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The Research and Application of High Temperature Resistance Plugging Agent and Plugging Technology

WANG Chunsheng[a]; SUN Yingfan[a],*; ZHANG Zhenzhen[a]; MENG Shan[a]; XU Chang[a]

[a] Northeast Petroleum University, Daqing, Hei Longjiang Province, China.
*Corresponding author.

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Abstract

For high temperature steam channeling problem of the middle and later of the heavy oil reservoir, using simple variable method to optimize the ratio of the of proportion the plugging agent and Static and dynamic performance are evaluated; combined the experimental data with CMG numerical simulation software to optimize the plugging process parameters. The formula of high temperature resistant gel type plugging agent system: The first working liquid: 1.8%cross-linking agent II+ 6% modified high temperature resistant main agent; The second working liquid: 0.03% coagulant aid+2.2% cross-linking agent I. The gelling viscosity of the plugging agent more than 2 x 10^6 mPa·s, PH = 6-8 is applied, heat-resistant > 280 ℃, plugging rate > 96.75%; Using the double fluid method and low-pressure low-emission to inject. Optimizing the radius of profile control is 15 m, valid for 7-10 months, it has the obvious effect of increasing oil and controlling water.

Key words: Steam flooding; Steam channeling; High temperature; Plugging agent; Profile control; Double fluid method

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INTRODUCTION

At present, the main high temperature profile control technology is to use resin, tannin extract plugging agent, it is insufficient heat resistance and hard to break down, lack of applicability high-temperature plugging agent system[1,2]. This project adopts the modification technology to improve the heat-resistant ability of the traditional high temperature resistant main agent, with coagulant and two types of cross-linking agent to form a quadripolymer gel. Through the perfect evaluation system to systematically describe the sensitivity, adaptability and effectiveness of the blocking agent to the formation environment[3]. Using the CMG numerical simulation software to improve the construction technology parameters, achieve the goal of increasing the steam sweep volume and enhancing the recovery efficiency. This study provides reference for other high-temperature profile control technology research and has a guiding significance for site construction applications.

1. THE DEVELOPMENT OF MODIFIED HIGH TEMPERATURE RESISTANT MAIN AGENT

65% concentrated nitric acid is used in experiments by a certain percentage which make modification reaction with the traditional high-temperature main agent, On the basis of the original molecules, increasing nitrocellulose to improve heat resistance performance. When the PH of solution is 7, the main agent solution viscosity increased with the increase of concentration, when the range of the main agent concentration is in 70 g/L-90 g/L, the main agent solution viscosity increases rapidly, it is from 4.75 mPa·s to 2112 mPa·s. When the solution concentration is greater than 90 g/l, the solution viscosity increase level off, viscosity is too large, it has effect on construction injection under the concentration of reaction solution.

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2. RATIO OPTIMIZATION EXPERIMENT OF PLUGGING AGENT SYSTEM

Ratio optimization experiments are performed under the simulated formation temperature 200 ℃ and the plugging agent solution PH = 7.

2.1 The Influence of Coagulant Aid HPAM on the Plugging Agent System

Main agent content is selected 6 wt.%, the content of cross-linking agent I is 2.2 wt.%, the content of cross-linking agent II 1.5 wt.%, Investigation into the effects of the content of HPAM on the gelling properties of the plugging agent system.

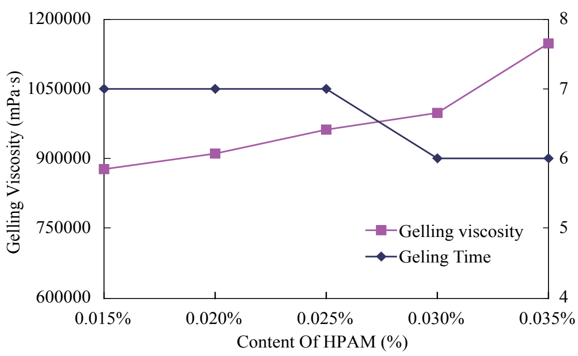

Figure 1
The Influence of HPAM on the Gel System

As shown in Figure 1, the content of HPAM is proportional to the initial viscosity of the solution, the viscosity increases with the content of HPAM increases, but the gelling time reduces. So, the content of HPAM is 0.03 wt.%.

