Study on Enhanced Oil Recovery Technology of LH2500 New Salt-Resistant Polymer

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Abstract. In order to explore a new way to improve the development efficiency of polymer flooding in sewage system, the laboratory evaluation of LH2500 new salt-resistant polymer was carried out, and the field test was carried out in the middle of Xing 6 area in Daqing Oilfield. The indoor results show that compared with the 25 million polymer of Daqing Refining & Chemical Co., Ltd. under the same concentration of the cleaning system, the viscosity of LH2500 salt-resistant polymer is about 29% higher, the residual resistance is more than 10%, and the dynamic adsorption capacity is more than 5%. Increase the recovery rate by 4 percentage points. In the field application process, through optimizing the design of the oil displacement scheme of salt-resistant polymer and establishing the on-site dynamic tracking and adjustment technology, the development effect of the test area is remarkable, with the lowest water cut falling below 80% and the maximum drop reaching 15.6 percentage points, with the low value period as long as 22 months, the staged enhanced oil recovery rate reaching 13.5 percentage points, and the ultimate enhanced oil recovery rate is expected to reach more than 16 percentage points. Compared with ordinary polymer blocks, the recovery ratio in the test area is increased by more than 4 percentage points. At the same time, due to the dilution of sewage system, the excess sewage in oil field is effectively alleviated, and the high and stable yield of environmental protection is realized.

Keywords: LH2500 new salt-resistant polymer, sewage, enhanced oil recovery

1. Introduction

After more than ten years of industrial popularization and application, polymer flooding in anniversary Oilfield has formed a relatively complete supporting technology [1~3]. At present, polymer flooding has been carried out in 93 industrial blocks, with 1.03 billion tons of geological reserves. Since 2002, the annual oil production has always remained above 8.5 million tons. However, from the development effect of common polyacrylamide polymer system currently used, the EOR value of sewage dilution block prepared with clean water is 10 ~ 12%, and the oil increase level per ton is less than 40t, mainly due to the high salinity of sewage and low viscosity retention. In order to ensure the oil displacement effect, the problems of high polymer concentration and large polymer consumption are more prominent. In order to further improve the polymer flooding efficiency, save the dry polymer powder, and improve the development effect, the indoor evaluation of the LH2500 new salt-resistant polymer was carried out, and field tests were carried out in the middle of Xing6 District of Daqing Oilfield. LH2500 salt-tolerant polymer is based on common polyacrylamide block copolymerization of 2-acrylamide-2-methylpropanesulfonic acid (AMPS) monomer (as shown in Figure 1), which greatly improves the temperature and salt resistance. At the same time, a post-hydrolysis process is used in the synthesis process, and the molecule retains a good linear structure [4-5].

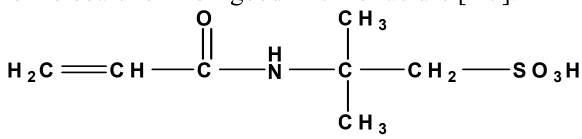

Figure 1 Schematic diagram of AMPS molecular structure

2. Indoor evaluation of LH2500 new salt-resistant polymer

2.1 Viscosity performance evaluation of blasthole and formation after shearing

Use LH2500 salt-resistant polymer and Daqing Refining & Chemical's 25 million molecular weight polymer (the same below), and prepare sewage to dilute 5 polymer solutions with different concentrations (respectively 250, 500, 1000, 1500, 2000 mg/L), and inject them into a slender tube +Tandem man-made core model. Simulate the shearing effect of polymer solution in the blasthole and formation, and measure the relationship between viscosity and concentration after shearing (as shown in Figure 2).

