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# Study on Characteristics of Polymer Surfactant and Application of Polymer Surfactant Flooding Technology in Oilfield

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**Abstract**

This paper briefly introduce that the development of polymer surfactant flooding in Daqing Oilfield. The polymer flooding technology has been studied for 30 and increased cumulatively more than 100 million tons crude oil in Daqing Oilfield. But the common polymers used in polymer flooding has poor resistance to shear, salt and high temperature and does not suitable to high temperatures, high salinity reservoir, so there are new type of polymer surfactant comes as polymeric surface-active agent be researched before decade and carried out a series of pilot test in Daqing Oilfield.

The polymer surfactant be used in S Ⅰ reservoir and X Ⅱ reservoir that belong to the second or third class reservoir at west and Pu I reservoir that belong to the first class reservoir of northeast in Daqing Oilfield. Where application of polymer surfactant flooding produced significant oil recovery than water flooding or common polymer flooding. The polymer surfactant flooding technology is the innovated and replaced methods that can decrease cost and further enhance the recovery.

It is studied on that the characteristics of polymer surfactant is strong emulsifying ability, salt resistance and suitable for EOR by SEM and other series of experiment. It contrast with normal polymer shows the oil recovery is higher, the injection process is simpler and the costs is lower and it has good application prospects.

**Key words :** Polymer surfactant ; EOR ; Emulsifying ability ; Salt resistance ; Molecular structure

## 1. Introduction

Daqing Oilfield has been produced after primary oil recovery by flowing well and the subsequent secondary oil recovery by water flooding and then tertiary recovery by chemistry since 1960. The primary oil production is the oil "blew out" to surface ground by natural pressure of formation, the secondary oil production are the oil "squeezed out" by injecting water into the formation, the tertiary oil production technology that be called EOR (Enhanced Oil Recovery) technology is more oil " washed out" by injecting chemical agents such as various polymers, surfactants and alkali. It is increased that scientific and technological research on EOR in recent years at practice.

The EOR base on polymer flooding technology and ASP（Alkaline-Surfactant-Polymer） flooding at Daqing Oilfield has been a leading position in the world as water flooding technology continues to be improved. The produced oil by EOR more than 1360 tons in 2012 and it has more than 10 million tons for 11 years continuously at Daqing Oilfield that becoming the largest EOR production Oilfield in the world.

Daqing is an "old Oilfield " that has developed more than 50 years and there are more than 50 million tons crude oil was yielded high and stable after 27 years, and then over 40 million tons of crude oil be produced for 10 years. It is unique on oil field development in the history of the world. It will be produced 40 million tons crude oil every year until 2025 depending on EOR technology.

Enhanced oil recovery is very important because the recovery increased 1% equivalent to finding a Yumen Oilfield, If it increased 5% equivalent to found a Karamay Oilfield. So the EOR technology researching must be accelerated as high water cut and ultra-high recovery levels that called "double ultra-high" stage of development in Daqing Oilfield.

In order to improve oil recovery, it is necessary to maintain stable production of crude oil relying on technological innovation and study on mechanisms for the development of new technological level.

The polymer surfactant flooding that can be used in different formations is the newest innovative technology of EOR and significantly increased recovery of oil in Daqing Oilfield.

## 2. The development of polymer surfactant flooding in Daqing oil field

### 2.1 Technological innovation and pilot test

The polymer flooding technology was studied for 30 and increased cumulatively more than 100 million tons crude oil in Daqing Oilfield. But common polymer used in polymer flooding has poor resistance to shear, salt and high temperature and does not suitable to high temperatures, high salinity reservoir conditions, so there are new type of polymer surfactant comes as polymeric surface-active agent be researched before decade and carried out a series of pilot test in Daqing Oilfield.

As a new type of flooding EOR technologies, the polymer surfactant is the first time to enter the pilot test with no experience can learn before, there is only

laboratory study based on gradually optimize the design, timely and efficient on-site tracking adjustment. The project has finally been successful significantly improve oil recovery and provided technology for future of production in Daqing Oilfield.

