

Performance Evaluation of a New Type of Polymer Profile Control Agent

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Abstract

The low-permeability oil and gas resources of our country are quite common and abundant. Their reserve has accounted for one-fifth of total oil reserves of our country, and their yield has constituted the important part of national petroleum annual yield, but its development is very difficult. Polymer gel technology is a technical method of improving sweep efficiency in recent years which substantially increases the viscosity of the polymer solution by adding a crosslinking agent to the polymer produced by intramolecular or intermolecular crosslinking.

Keywords

Low-Permeability, Polymer Gel, Profile Control Agent

1. Preferred Formulations of Profile Control Agent

Profile control agent is made up of main agent, crosslinking agents and additives. The main agent is HPAM; the main raw material of crosslinking agent is chromium chloride; and additive is mainly thiourea [1].

1.1. Determination of Polymer Concentration

The results show that the solution initial viscosity and gel viscosity heighten with the increase of polymer concentration. Considering the gel viscosity and actual injection ability, we determine that the suitable polymer concentration is 800 - 1200 mg/L (Figure 1 and Figure 2).

1.2. Development of Crosslinking Agent

The main raw material of synthesis crosslinking agent is chromium chloride. The main component of crosslinking agent which reacts with the partially hydrolyzed polyacrylamide is chromium ions. The results show that the

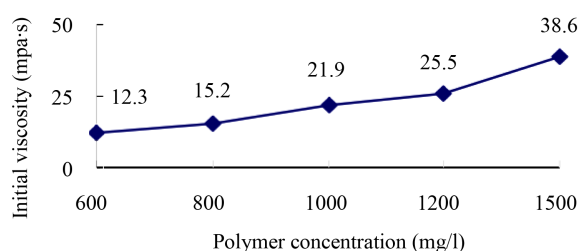


Figure 1. The curve of initial viscosity at different polymer concentration.

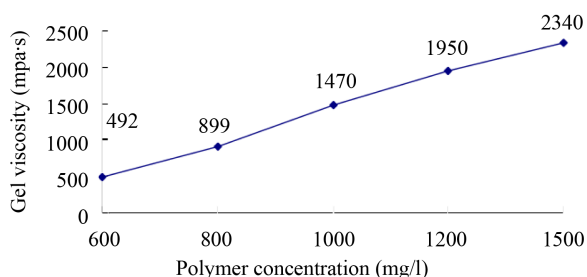


Figure 2. The curve of gel viscosity at different polymer concentration.

suitable pH value of gel formation ranges 6.5 from 8.5. The optimal composition of the crosslinking agent is shown in the [Table 1](#).

1.3. Determination of the Ratio of Crosslinking

When the polymer and the crosslinking agent are confirmed, the ratio of polymer concentration, polymer/crosslinker ratio of the polymer solution is the key factor that affects the gelling properties of the polymer solution. By experiment we found that gel viscosity increased with an increase in crosslinking ratio. Considering gel viscosity and economic efficiency, we determine the suitable crosslinking ratio is 15:1 ([Figure 3](#)).

1.4. The Determination of Additive Concentration

By experiment we found that NaCl and NaHCO₃ could adjust the speed of the crosslinking system [2], the higher the concentration, the faster the crosslinking reaction. By experiment we found that adding 600 - 800 mg/L NaCl and 500 - 750 mg/L NaHCO₃ was the most suitable and the optimal concentration was 1000 mg/L with thiourea as a stabilizer for the gel formulation ([Figure 4](#) and [Figure 5](#)).

1.5. The Determination of Profile Control Agent Formulation

Considering the reservoir permeability, reservoir temperature, injection pressure and other factors, we determine the suitable profile control system formulation as shown in [Table 2](#).

2. Performance Evaluation of Profile Control Agent

2.1. The Compatibility with Injected Water

By experiment we found that polymer prepared by injecting water has a good crosslinking properties with crosslinker mixed solution, and the crosslinking system also has good compatibility with injected water ([Figure 6](#)).

2.2. Rheology

We determined the static flow curve of polymer solution at a concentration of 1000 ppm and profile liquid after the formation of the gel, then we found the rheological type of polymer solution and the gel is same, which is

Table 1. The composition of the crosslinking agent.

Name	Chromium chloride	Lactate	NaOH
Content (%)	2.22	2.65	1.96

Table 2. The formulations of profile.