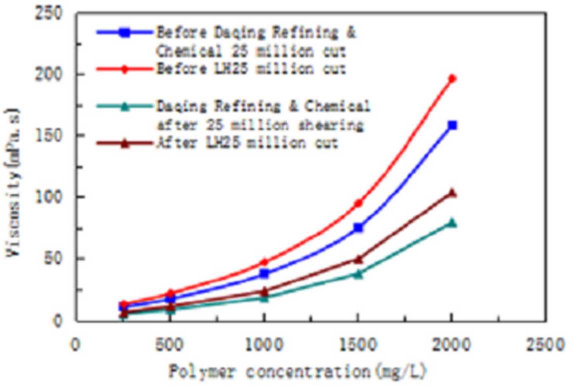

Figure 2 Viscosity curve of polymer solution before and after shear

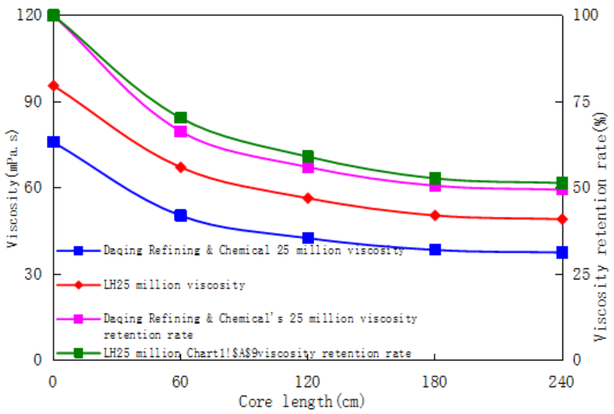

Figure 3 Viscosity loss curve of two polymer solutions with a concentration of 1500mg/L

From the comparison results, the viscosity of the LH2500 salt-resistant polymer before shearing is about 24% higher than that of the 25 million molecular weight polymer of Daqing Refinery and Chemical. After slender tube +180cm core shear, the viscosity loss law is equivalent to that of blasthole and near-wellbore zone. After shearing, the viscosity retention rate of Daqing Refining & Chemical's 25 million molecular weight polymer was 50%, the viscosity retention rate of LH2500 salt-resistant polymer was 52%, and the viscosity of LH2500 Salt-resistant polymer was 29% higher than that of Daqing Refining & Chemical's 25 million molecular weight polymer (As shown in Figure 3).

2.2 Residual drag coefficient evaluation

The residual resistance coefficient reflects the permanent loss of rock permeability caused by the polymer. The higher the residual resistance coefficient, the stronger the polymer solution's ability to adjust the profile [6]. Using LH2500 salt-tolerant polymer and Daqing Refining & Chemical's 25 million molecular weight polymer, configure polymer solutions of different concentrations (1000, 1500, 2000 mg/L), and select 3 different permeability levels (respectively 300, 500, 700×10^{-3}mD) Core seepage experiments were carried out to determine the residual resistance coefficient (see Table 1). Taking Daqing Refining and chemical 25 million polymer with a concentration of 1500 mg / L as an example, the permeability injected into the core is 500×10^{-3}mD, measure the pressure of water drive, polymer drive and subsequent water drive, and the residual resistance coefficient (FRR) is the ratio of the stable differential pressure of subsequent water drive to the differential pressure of water drive. The results show that the residual resistance coefficients of the two polymers increase with the increase of polymer concentration, and decrease with the increase of core permeability; At the same concentration, the residual resistance coefficient of LH2500 salt resistant polymer is more than 10% greater than that of Daqing Refining and chemical 25 million polymer.

Table 1 Test results of residual resistance coefficient of 25 million and LH salt-resistant polymer of Daqing Refining & Chemical Co., Ltd.

Polymer	Concentration(mg/L)	Residual resistance factor(FRR)		
		Permeability grade(10-3mD)		
		300	500	700
Daqing Refinery 25 million	1000	7.3	5.53	4.67
	1500	9.87	7.32	5.19
	2000	14.87	9.02	6.12
LH 2500 salt resistant polymer	1000	8.94	6.4	5.17
	1500	11.98	8.24	5.84
	2000	16.47	10.55	6.94

2.3 Evaluation of polymer adsorption performance

Adsorption is the aggregation of polymer on rock surface caused by electrostatic attraction and weak bonding of hydrogen bonds, which will lead to the decrease of mass concentration of polymer in solution and viscosity of displacement front, thus affecting the oil displacement effect. In this study, the material balance method is used to calculate the adsorption amount of polymer in reservoir rocks, that is, the polymer solution is used to displace the water in the rock core, and then the polymer slug is displaced by water, and the change of polymer concentration at the outlet with the injection amount is detected. The concentration of polymer solution is detected by the starch-chromium iodide method. Use the material balance method to calculate the polymer retention in the formation. Select LH2500 salt-resistant polymer and Daqing Refining & Chemical's 25 million molecular weight polymer, configure polymer solutions of different concentrations (500, 1000, 1500, 2000 mg/L), and select 3 different permeability levels (respectively 300, 500, 700) ×10^{-3}mD) (respectively shown in Figures 4, 5, and 6) cores carry out adsorption capacity determination experiments.