2.2 The Influence of the Modified High Temperature Resistant Main Agent on the Plugging Agent System

The content of HPAM is selected 0.03 wt.%, the content of cross-linking agent I is 2.2 wt.%, the content of cross-linking agent II 1.5 wt.%. Investigation into the effects of the content of high temperature resistant main agent on the gelling properties of the plugging agent system.

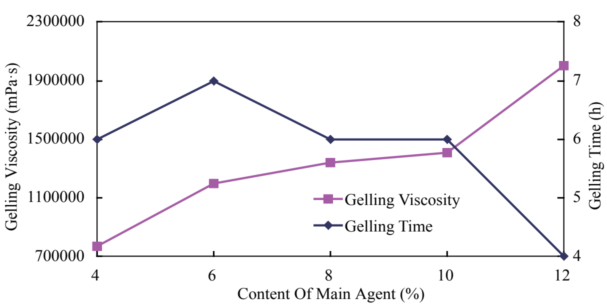

Figure 2
The Influence of the Content of Main Agent on the Gelling Time and the Gelling Viscosity

As shown in Figure 2, the content of the main agent is proportional to the gelling viscosity, but inversely proportional to the gelling time. When the content of the main agent is 6%, the gelling time is 7 hours. When main agent content is between 6% and 10%, the viscosity change is little. So, the content of the main agent is 6%.

2.3 The Influence of the Cross-linking Agent I on the Gel System

Main agent content is selected 6 wt.%, the content of HPAM is 0.03 wt.%, the content of cross-linking agent II 1.5 wt.%. Investigation into the effects of the content of cross-linking agent I on the gelling properties of the plugging agent system.

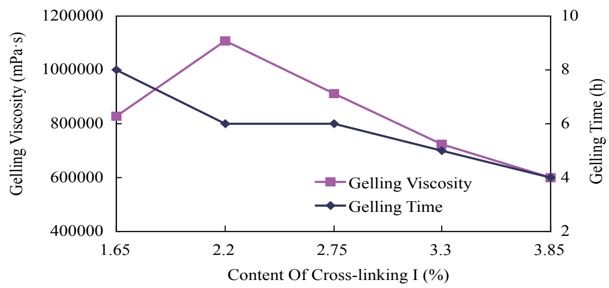

Figure 3
The Influence of the Content of Cross-Linking Agent I on the Gelling Time and the Gelling Viscosity

The content cross-linking agent I is 2.2%, the mole ratio of cross-linking agent and cross-linking agent I:II is 2:5, the gelling viscosity of the System is the largest. When the content of cross-linking agent increases, the viscosity decreases; The gelling time of the cross-linking agent I content within 1.65%-3.85% reduces with the increase of the content of cross-linking agent. So, the content of cross-linking agent I is 2.2%.

2.4 The Influence of the Cross-Linking Agent II on the Plugging Agent System

Main agent content is selected 6 wt.%, the content of HPAM is 0.03 wt.%, the content of cross-linking agent I 2.2 wt.%. Investigation into the effects of the content of cross-linking agent II on the gelling properties of the plugging agent system.

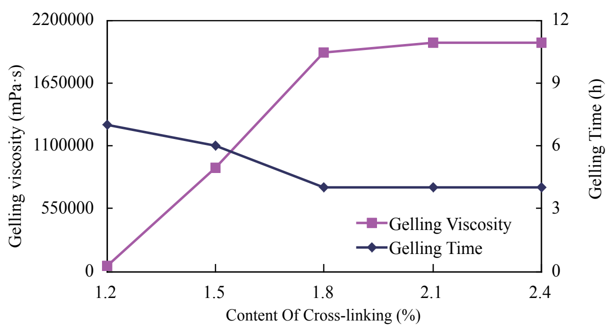

Figure 4
The Influence of the Content of Cross-Linking Agent II on the Gelling Properties

The content of cross-linking agent II is proportional to the gelling viscosity[5,6], is inversely proportional to the

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gelling time, When the content of cross-linking agent II is more than 1.8%, the final gel is semi-solid state, the gel is strength and the gel time is less than 4 hours, gelling time is short.

At last, through the experiment of ratio optimization, the formula is 0.03% coagulant aid 2.2%cross-linking agent I + 1.8% cross-linking II + 6% high efficient main agent.

3. STATIC PERFORMANCE EVALUTI-N OF PLUGGING AGENTS SYSTEM

3.1 The Influence of Temperature on the Gel Properties

Set the temperature 160 ℃, 180 ℃, 200 ℃, 240 ℃, 280 ℃, examine the impact of temperature on the gel properties (Table 1).

