Optimization of injection parameters for temperature time response gel plugging agent

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Abstract. Aiming at the temperature time response gel plugging agent developed by Daqing exploration and development institute. In this paper, the injection volume, injection speed and injection concentration are optimized. The experimental results show that: the temperature time response gel can achieve the best plugging effect under the injection volume 0.1PV, injection concentration 1000mg/L and injection speed 0.6ml/min. In the subsequent water injection stage, the conductivity of high permeability layer decreases from 72.7% to 0.7%, that of low permeability layer increases from 4.1% to 14.3%, and that of medium permeability layer increases from 23.2% to 85%.

1. Introduction

After polymer flooding, the oil reservoir anisotropy is more serious, the oil displacement system is easy to rush along the high permeability layer or dominant seepage channel, resulting in inefficient / ineffective circulation, which needs to be treated by plugging control technology[1-4]. For this reason, the Daqing oilfield exploration and development institute has developed a temperature time response gel plugging agent. In order to produce the best plugging effect, the injection volume, injection speed and injection concentration are optimized through orthogonal experimental design and three pipe parallel experiment. The results are of great significance to further enhance oil recovery after polymer flooding[5-7].

2. Experimental part

2.1 Experimental materials

(1) temperature time response gel plugging agent, produced by Daqing exploration and development institute of China;

(2) Partially hydrolyzed polyacrylamide HPAM with a relative molecular weight of 2500 × 104, produced by Petro China Daqing refining and chemical company;

(3) Sewage, Petro China Daqing Oilfield No. 3 plant;

(4) There are 7 groups of artificial homogeneous cores with 3 pieces in each group. The physical properties of each group of cores are shown in Table 1.
Table 1. Physical model design parameters.

| Order number | Thickness(cm) | Length (cm) | Width (cm) | Air permeability ($\times 10^{-3}\mu m^2$) |
|--------------|---------------|-------------|------------|----------------------------------|
| 1            | 2.0           | 30          | 4.5        | 0.500                            |
| 2            | 4.5           | 30          | 4.5        | 2.000                            |
| 3            | 1.8           | 30          | 4.5        | 4.000                            |

2.2 Experimental equipment

(1) Dv-ii + Pro digital display viscometer, produced by bolefield company of the United States;
(2) Gtl-1 thermostat, produced by Nantong Zhongjing Machinery Co., Ltd;
(3) ZR-3 intermediate vessel, produced by Haian Yueda petroleum laboratory device accessories factory;
(4) Waring LB20EG Laboratory Mixer, produced by Wu Yin company of the United States;
(5) Hand operated ring pressure pump, produced by Haian Petroleum Scientific Research Instrument Co., Ltd;
(6) ISCO pump, produced by bolefield company of the United States;
(7) 1000ml and 500ml beakers, 50ml measuring cylinders, etc.

2.3 Experimental scheme

The experimental scheme is water flooding 1PV (pressure stable) +0.57PV polymer flooding (1200-1600 MW polymer, 1000mg/L) + polymer flooding followed by water flooding 1PV+0.1PV gel flooding (1000mg/L concentration) + gel flooding followed by water flooding (2PV).

2.4 Orthogonal experimental design

Through orthogonal design core experiment, the optimal injection parameters are determined\cite{8-10}. The factors in the design are injection pore volume multiple, injection concentration and injection velocity; The injected pore volume multiple is divided into 0.05pv, 0.1pv, 0.2pv and 0.3pv; The three levels of injection concentration were 500mg/L, 1000mg/L and 1500mg/L respectively; The injection rate was 1.2ml/min and 0.6ml/min, respectively. The orthogonal experimental table (Table 2) was designed.

Table 2. Orthogonal experimental design.

| Experiment number | Injection volume (PV) | Concentration (mg/L) | Injection speed (mL/min) |
|-------------------|-----------------------|----------------------|--------------------------|
| 1                 | 0.05                  | 1000                 | 0.6                      |
| 2                 | 0.1                   | 500                  | 0.6                      |
| 3                 | 0.1                   | 1000                 | 1.2                      |
| 4                 | 0.2                   | 500                  | 1.2                      |
| 5                 | 0.2                   | 1500                 | 0.6                      |
| 6                 | 0.3                   | 1000                 | 0.6                      |
| 7                 | 0.3                   | 1500                 | 1.2                      |

3. Experimental results and analysis

Through orthogonal experiment design table, temperature, time response gel plugging agent injection volume, injection speed, injection concentration and optimal combination were optimized to achieve the best plugging effect. The experimental results are shown in Figure 1- Figure 7.
Figure 1. Comparison of water flooding rate before and after gel 1 test

Figure 2. Comparison of water flooding rate before and after gel 2 test

Figure 3. Comparison of water flooding rate before and after gel 3 test

Figure 4. Comparison of water flooding rate before and after gel 4 test

Figure 5. Comparison of water flooding rate before and after gel 5 test

Figure 6. Comparison of water flooding rate before and after gel 6 test

Figure 7. Comparison of water flooding rate before and after gel 7 test
It can be seen from the results of 7 groups of experimental shunt rate: The plugging effect of high permeability layer in Experiment 1 and Experiment 2 is good, and the diversion rate is significantly improved. Using the range analysis method of orthogonal experimental design, the optimal combination was determined as the injection volume of 0.1pv, the injection concentration of 1000mg / L and the injection speed of 0.6ml/min.

In order to verify the optimal injection parameters, the optimal combination of three-layer core verification experiments were carried out, the experimental process is water flooding 1PV (pressure stable) +0.57PV polymer flooding (1200-1600 MW polymer, 1000mg/L) + polymer flooding followed by water flooding 1PV+ gel drive 0.1PV+ gel flooding followed by water flooding (2PV). The gel concentration was 1000mg/L, the injection speed was 0.6ml/min, and the injection volume was 0.1PV (Figure 8).

![Figure 8. The curve between optimal combination core injection rate and instantaneous divergence rate](image)

As can be seen from Figure 8, temperature time responsive gel effectively plugging dominant seepage channels. After the polymer flooding, the follow-up rate of the water flooding high permeability layer decreased from 72.7% to 0.7%, the low permeability layer increased from 4.1% to 14.3%, and the middle permeable layer increased from 23.2% to 85%.

4. Conclusion

Through the optimization experiment of temperature time response gel plugging agent injection parameters, the following conclusions are obtained.

(1) The optimum injection time of temperature time response gel is 0.1PV, the best injection concentration is 1000mg/L, and the best injection rate is 0.6ml/min.

(2) Under the optimum injection parameters, the diversion rate of high permeability layer is reduced from 72.7% to 0.7%, and that of low and medium permeability layer is increased from 4.1% and 23.2% to 14.3% and 85% respectively.

(3) Through indoor physical experiments, the optimal parameters of temperature time response plugging control agent injection are determined from the core scale, which can be further verified and adjusted through the actual situation of field tests.
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