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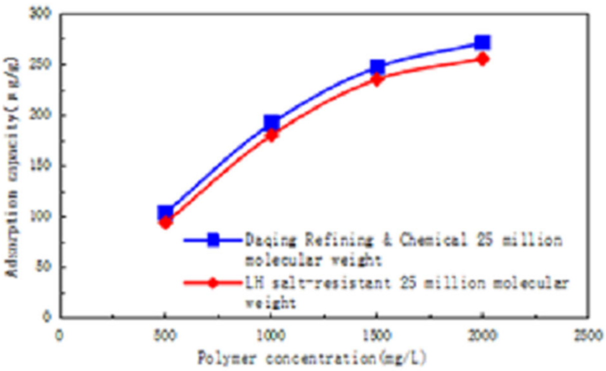


Figure 4 Permeability 300×10-3mD adsorption situation

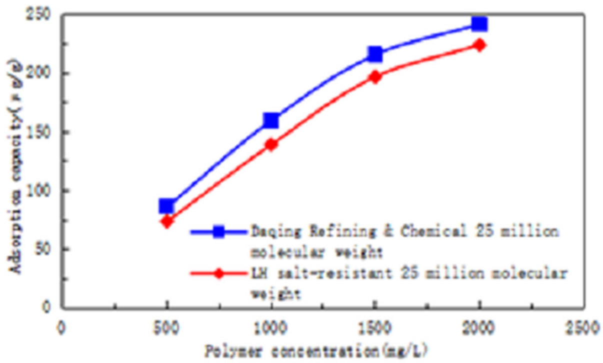


Figure 5 Adsorption of 500×10-3mD permeability

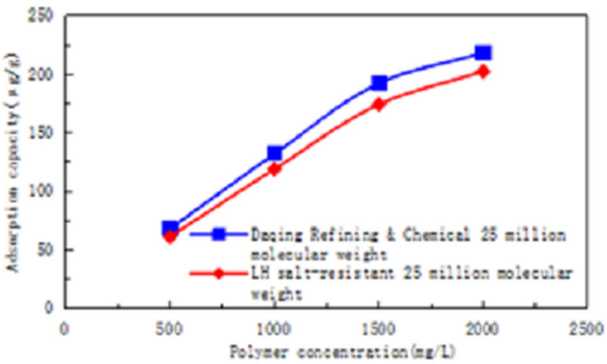


Figure 6 Adsorption of 700×10-3mD permeability

The results show that with the increase of polymer concentration, the adsorption of polymer on rock increases, while with the increase of core permeability, the adsorption of polymer on rock decreases. According to the comparison of dynamic adsorption data, the anti-adsorption ability of LH2500 salt-resistant polymer is stronger than that of Daqing Refinery's 25 million molecular weight polymer, and the dynamic adsorption capacity of LH2500 salt-resistant polymer is 5% less than that of Daqing Refinery's 25 million molecular weight polymer under the same concentration and permeability core.

2.4 Laboratory core flooding experiment evaluation

A vertical three-layer heterogeneous square model with a size of 30cm×30cm×4.5cm is designed according to the reservoir conditions of Daqing Oilfield. Well pattern types are five-point pattern, one oil production well in the middle, four injection wells in the side, core data (see Table 2) and model (as shown in Figure 7).

Table 2 Basic data of core

Core number	Porosity(%)	Permeability(10-3mD)	Initial oil saturation(%)
1#	26.14	295/499/706	65.78
2#	25.97	304/521/695	65.37
3#	26.58	316/488/713	65.96

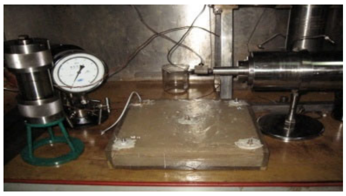


Figure 7 Physical simulation model

Using LH2500 salt-tolerant polymer and Daqing Refining & Chemical's 25 million molecular weight polymer, three sets of oil flooding experiments were carried out (see Tables 3 and 4).