Table 1
The Influence of Temperature on Gelling Time and Viscosity

T/℃	160	180	200	240	280
Gelling viscosity / $mPa{\cdot}s{\times}10^4$	43.2	125	200	135	200

Experiment results show that the gelling viscosity of the profile control agent system is more than $43.2{\times}10^4$ mPa·s in the range of the simulated formation temperature, it can meet the needs of the plugging, the system has the advantage of high efficiency and the wide range of gelling temperature.

3.2 The Influence of PH Value on Gel Properties

Set reaction temperature 200 ℃, studying the effect of PH on gel properties (Table 2).

Table 2
The Influence of PH Value on Gelling Time and Viscosity

No.	PH	Gelling time /h	Gelling viscosity/ mPa·s
1	6	6	$2{\times}10^6$
2	7	5	$2{\times}10^6$
3	8	7	$1.57{\times}10^6$
4	9	—	No gelling

Experiments show that when PH is between 6 and 8, it has a little influence on gelling viscosity and gelling time, When the PH > 9 or PH < 6, the change of the gelling viscosity is irregular over time, it can not gel. Salinity has little influence on the performance of gel, therefore it is no longer here.

4. DYNAMIC EVALUATION TEST

4.1 Plugging Ratio and Residual Resistance Factor

Turn the sand filling tube into vacuum, water-saturated. Then, measured the pore volume and the permeability before plug, displace 3 PV profile control agent into sand filling tube at a constant speed of 1 ml/min, sealed, and put it into thermostat at the temperature of 200 ℃ for 12 hours until gelatinized compare the plugging ratio and residual resistance factor of gel system and composite system at different temperature.

Table 3
Result of Plugging Ratio and Residual Resistance Factor

Type	T (℃)	Perm-plug method (mD)	Water permeability measurement (mD)		Plugging ratio (%)	RRF
			Before plugging	After plugging		
Gel	200	3435	680	14	97.94	48.57
	240	2830	670	12	98.21	55.83
	280	3611	801	26	96.75	30.81

As is shown in Table 3, plugging rate achieves at least 96.75% under different reaction temperature, Plugging effect is little changed with high temperature.

4.2 Scouring Resistance and Thermal Stability

4.2.1 Scouring Resistance

Injecting 30 PV steam into the sand filling tube at the rate of 3 ml/min after sealed, Simulation environment temperature is 280 ℃, back pressure is 2.4 MPa. Measure water phase permeability after scouring, compare the plugging ratio before and after sourced.

Table 4
The Result of Scouring Test

Perm-plug method (mD)	Water permeability measurement (mD)				Plugging ratio (%)		
	Before plugging	After plugging	15 PV	30 PV	After plugging	15 PV	30 PV
3435	680	14	71	336	97.94	89.56	50.59

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The test shows that plugging ratio is still above 89% after 15 PV steam washing. When it increases to 30 PV, permeability become 50.59%. Permeability decline in half is enough to adjust the formation permeability difference, it still reflects the characteristics that plugging agent can be degraded and broke.

4.2.2 Thermal stability

Under the condition of high temperature, polymers are prone to degradation to hydration[7]. In the steam flooding, retention ability of profile control agent can be measured by thermal stability through the curve of time-plugging ratio. The simulation of formation temperature is 280 ℃.

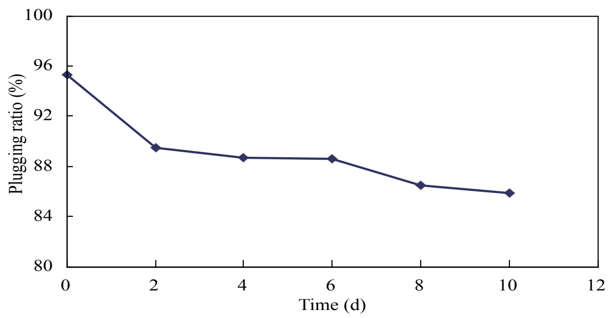

Figure 6
Result of Thermal Stability

At a temperature of 280 ℃, plugging ratio is still above 85%. After 8 days, the thermal stability curve is gradually steady. The plugging profile control agent is little degraded under high temperature.

