well end of the visualization model after a cross link, as shown on the left of figure 7.

Constant temperature under 70 °C, after 48 h the visualization model is taken out and the formation water is injected into the bottom water to carry out water flooding, as shown on the right side of figure 3.5.
Fig. 7 water flooding after second injection of plugging agent

From the above series of water blocking visualized simulation experimental images, it can be seen clearly that the bottom water breaks along the high permeability zone and points into the wellbore. Double crosslinking gel plugging agent mainly enters high permeability zone, effectively sealing the channel of high permeability zone and bottom water, and improving the sweep coefficient of injection water.

This shows that the selective water plugging effect depends on the selectivity of the double crosslinking gel plugging agent and the selectivity of the formation. Through the above experiments, it can be seen that the selective shutoff effect of double crosslinked gel type plugging agent is very good.

4. Conclusion
(1) "Main chain + branched chain + Chain membrane" tends to form three-dimensional space pore structure, which has the strongest binding force to water.

(2) The polymer gel system can improve the viscoelasticity and toughness of the double-network hydrogel, so that the double cross-linked gel has high mechanical properties.

(3) The visualization of the simulation results show that multiple rounds of water plugging can prevent water break through again, can further improve the sweep efficiency and higher recovery efficiency.

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