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Study on Optimization of Polymer Enhanced Foam Formulation System

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Abstract

Taking the pilot test area of polymer enhanced foam flooding in Y oilfield as the prototype, a numerical core model was established, and the polymer enhanced foam formulation system was optimized by analyzing the resistance factor and the change rule of oil recovery of different formulation systems. Research shows that the higher the polymer concentration, the greater the resistance factor, and the more obvious the sealing effect formed in the formation. The concentration of surfactant has a greater impact on the resistance factor. With the increase of surfactant concentration, the resistance factor increases significantly, and the plugging effect of foam agent on core is significantly enhanced. With the increase of gas-liquid ratio, the resistance factor first increases and then decreases. When the gas-liquid ratio is 1:1, the resistance is the largest, and the foam agent has the strongest plugging effect on the core. The optimal formula system of polymer enhanced foam flooding in Y oilfield is: polymer concentration is 1200 mg/L, surfactant concentration is 0.25 wt%, gas-liquid ratio is 1:1.

Keywords

Enhanced Foam, Polymer Concentration, Surfactant Concentration, Gas-Liquid Ratio

1. Introduction

Polymer enhanced foam flooding is a new tertiary oil recovery technology, which plays a very important role in today's increasingly scarce oil resources and increasingly difficult exploitation [1] [2] [3] [4]. For this reason, scholars at home and abroad have done a lot of indoor experiments and field experiments on foam flooding [5] [6] [7] [8]. The polymer enhanced foam profile control agent is composed of polymer, surfactant and gas CO_2. The surfactant, as a foaming agent, reacts with gas CO_2 to generate foam. As a foam stabilizer, polymer increases the viscosity of the system, thus improving the stability of foam. The gas liquid ratio determines the foam concentration and migration speed [9] [10] [11] [12]. In this system, the formula combination of surfactant, polymer and gas-liquid ratio is the key to the effect of foam flooding [13] [14] [15]. This paper takes the pilot test area of polymer enhanced foam flooding in Y oilfield as the prototype, establishes a numerical core model, analyzes the resistance factor and the change rule of oil recovery of different formula systems, and carries out the optimization study of polymer enhanced foam formula system, which lays the foundation for ensuring the profile control effect.

2. Model Parameter

Numerical cores are established to simulate polymer enhanced foam flooding. The displacement process is as follows: conduct displacement at the injection rate of 0.7 mL/min, inject 2 PV foam agent after water drive until the pressure is stable, record the pressure difference and calculate the resistance factor after the pressure is stable. Subsequently, water drive to 98% water content and calculate the recovery factor. The model parameters are shown in **Table 1**.

3. Optimization of Polymer Concentration

Using numerical core simulation schemes 1 to 6 to optimize polymer concentration, the formulas and simulation results of schemes 1 to 6 are shown in **Table 2**.

According to **Table 2**, plot the curve of resistance factor and recovery rate increase with polymer concentration, as shown in **Figure 1**.

Table 1. Model parameter table.

Parameter	Value
Permeability (10^{-3} μm^2)	47.3
Porosity (%)	22.7
Model dimension (cm × cm × cm)	3 × 3 × 60
Oil saturation	0.69

Table 2. Formulas and simulation results for schemes 1 to 6.

Scheme	Polymer concentration (mg/L)	Surface active agent concentration (wt%)	Gas-liquid ratio	Resistance factor	Recovery rate improvement value (%)
1	600	0.1	1:1	25.36	5.33
2	800	0.1	1:1	28.22	6.15
3	1000	0.1	1:1	31.34	8.23
4	1200	0.1	1:1	33.83	9.62
5	1400	0.1	1:1	34.96	10.25
6	1600	0.1	1:1	35.35	10.54

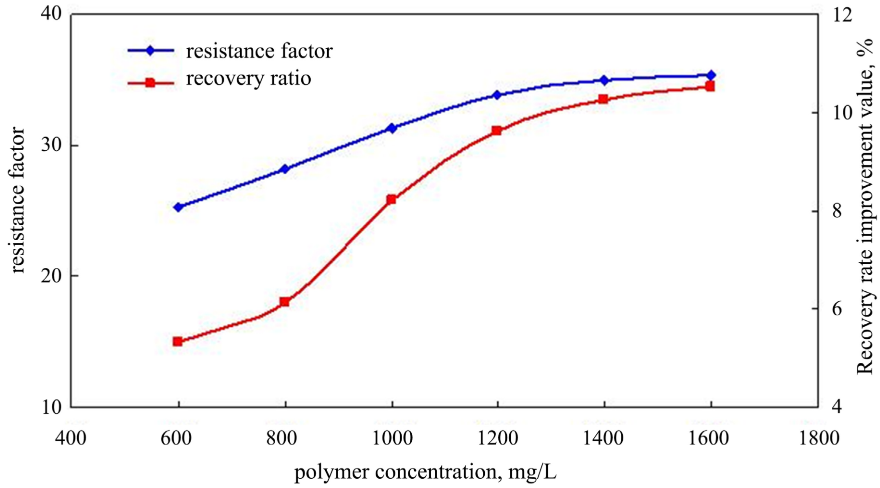

Figure 1. Resistance factor and recovery rate increase curve with polymer concentration.