5. SEALING PROCESS NUMERICAL SIMULATION AND THE EFFECT EVALUATION

5.1 Plugging Agent Injection Process

Adopting the method of two-fluid process at low pressure and low emissions, injection speed range is from 0.2 m^3/min to 0.4 m^3/min. climbing pressure range from 3.0MPa to 5.0MPa, no more than 80% of the formation fracture pressure. Displacement fluid is usually 15% of the dosage of profile control agent.

$$V = \pi R^2 H \phi \tag{1}$$

Where V is dose of profile control agent, H is processing layer thickness, R is average of process radius, ϕ is porosity[8].

In addition we should consider the scene construction wastage.

5.2 Optimization of Plugging Radius

Combined with the parameters that provided by experiment, such as: The nonlinear viscosity curve of main agent, sorption isotherm, the maximum adsorption amount, residual resistance coefficient. Using of CMG numerical simulation to predict production effect, optimal radius of profile control agent. Evaluate efficacy after plugged[9,10].

Selected plugging radius of 5 m, 10 m, 15 m, 20 m, 25 m, compared with no plugging measures, analysis the factors of moisture content, cumulative oil output to optimizing the radius of profile control. The results of numerical simulation are shown in Figure 6.

(i) Daily oil output

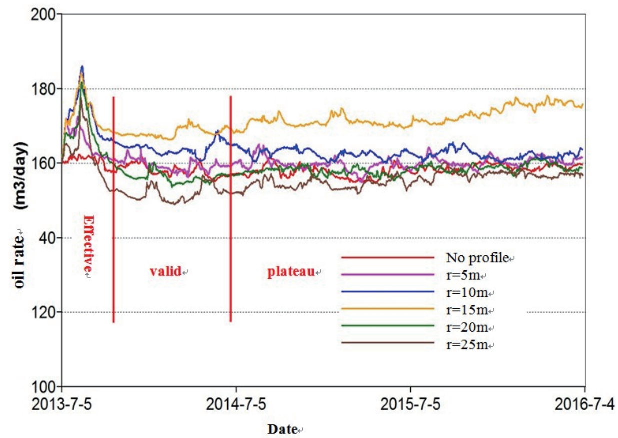

Figure 7
Daily Oil Production Curve of Different Plugging Radius

When plugging radius range from 5 m to 15 m, oil production increased obviously. When it is 15 m, oil increased ratio is 8.2789%, improve the recovery degree of 0.342%. When it is 20 m and 25 m, production declined, because plugging radius is too large, available area is jammed.

(ii) Moisture content

Moisture content achieves maximum value two month later after sealed. When plugging radius is 20 m, moisture content is similar to not sealed.

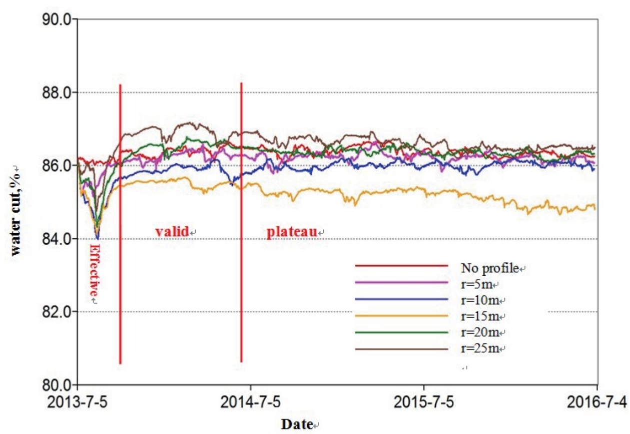

Figure 8
Moisture Content Curve in Different Plugging Radius

When it is not plugged, the average moisture content is 86.35% after three years' production. When the radius is 15 m, the ratio is 84.79%, and later there is still a steady oil water control ability.

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CONCLUSION

a. High temperature resistant main agent, after modified, combined with cross-linking agent. Coagulant can generate high viscosity semisolid quaternary copolymer gel colloid at high temperature, withstand at least 280 ℃. After shearing, micelle of plugging agent gel can transport into deep of formation to achieve a deep profile control.

b. Plugging agent has low initial viscosity, a large range of reaction temperature, plugging ratio above 96.75%, with excellent thermal stability and souring resistance, and can flush broken down with the steam washing.

c. Use the method of double-fluid under the condition of low pressure and low emissions during the inject operation, the optimum plugging radius is 15 m, has a long period of validity, can improve oil production and Reduce the moisture content effectively, there is still a steady oil water control ability follow-up. Numerical simulation parameters adopts the actual experimental data and the actual production data, has reliable reference value.

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