The analysis of influencing factors on profile control effect of profile control agent in HX oilfield

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ABSTRACT: In order to optimize construction parameters of profile control in HX oilfield and improve the profile control effect, we studied the influences of permeability, oil saturation, water shutoff agent concentration and injection rate on profile control performance through orthogonal experimental method in this paper. The research showed that, permeability, the concentration of profile control agent and injection rate effect most on profile control performance. For artificial core of 2000×10-3μm2 gas permeability, the optimum dosage of profile control agent is 0.2PV and the injection concentration is 1%.

Introduction

Water producing is an inevitable problem in the process of oilfield development and production. With the constant development, the oil fields which have been in high water cut or extra high water cut development period are influenced by formation heterogeneity, differences between water and oil mobility ratio and intensive injection and production etc. These factors lead to the injected water rushing along high permeability layer or strip and the effect of water flooding development decreasing. Therefore, chemical profile control technology has been widely used in HX oilfield.

HX oilfield is a heavy oil reservoir. profile control technology has been used as auxiliary on steam soak the exploitation in high water-cut stage currently. As reservoir's vertical and plane heterogeneity is more serious in high water-cut stage, permeability difference is increased further and the effect of profile control is gradually decreased, so that the oil recovery is seriously affected. So it is necessary to do further analysis of the influence factors on profile control effect of profile control agent.

Orthogonal experiment design of profile control agent

This experiment mainly analyzed the effect of permeability, oil saturation, oil viscosity and different injection parameters on profile control performance of profile control agent through the core experimental, providing the basis for decision-making of profile control agent.

The analysis showed that, many factors such as permeability of reservoir rocks, oil saturation, concentration of profile control agent and injection parameters all influence the profile control performance of profile control agent. In order to determine the effect of various factors and decrease the workload at the same time, orthogonal experimental was used to design the experiment scheme .

Experimental drugs and instruments

The experimental equipment: core displacement device under high temperature and high pressure, which produced by Huaxing Petroleum Instrument Limited Company.

Experimental materials: simulated formation water (salinity is 2010 mg/L), crude oil from HX oilfield (500 mPa·s), the profile control agent from wellsite, artificial core (cylindrical).

The experimental temperature: 50 ˚C.

Experimental procedures

(1) Prepare 1% , 2%, 3% profile control agent solution.

(2) Dry the core and saturate it with simulated formation water, then saturate it with oil by displacing device and maturate it. Displace the core with the simulated formation water until the remaining oil saturation is about So and measure the core permeability K_1 with water.

(3) Inject positively profile control agent solution of predetermined pore volume into the core with 0.1mL/min injecting rate. After 24h reaction, measure core permeability K_2 respectively by using the simulated formation water to inject forward. Then calculate the core plugging rate B.

$$B = \frac{K_1 - K_2}{K_1} \times 100\% \qquad (1)$$

(4) Repeat the above steps according to the experiment scheme to determine the data successively.

Orthogonal experiment scheme and analysis of experimental results

According to the experimental procedures above, with 9 core samples, at different gas permeability K_g, oil saturation S_o, concentration of profile control agent C_d, injected volume V_j, initial core water permeability K_1 and the core water permeability after profile control agent injected K_2 were measured, then B was calculated. The experimental data was shown in Table 1.

Table 1. Experimental data and results.

Core number	K_g ($10^{-3}\mu m^2$)	S_o (%)	C_d (%)	V_j (PV)	K_1 ($10^{-3}\mu m^2$)	K_2 ($10^{-3}\mu m^2$)	B (%)
HX-1	516	51.5	1	0.1	172.0	55.2	69.06
HX-2	507	60.8	2	0.2	169.0	51.6	69.48
HX-3	500	71.4	3	0.3	166.7	45.0	72.00
HX-4	2024	49.7	2	0.3	674.7	204.0	69.76
HX-5	2031	60.5	3	0.1	677.0	217.3	65.90
HX-6	2005	71.7	1	0.2	668.3	232.3	66.24
HX-7	3012	50.6	3	0.2	1004.0	320.6	67.07
HX-8	2985	61.8	1	0.3	995.0	339.3	67.90
HX-9	3084	70.4	2	0.1	1028.0	371.7	63.84
average 1	70.18	68.63	66.34	66.26			
average 2	67.30	67.76	67.69	67.59			
average 3	66.27	67.36	69.66	69.88			
level difference	3.91	1.27	3.31	3.62			
sum of square deviations	24.64	2.53	16.62	20.12			