Table 3 Oil displacement plan

Plan	Injection situation		
1	Water flooding to 98% water cut		
2	Water flooding to 96% water cut	Daqing Refining & Chemical 25 million polymer solution 1500mg/L, injection volume 0.75PV	Follow-up water flooding to 98%
3	Water flooding to 96% water cut	LH25 million salt-resistant polymer solution 1500mg/L, injection volume 0.75PV	Follow-up water flooding to 98%

Table 4 Oil displacement effect of the three schemes

Plan	Core	Lowest water content (%)	Degree of declining (%)	Recovery degree during polymer flooding (%)	Ultimate recovery(%)	Improve oil recovery than water flooding(%)
Plan 1	1#	\	\	\	48.32	\
Plan 2	2#	77.2	18.8	12.81	60.92	12.60
Plan 3	3#	74.1	21.9	16.97	65.01	16.69

From the oil displacement experiment results, it can be seen that the recovery ratio of water flooding is 48.32%; In the stage of polymer flooding with 25 million molecular weight polymer injected into Daqing Refinery, the lowest water content is 77.2%, the water content decreases by 18.8%, and the final recovery ratio is 60.92%, which is 12.60% higher than that of water flooding. In the polymer flooding stage with LH2500 salt-resistant polymer, the water cut is the lowest point of 74.1%, the water cut decreases by 21.9%, and the final recovery factor is 65.01%, which is 16.69% higher than that of water flooding. The injection of LH250 salt-resistant polymer can increase the recovery rate by about 4% more than the injection of 25 million molecular weight polymer of Daqing Refining & Chemical Corporation.

3. Field application of LH2500 new salt-resistant polymer

In January, 2014, the field test of LH2500 new salt-resistant polymer was carried out in the middle of Xingliu District, to investigate the reservoir adaptability of salt-resistant polymer system under the condition of field sewage system, and to study the dynamic change law of injection-production and matching adjustment technology.

3.1 Study on optimization and adjustment method of injection parameters of LH2500 new salt-resistant polymer flooding

Through mathematical model research and field production statistics, the optimal injection mode of LH2500 new salt-resistant polymer for gradient concentration reduction was determined. According to the numerical simulation prediction, the development effect of injection concentration cascade reduction is the best, and the EOR level is higher, up to more than 14 percentage points. According to the statistics of reservoir production of different well groups on site, the reservoir production degree of echelon concentration reduction well group can reach 84.9%, which can be increased by more than 10 percentage points compared with a single concentration (see Table 5).

Table 5 Comparison of the effects of different development plans in the test area

Injection scheme	Digital and analog prediction situation				On-site production statistics of oil layers(%)
	Minimum water content (%)	Water cut reduction (%)	Recovery degree (%)	Enhanced oil recovery (%)	
Stepwise concentration reduction 2000-1400mg/L	79.17	16.4	17.58	14.21	84.9
Single low concentration 1400mg/L	83.39	12.18	14.47	11.1	70.2
Single high concentration 1800mg/L	81.9	13.67	15.97	12.6	72.3
Pre-high concentration 2000mg/LSingle concentration 1500mg/L	79.9	15.67	16.77	13.4	75.9

Statistic on-site profile data, establishes the injection concentration matching relationship chart of different permeability reservoirs [7,8] (see Table 6), which effectively guides the adjustment of on-site injection parameters. In the salt-resistant test area, the injection parameters have been adjusted for 152 well times, and the production degree of oil layer has been effectively improved by more than 80%.

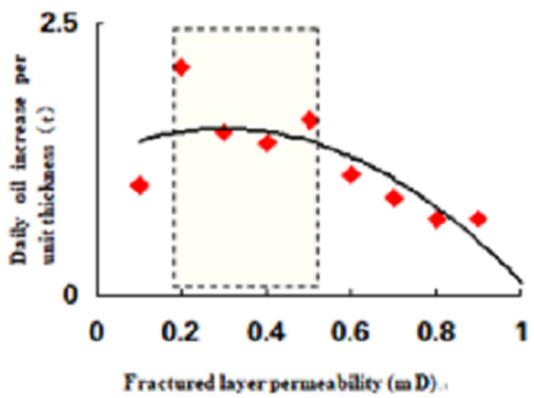
Table 6 Sewage dilution and injection plan for clean water preparation

Effective permeability(10-3mD)	Salt-tolerant polymer concentration					
	1200 mg/L	1400 mg/L	1600 mg/L	1800 mg/L	2000 mg/L	2200 mg/L
<300	1	2	2	3	3	3
300-400	1	2	2	3	3	3
400-500	1	1	2	2	3	3
500-600	1	1	1	2	3	3
600-700	1	1	1	1	1	2
>700	1	1	1	1	1	1

Note: ① "1" means the production ratio of the oil layer is ≥70%. ② "2" means that the production ratio of the oil layer is 50-70%. ③"3" means that the proportion of oil formation production is ≤50%.