From **Table 2** and **Figure 1**, it can be seen that the higher the polymer concentration, the greater the resistance factor. When the polymer concentration exceeds 1200 mg/L, the increase in resistance factor slows down. The higher the polymer concentration, the greater the recovery rate. When the polymer concentration exceeds 1200 mg/L, the increase in recovery rate slows down. Therefore, the optimal polymer concentration is chosen as 1200 mg/L.

The higher the polymer concentration, the greater the viscosity of displacement fluid, the more obvious the strengthening effect on foam, the lower the natural defoaming speed of foam, and the higher the foam concentration, the greater the viscosity of foam system, the greater the resistance factor, and the more obvious the plugging effect formed in the formation. At the same time, with the increase of the viscosity of the foam system, the mobility ratio of oil to displacement agent increases, which is more conducive to the flow of oil, slows down the flow of displacement agent, and the water content at the outlet end decreases, so the recovery factor increases. But as the polymer concentration increases, the increase in resistance factor and recovery rate slows down.

4. Optimization of Surfactant Concentration

Using numerical core simulation schemes 7 to 12, optimize the concentration of surfactants. The formulas and simulation results of schemes 7 to 12 are shown in **Table 3**.

According to **Table 3**, plot the curve of resistance factor and recovery rate increase with surfactant concentration, as shown in **Figure 2**.

It can be seen from **Table 3** and **Figure 2** that the concentration of surfactant has a greater impact on the resistance factor. With the increase of the concentration of surfactant, the resistance factor increases from 33.83 to 66.40, and the plugging effect of foam agent on the core is significantly enhanced. When the concentration of surfactant is 0.25 wt%, the resistance factor and recovery factor increase the most. Therefore, the optimal concentration of surfactant is 0.25 wt%.

Table 3. Formulation and simulation results of schemes 7 to 12.

Scheme	Polymer concentration (mg/L)	Surface active agent concentration (wt%)	Gas-liquid ratio	Resistance factor	Recovery rate improvement value (%)
7	1200	0.10	1:1	33.83	8.23
8	1200	0.15	1:1	36.38	10.37
9	1200	0.20	1:1	48.45	15.65
10	1200	0.25	1:1	61.05	18.92
11	1200	0.30	1:1	65.25	20.15
12	1200	0.35	1:1	66.40	20.56

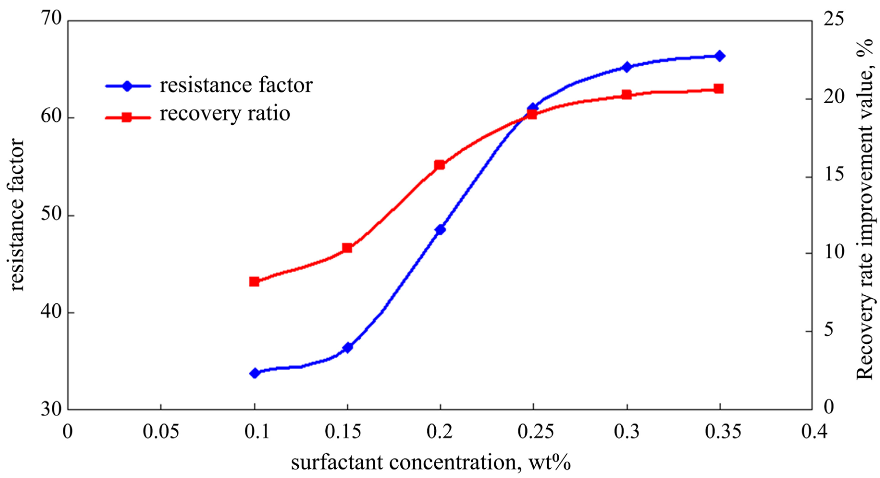

Figure 2. Resistance factor and recovery rate increase curve with surfactant concentration.

Surfactant plays a foaming role in the foam system. The higher the concentration, the greater the foam generation speed, the stronger the foaming ability, the stronger the plugging ability, and therefore the greater the resistance factor. When the concentration of surfactant is less than 0.25 wt%, the resistance factor changes greatly, indicating that the concentration of surfactant has a significant impact on foaming ability at this time. When the concentration of surfactant exceeds 0.25 wt%, the change in resistance factor is relatively small, indicating that when the concentration of surfactant reaches a certain value, the foaming ability tends to stabilize. At the same time, with the increase of surfactant concentration, the foam volume is larger, the viscosity of foam system is increased, and the mobility ratio of oil and displacement agent is increased, which is more conducive to the flow of oil, slows down the flow of displacement agent, and the water content at the outlet end decreases, so the recovery factor is increased. But with the increase of surfactant concentration, the change in resistance factor is no longer significant, and the increase in recovery rate slows down.