As the pilot tests of polymer surfactant used for EOR are carried out, the results show that the polymer surfactant is very different from the normal polymers, which were used for EOR in the same field, but with the differences of the production process, type, structure, component, physicochemical properties and so on. The polymer surfactant produced by the Daqing refinery which has evolved to various polymers such as the low molecular weight, middle weight, high molecular weight, cationic, anionic, nonionic complex, and functional polymer. These products are not only used in EOR oil field , and is widely used in sewage treatment, coal, mining, paper, chemical, metallurgy and other fields.

**2.2 Application of polymer surfactant flooding**

The polymer surfactant is used in S Ⅰ reservoir that belong to the second or third class reservoir at west-middle of Daqing Oilfield to carried out pilot test firstly in 2005. After 7 years, this project is successful check and accept by Daqing Oilfield in February 2012. It is reported that the oil recovery of center testing area produced wells is higher than normal water flooding produced wells about 27.5% after applying polymer surfactant flooding method. If the additional recovery is plus the recovery of 46.3% that come from same area after water flooding before polymer surfactant flooding, the ultimate recovery from the reservoir will reach to 73.8%.

The polymer surfactant is used in X Ⅱ reservoir that belong to the second or third class reservoir at west of Daqing Oilfield to carried out pilot test firstly in 2011. Water cut in the center produced well is decreased 6.8% than water flooding and increased nearly 10 tons of crude oil per day.

The third class reservoir refers to the types of thin, low permeability oil sand layer, in which the oil recovery of application ordinary EOR is far less than polymer surfactant flooding.

The first class reservoir is a reservoir that the earliest development of oil field, after which water flooding and then injection normal polymer for many years, the remaining oil in the reservoir has been highly difficult to recovered. But there are a large number of geological reserves of oil remaining underground.

Polymer surfactant flooding is used at Pu I that belong to the first class reservoir of northeast at Daqing Oilfield. The pilot test that applied technology of polymer surfactant flooding after normal polymer flooding have achieved remarkable results which improve the oil recovery more 10%, the ultimate recovery reach to 62% in February 2013. At the same time, the pilot test of polymer surfactant flooding be used after water flooding at Pu I reservoir of west Oilfield has total recovery to 73.65% and chemical agent cost lower than normal polymer flooding 30 %.

The polymer surfactant flooding technology is more perfect and it is expected to be replacement technique that decreased produced cost and further enhance the recovery.

## 3. The characteristics of polymer surfactant

### 3.1 The morphology

The equipment of experiment : LEO435VP type environmental scanning electron microscope (SEM), LEO UK company ;

Experiment method : It is prepared with 2000 mg/l polymer surfactant aqueous and 2000 mg/l normal polymer solution. They are frozen by liquefied nitrogen and then quickly transferred to a vacuum freeze dryer for 48h at -30℃, so keep the original structure and morphology of the polymer molecules of hydration. The samples were shifted SEM scanning electron microscope to observe the morphology of the polymer hydration molecules line group, select the picture in figure 1 to analysis.

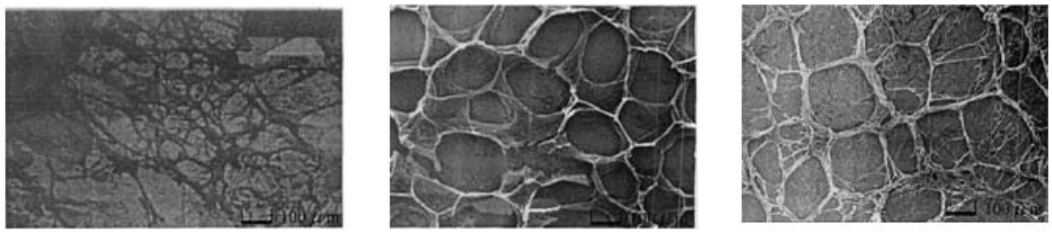


**Figure 1** The picture of polymer micro morphology in clean water （a）the network molecular structure of normal polymer ; （b）and（c）the “piece-mesh”molecular structure of polymer surfactant.