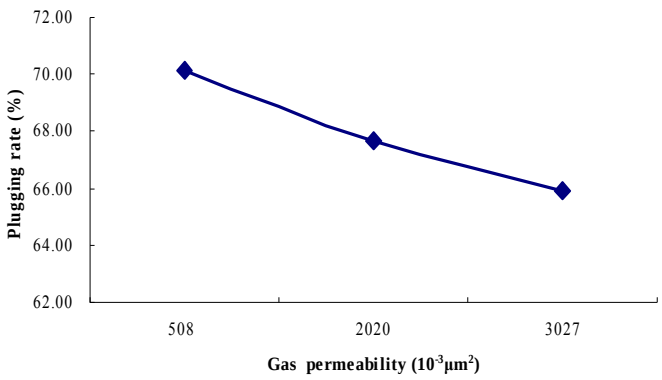

Figure 1. The effect of gas permeability on plugging rate.

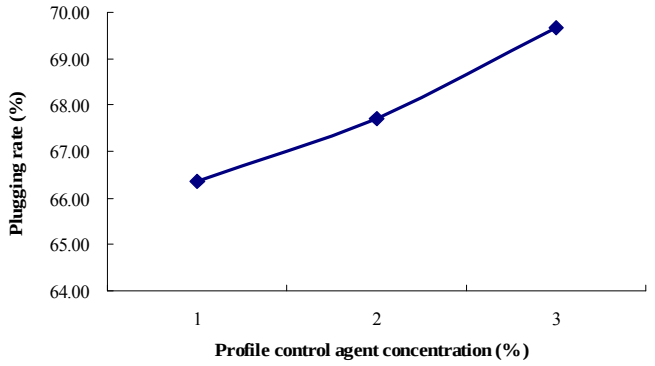

Figure 2. The effect of profile control agent concentration on plugging rate .

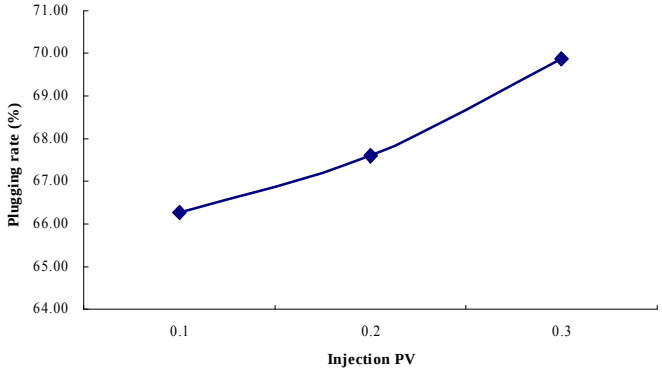

Figure 3. The effect of injected PV on plugging rate.

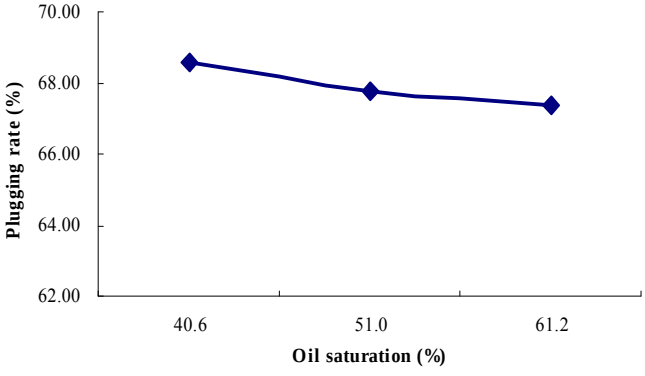

Figure 4. The effect of oil saturation on plugging rate.

As we can see from Figure 1 to Figure 4, plugging rate reduced greatly with the increase of core permeability. With the increase of the profile control agent concentration and injection PV, plugging rate has a great tendency to increase. With the increase of oil saturation, the change of plugging rate is not obvious.

From the analysis of the orthogonal experiment results, we can see that the level difference of gas permeability is 3.91, the level difference of oil saturation is 1.27, the level difference of the concentration of injected profile control agent is 3.31, and the level difference of the injected amount of profile control agent is 3.62. So the influence of permeability, the injected amount and the concentration of profile control agent on the oil sweep efficiency is larger, and the oil saturation takes the second place.