3.2 Research on LH2500 new type salt-resistant polymer flooding production well fracturing well selection and layer selection technical standard

Combined with the statistics of the fracturing effect of the production wells that have been implemented, and by analyzing the relationship between the dynamic and static sensitive parameters and the fracturing oil enhancement effect (as shown in Figure 8), the LH2500 new salt-resistant polymer flooding production well fracturing well selection layer was established Technical standards (see Table 8). Using this standard, 12 fracturing wells were optimized in the test area. The average daily oil production of a single well reached 8.5 tons, the water cut decreased by more than 7 percentage points, and the effective period reached more than 80 days.



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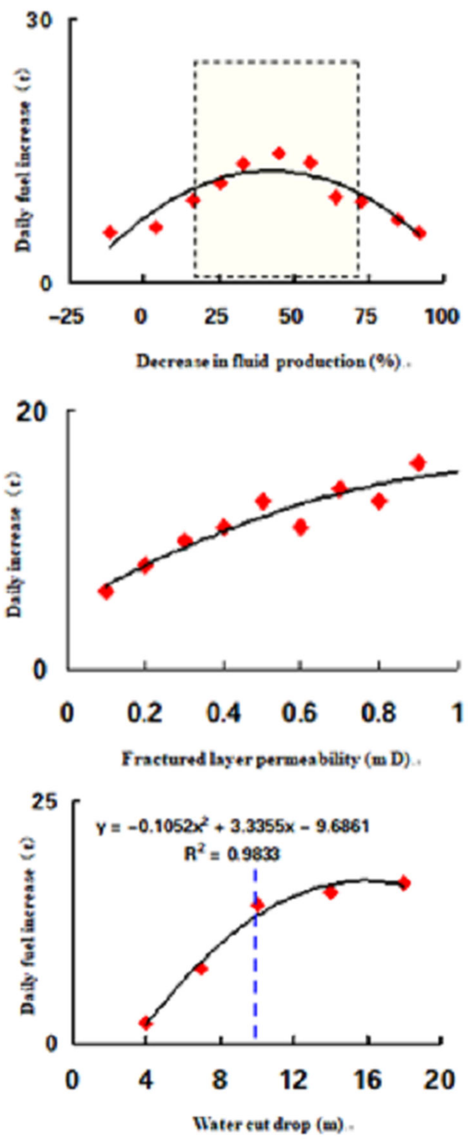

Figure 8 Relationship between oil enhancement effect and sensitive parameters

Table 7 Standards for fracturing and layer selection of LH2500 new salt-resistant polymer flooding production wells

The principle of well selection	Layer selection
1. The water content has decreased by more than 10% 2. The drop in liquid production is between 20% and 80% 3. The sinking degree is less than 300m	1. The water content has decreased by more than 10% 2. The drop in liquid production is between 20% and 80% 3. The sinking degree is less than 300m

3.3 Field application effect of LH2500 new salt-resistant polymer flooding

The field test and development effect of LH2500 new salt-resistant polymer is remarkable, with the minimum water content falling below 80% and the maximum drop of 15.6 percentage points. The low value period is as long as 22 months, and the staged enhanced oil recovery has reached 13.5 percentage points. And it is predicted that the ultimate enhanced oil recovery can reach more than 16 percentage points. Compared with ordinary polymer blocks, it can increase the recovery ratio by more than 4 percentage points. At the same time, due to the dilution of sewage system, the excess sewage in oil field is effectively alleviated.

4. Conclusion

Salt-resistant polymer has strong viscosity-increasing, salt-resistant and injection properties, high viscosity retention rate in field application, strong ability to expand swept volume, high production degree of oil layer and strong injection-production ability, and achieved good development effect. Compared with ordinary polymer flooding, it has remarkable technical and economic benefits and broad prospects for popularization and application, opening up a new mode of tertiary oil recovery, water control and oil increase.

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