Figure 1 shows that there are different morphology of the two polymers by SEM electron micrograph scanning the structure, the polymer surfactant with regular ultramolecular structure of micellar aggregates and the performance of increasing viscoelasticity.

The polymer surfactant molecules has“piece-mesh”molecular structure compare with normal polymer and their molecular size is larger, the effect of increasing viscosity is better, but the transmission and migration ability is worse. There is micro active substance in polymer surfactant, which has stronger emulsifying and cleaning oil capability. The higher the concentration of polymer surfactant, the more volume of chemical agent and the earlier the injection time, the more recovery increased.

### 3.2 The viscosity and salt resistance

Figure 2 is the picture of the two kind of polymers in salt water, it shows that the polymer surfactant be good at salt resistance as it is relatively regular spatial mesh structure in salt aqueous.

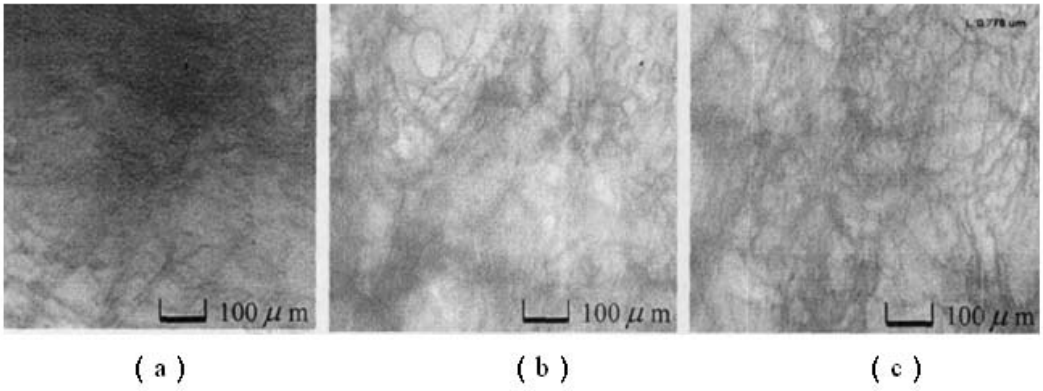


**Figure 2** The picture polymer micro morphology in salt water （a）the network molecular structure of normal polymer ; （b）and（c）the “piece-mesh”molecular structure of polymer surfactant.

The laboratory data shows that the polymer surfactant suitable for sewage preparation in practice and reduce cost in service. Because the polymer surfactant is created by adding function monomer to the framework of polymer molecule and form triaxial stereoscopic net structure filling the entire aqueous system uniformly. The polymer surfactant exist threshold concentration, favorable quality of viscosity raising and viscosity stability.

The polymer surfactant has the ability of shearing resistant and emulsifying ability that is superior to normal polymer of middle molecular weight. The polymer surfactant can not only keep the rock water wet behavior, but also can change the oil wet rock to water wet rock varying degrees.

The polymer surfactant is copolymerizated by acrylamide (AM) monomers with surface active groups on backbone that is the chain of poly acrylamide (PAM), and particular surface active groups are grafted by anionic and non-ionic and/or cationic surfactants in the side chain. Therefore, the polymer surfactant has some chemical properties of both polyacrylamides and surfactants.

Through comparing with common polymer with medium molecular weight, it is founded out that polymer surfactant low concentration, high viscosity that is higher than common polymer with medium molecular weight.

The polymer surfactants has characteristics of self-cross-linking, bacterium resistance, salt resistance, high stability of viscosity and emulsifing ability, enlarging the sweep efficiency, raising the solubilization and emulsifying power in no alkaline conditions, et al. So it is a kind of perfect chemical agent used for EOR.

## Conclusion

（1）The polymer surfactant flooding technology is the innovated and replaced

methods that can decrease cost and further enhance the recovery because there are the ultimate recovery from the reservoir will reach 73.8% and excellent characteristics.

（2）The polymer surfactants has characteristics of self-cross-linking, bacterium resistance, salt resistance, high stability of viscosity and emulsifing ability, enlarging the sweep efficiency, raising the solubilization and emulsifying power in no alkaline conditions.

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