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Steam Channeling Plugging Agent Development and Performance Evaluation of Heterogeneous Heavy Oil Reservoir Thermal Recovery

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Abstract: To the conditions of reservoir heterogeneity, high temperature, developing a high temperature resistance gel plugging agent. the study mainly use simple variable method to optimize the ratio of the of proportion the plugging agent and Static and dynamic performance are evaluated. The formula of high temperature resistant gel type plugging agent system: The first working liquid: 1.2%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 is between 3×104~7×104mPa•s, PH=6~8 is applied, heat-resistant > 280 ℃, plugging rate > 93.1%; 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. this study provide reference for other high-temperature profile control technology research and has a guiding significance for site construction applications.

Keywords: High temperature; Agent; Double fluid method

1. Introduction

High temperature profile control medium at home and abroad mainly for the high temperature resistant foam, gel, inorganic particles. Under the condition of meet the requirements of heat resistance, foam profile control agent is poor stability, the validity of gel profile control agent is short, the particle profile control agent is easy to cause the rigid block and poor injection, and then damage the formation[1]. The mechanical of resins profile control agent is poor, it easily plugs the formation. For the vertical permeability differences, we should use gel plugging agent with low deformation and liquidity, under the condition of meet the requirements of heat resistance, it has effective adjustment block effect[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 space mesh quadripolymer gel and Used with new type of high temperature resistance inorganic particle; Through the perfect evaluation system to systematically describe the sensitivity, adaptability and effectiveness of the blocking agent to the formation environment. It is an ideal profile control agent. this study provide reference for other high-temperature profile control technology research and has a guiding significance for site construction applications.

2. The Development of Plugging Agent System

The Development of 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. By contrast gelling colloidal temperature resistance, screening and optimizing Formulation the best of the main agent.

High temperature resistant test results show that when the solid-liquid ratio is 1:6, it has the least amount of dehydration at high temperatures after the Generated main agent gelled, And still keep high strength and toughness. the PH of the preparation of modified high temperature resistant main agent product is between 2 ~ 3 in the end, the PH of aqueous solution value is neutral, when the mass fraction is greater than or equal to 14%, the solubility is saturated and is dark red, the generated gel meet the requirements of high temperature resistant performance under the high temperature of 280℃.

3. The Experiments of Ratio Optimization

Experimental drug: Coagulant, Modified high temperature resistant main agent, cross-linking agent I, cross-linking II, PH adjusting agent, formation water.
Experiment instrument: Hydrothermal synthesis reactor, electric balance, Brookfield rotary viscometer, incubator, electric blender, PH meter, measuring cylinder, beaker and so on[3,4].
Gel system optimization experiments by changing the ratio of different ingredients, In a gelling properties (gelling time, gelling viscosity) as the screening criteria, Optimizing the component content of plugging agent system. the temperature of Simulated formation is 200 ℃,the PH of the plugging agent solution is 7.

3.1. The influence of coagulant aid HPAM on the plugging 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.

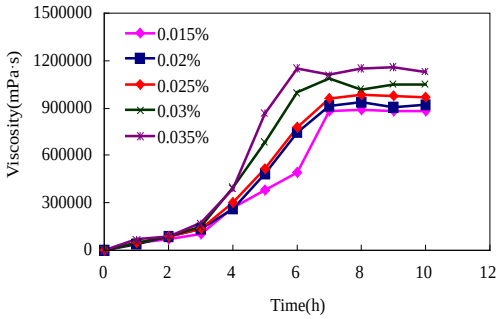

Figure 1. The Influence of HPAM on the Gel System

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 0.03wt.%.

3.2. 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.
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%, gelling time is the longest, the content of the main agent is between 6% and 10%, gelling viscosity change little. So, the content of the main agent is 6%.

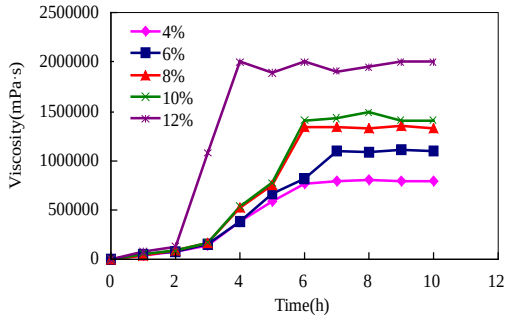

Figure 2. The Influence of the Content of main Agent on the Gelling Time and the Gelling Viscosity

3.3. 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.

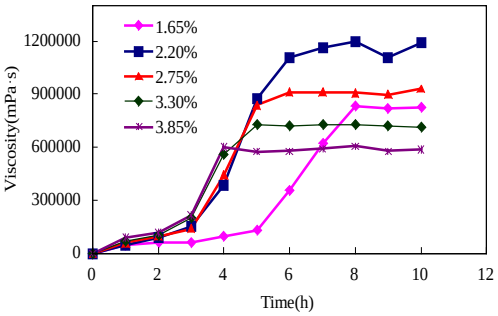

Figure 3. The Influence of the Content of Cross-linking Agent I on the Gelling Time and the Gelling Viscosity

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 increase, the viscosity decrease; The gelling time of the cross-linking agent I content within 1.65% ~ 3.85% reduce with the increase of the content of cross-linking agent. So, the content of cross-linking agent I is 2.2%.

3.4. 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.