5. Optimization of Gas-Liquid Ratio

Using numerical core simulation schemes 13 to 17 for gas-liquid ratio optimization. The formulas and simulation results of schemes 13 to 17 are shown in Table 4.

According to Table 4, plot the curve of resistance factor and recovery rate increase with gas-liquid ratio, as shown in Figure 3.

It can be seen from Table 4 and Figure 3 that the gas-liquid ratio has a greater impact on the resistance factor. With the increase of the gas-liquid ratio, the resistance factor increases first and then decreases. When the gas-liquid ratio is 1:1, the resistance is the largest. Foam agent has the strongest plugging effect on the core, and the recovery factor is also the largest at this time. Therefore, the optimal gas-liquid ratio is 1:1.

The gas-liquid ratio is a direct factor affecting the amount of foam generated, thus affecting the seepage resistance of foam fluid in porous media. When the gas-liquid ratio is less than 1:1, with the increase of the gas-liquid ratio, the production of foam sharply increases, the plugging ability increases, the resistance factor increases, and the viscosity of the foam system increases, the mobility ratio of oil and displacement agent increases, the water cut decreases, and the oil recovery increases. However, when the gas-liquid ratio is greater than 1:1, the resistance factor of foam decreases. This is because when the gas-liquid ratio increases

Table 4. Formulation and simulation results of schemes 13 to 17.

Scheme	Polymer concentration (mg/L)	Surface active agent concentration (wt%)	Gas-liquid ratio	Resistance factor	Recovery rate improvement value (%)
13	1200	0.25	1:3	30.56	7.48
14	1200	0.25	1:2	51.36	13.88
15	1200	0.25	1:1	61.05	18.92
16	1200	0.25	2:1	48.34	15.57
17	1200	0.25	3:1	28.15	9.98

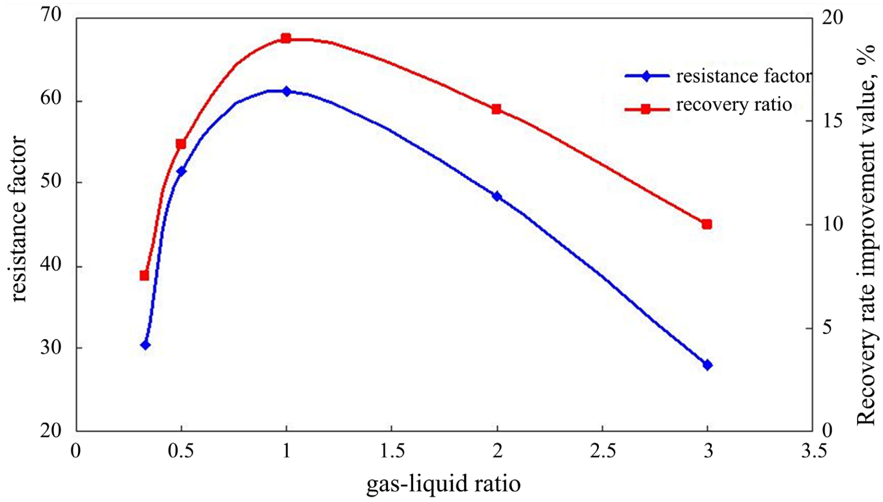

Figure 3. Curve of resistance factor and recovery factor changing with gas-liquid ratio.

to a certain value, the gas viscosity is much smaller than the liquid, and its propulsion speed is higher than the liquid, which is not conducive to the gas-liquid mixing in the foam system, and cannot form a stable injection production pressure difference. At the same time, with the increase of the gas-liquid ratio, the gas channeling phenomenon is obvious, which reduces the plugging ability of foam, so the resistance factor decreases sharply and the recovery factor decreases.

6. Conclusions

1) The higher the polymer concentration, the greater the resistance factor. When the polymer concentration exceeds 1200 mg/L, the increase in resistance factor slows down. The higher the polymer concentration, the greater the recovery rate. When the polymer concentration exceeds 1200 mg/L, the increase in recovery rate slows down. Therefore, the optimal polymer concentration is chosen as 1200 mg/L.

2) The concentration of surfactant has a greater impact on the resistance factor. With the increase of surfactant concentration, the resistance factor increases from 33.83 to 66.40. The plugging effect of foam agent on the core is significantly enhanced. When the concentration of surfactant is 0.25 wt%, the resistance factor and recovery factor increase the most. Therefore, the optimal surfactant concentration is 0.25 wt%.

3) The gas-liquid ratio has a greater impact on the resistance factor. With the increase of gas-liquid ratio, the resistance factor first increases and then decreases. When the gas-liquid ratio is 1:1, the resistance is the largest. The foam agent has the strongest plugging effect on the core, and the recovery factor is the largest at this time. Therefore, the optimal gas-liquid ratio is 1:1.

4) The optimal formulation system of polymer enhanced foam in Y oilfield is: polymer concentration is 1200 mg/L, surfactant concentration is 0.25 wt%, and gas-liquid ratio is 1:1.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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