Composition	HPAM (mg/L)	Thiourea (mg/L)	NaCl (mg/L)	NaOH (mg/L)	Crosslinking ratio
Slug 1	800	1000	600	500	15:1
Slug 2	1000	1000	800	750	15:1
Slug 3	1200	1000	800	650	15:1

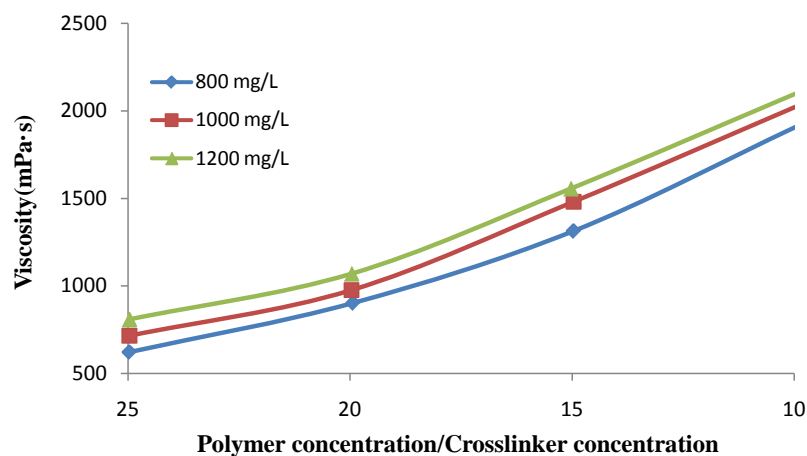


Figure 3. The curve of different crosslinking ratio and gel viscosity.

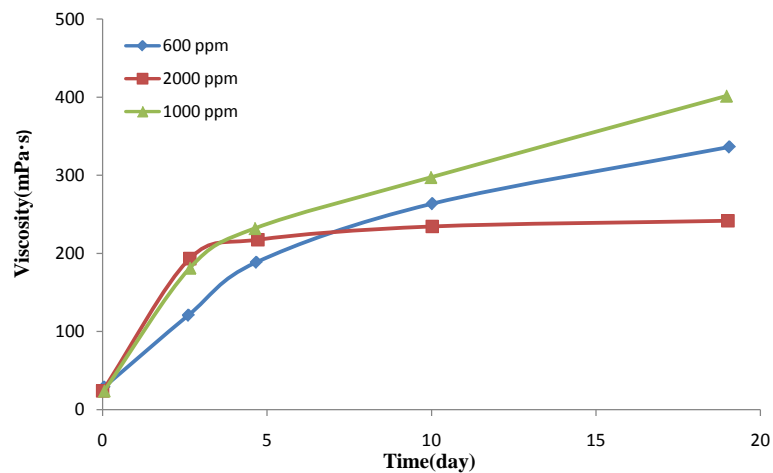


Figure 4. The effect of NaCl concentration on the gelling time.

similar to plastic non-Newtonian fluid having a yield stress [3]. The gel has large yield stress and high viscosity, which shows that gel has better control of mobility. The shear stability of profile control agent at 70°C is shown as **Table 3**.

Experimental results show that the mechanical shear has greater impact on the gel strength, shear viscosity decreased by 50% in the shear conditions, but the viscosity under the shear conditions still meets the fields application requirements.

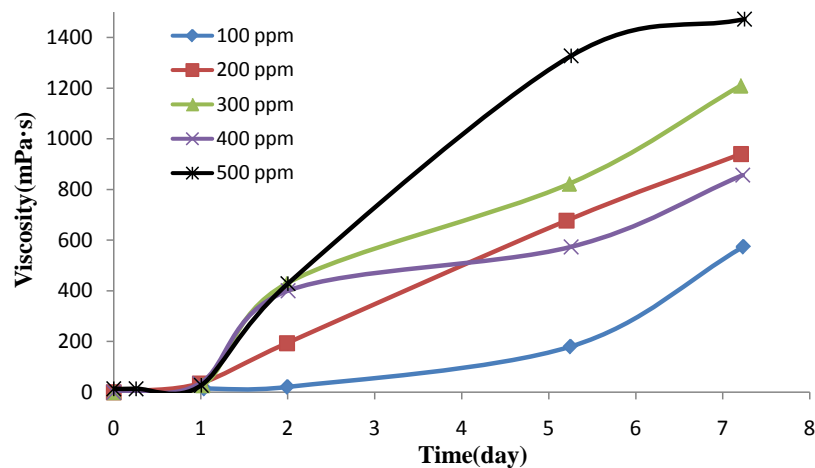


Figure 5. The effect of NaHCO₃ concentration on the gelling time.