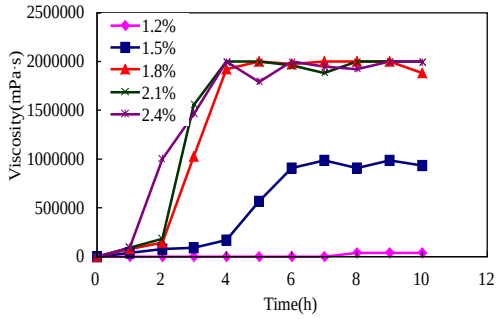

Figure 4. The Influence of the Content of Cross-linking Agent II on the Gelling Groperties

The content of cross-linking agent II is proportional to the gelling viscosity, is inversely proportional to the gelling time, When the content of cross-linking agent II is more than 1.2%, 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 + 1.2% cross-linking II + 6% high efficient main agent.

4. Static Performance Evalutin of Plugging Agents System

4.1. The Influence of Temperature on the Gel Properties

Set the temperature 200 ℃, 240 ℃, 280 ℃, examine the impact of temperature on the gel properties(Table1)

Table 1. The Influence of Temperature on Gelling Time and Viscosity

T/℃	200	240	280
Gelling viscosity /mPa·s	37592	64750	13797
Gelling time /h	8	7	5

experimental results show that when the reaction temperature is 240 ℃, the gelling viscosity of the plugging agent is up to 65624 mpa· s. High temperature viscosity is between 10000 mpa ·s and 60000 mpa ·s. the system has the advantage of high efficiency and the wide range of gelling temperature.

4.2. The influence of temperature on gel Properties

experimental results show that when the salinity is between 1600 mg/L ~ 3200 mg/L, the viscosity of the plugging agent changes little, gelling time increases, When salinity is greater than 4800 mg/L, it is no gelling or the low viscosity.

4.3. The influence of PH value on gel properties

Set reaction temperature 200 ℃, studying the effect of PH on gel properties. Experiments show that when PH is between 6 ~ 7, it has a little influence on gelling viscosity and gelling time,The viscosity of the system decreases, gelling time rise. When the PH ＞ 9，the change of the gelling viscosity is irregular over time, it cannot gel.

5. Dynamic Evaluation Test

5.1. 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 3PV 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[5,6].

As is shown in Table 3, plugging rate achieves at least 93% under different reaction temperature, Plugging effect is little changed with high temperature.

5.2. Scouring resistance and thermo stability

5.2.1. scouring resistance

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

Table 2. 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	3538	712	20	97.19	35.6
	240	2830	675	14	97.93	48.21
	280	3476	667	46	93.1	14.5

Table 3. The Result of Scouring Test

perm-plug method (mD)	Water permeability measurement（mD）				plugging ratio（%）		
	Before plugging	After plugging	15PV	30PV	After plugging	15PV	30PV
3538	712	20	80	355	97.19	88.76	50.14

The test shows that plugging ratio is still above 83% after 15PV steam washing. when it increases to 30PV, permeability become 50.14%.Permeability decline in half is enough to adjust the formation permeability differences, t still reflects the characteristics that plugging agent can be degraded and broke.

5.2.2 Thermostability

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

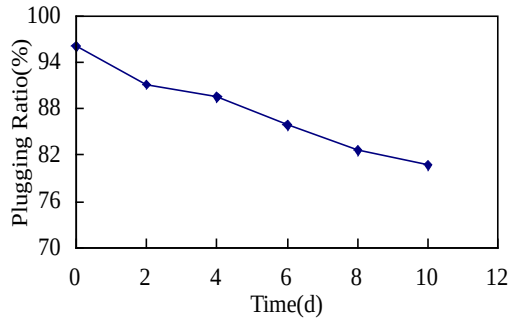

Figure 5. Result of Thermostability

At a temperature of 280℃, plugging ratio still above 80%,after 10 days, the thermostability curve gradually to be steady. The plugging profile control agent is little degraded under high temperature.

6. Construction Process Parameterrs

6.1. Profile control agent

Calculate profile agent dosage according to Plugging radius :

$$V = p R^2 H f \quad (1)$$

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

In addition we should consider the scene construction wastage.

6.2. Injection pressure

The injection pressure of the profile control agent should be higher than that of high permeable zone of start-up pressure, should be lower than that of low permeability layer start-up pressure To ensure that the majority of profile control agent priority into high permeable formation[7], adjustment and plugging water as the purpose of the macroscopic throats.

According to numerical simulation of the optimization of injection pressure and profile control agent and the formation of the actual situation of integrated to determine the reasonable injection pressure and displacement.

$$0.8P_{破} \geq P_{注} \geq P_{地} + P_{fr} + P_H \quad (2)$$

Where P 破 is processing layer fracture pressure, MPa ; Pis Oil displacement agent injection pressure, MPa ; P is processing layer formation pressure, MPa ; Pfr is friction loss along the injection oil displacement agent, MPa ; PH is the well fluid column pressure, MPa.

Injection speed

Adopting the method of two-fluid process at low pressure and low emissions,injection speed range from 0.2m3/min to 0.4 m3/min.

Replace liquid dosage

At the end of the profile control of construction, in order not to make high temperature profile control agent in the near well bore zone cause congestion and prevent steam around and pressure-out, destroy the gel plugging agent, general for the entire displacement profile control agent of 15%[8].

The construction parameters is based on the predicted results, the design of the actual injection process using injection method, if the pressure rise faster, to do the appropriate adjustment, to ensure that need.

7. Conclusions

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℃.

Plugging agent has low initial viscosity, applicable to the PH = 6 ~ 8, a large range of reaction temperature, plugging ratio above 93.1%, With excellent thermal stability and souring resistance, And can flush broken down with the steam washing.

Use the method of double-fluid under the condition of low pressure and low emissions during the inject operation. After shearing, micelle of plugging agent gel can transport into deep of formation to achieve a deep profile control.

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