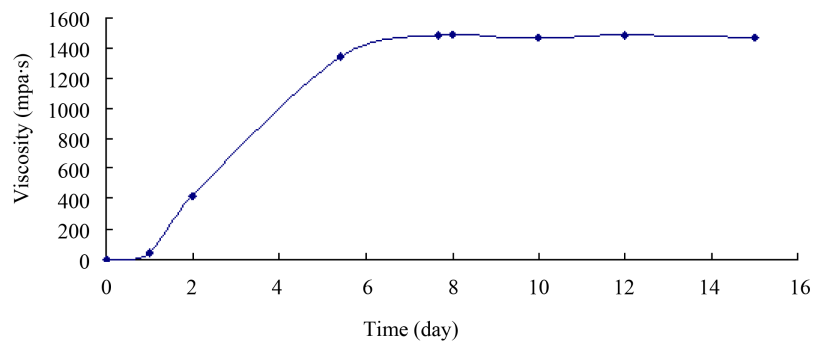


Figure 6. The gel curve of profile control agent prepared with water injection.

Table 3. Shear stability.

The concentration of profile control agent (%)	No shear		Shear	
	Initial viscosity (mPa·s)	Gel viscosity (mPa·s)	Initial viscosity (mPa·s)	Gel viscosity (mPa·s)
0.5	286	116,300	127	59,765
0.6	398	155,609	156	63,553

Remark: shear speed: 4000 r/min, shear time: 5 min.

2.3. The Effect of Temperature to the Gel Time of the Mixed Solution of Polymer and Crosslinker

For the study of the effect of temperature to the gel time of the mixed solution of polymer and crosslinker, we placed the mixed solution of polymer and crosslinker in 30°C, 45°C, 55°C, 65°C, 75°C environment respectively and measured the viscosity of the solution at different times [4]. The result is shown as Figure 7.

From the figure we found that temperature has great impact on the gel time, the higher the temperature, the shorter the gel time, so the gel time in cryogenic reservoir is much longer than in the mid or high-temperature reservoir for the crosslinking system.

3. Conclusions

1) Through laboratory experiments, we select a suitable formula of profile control agent. Polymer concentration is 800 - 1200 mg/L. Crosslinking ratio is 15:1. Using NaHCO₃ and NaCl to control the gelation time of crosslinking system, their concentrations are 500 - 750 mg/L and 600 - 800 mg/L, respectively. Thiourea is the

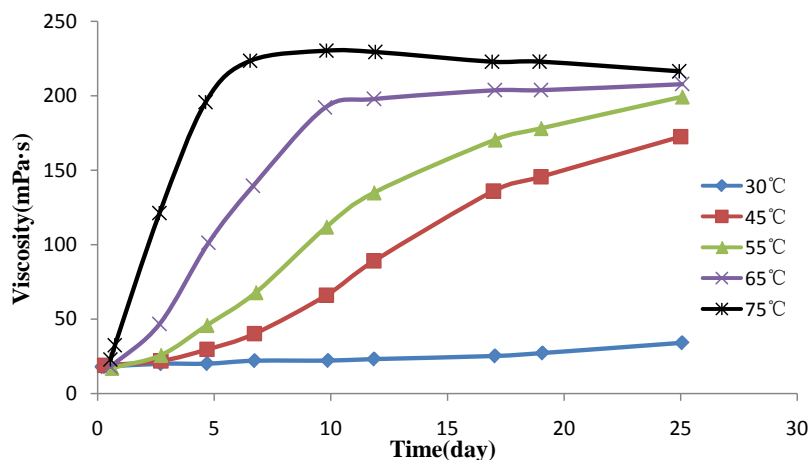


Figure 7. The effect of temperature on the gelling time.

stabilizing agent of gel in formula, whose concentration is 1000 mg/L.

2) The crosslinking system formed by the formula has good compatibility and strong rheology with formation water and injected water, and temperature has larger effect on profile control agent.

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