Optimization of injection parameters

The oil saturation is determined to be 50%. We have investigated the plugging effect of $2000\times10^{-3}\mu m^2$ permeability core under different injection quantity and different profile control agent concentration. With the same steps as 1.2, the experimental results are as follows:

Table 2. The influence of different injection amount on plugging rate under 1% water shutoff agent concentration.

Core number	Gas permability ($10^{-3}\mu m^2$)	Injection PV	Permeability befor profile control ($10^{-3}\mu m^2$)	Permeability after profile control ($10^{-3}\mu m^2$)	Plugging rate (%)
HX-10	2014	0.10	671.3	228.9	65.90
HX-11	1985	0.15	661.7	219.3	66.86
HX-12	1988	0.20	662.7	208.5	68.54
HX-13	2004	0.25	668.0	208.4	68.80
HX-14	2008	0.30	669.3	207.4	69.12

Table 3. The influence of different water shutoff agent concentration on the plugging rate under 0.1 PV injection .

Core number	Gas permeability ($10^{-3}\mu m^2$)	Water shutoff agent concentration (%)	Permeability before profile control ($10^{-3}\mu m^2$)	Perme-ability after profile control ($10^{-3}\mu m^2$)	Plugging rate (%)
HX-15	2022	0.5	674.0	234.6	65.20
HX-16	1996	1.0	665.3	209.3	68.54
HX-17	1993	1.5	664.3	207.9	68.70
HX-18	2014	2.0	671.3	208.4	68.95
HX-19	2016	3.0	672.0	207.5	69.12

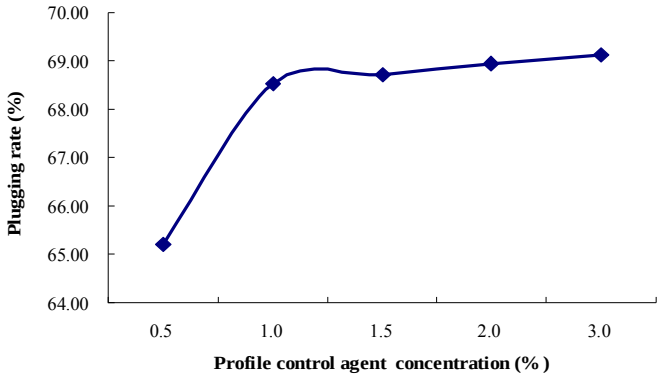

Figure 5. The effect of profile control agent concentration on plugging rate.

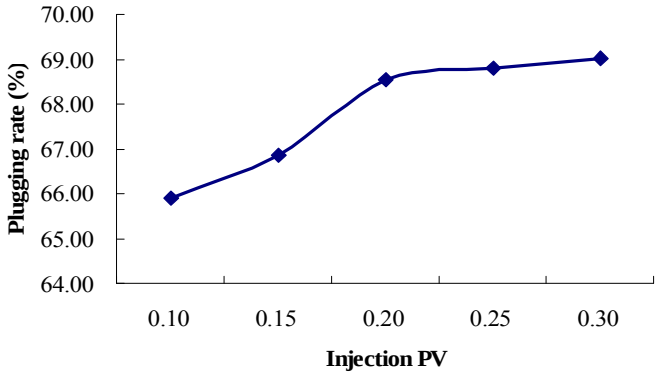

Figure 6. The effect of injected PV on plugging rate.

From the Figure 5 and Figure 6 above, we know that increasing profile control agent injection amount can improve the plugging rate when profile control agent concentration is at same value for a certain permeability core. When 0.2 PV profile control agent is injected into the core, plugging rate reached more than 68%. But when the amount of profile control agent injected is increased further more, plugging rate does not increased significantly. For a certain permeability core, increasing the concentration of profile control agent can improve the plugging rate when the profile control agent injection amount is at the same value. When the profile control agent concentration is 1%, the plugging rate can reach more than 68%. When the concentration of profile control agent is increased further more, the plugging rate will not increase significantly. Therefore, for the artificial core with $2000\times10^{-3}\mu m^2$ gas permeability, the best profile control agent dosage is 0.2 PV and the best injection concentration is 1%.

Conclusion

(1) The analysis of the orthogonal experiment results shows that the level difference of gas permeability is 3.91, the level difference of oil saturation is 1.27, the level difference of the concentration of injected profile control agent is 3.31, and the level difference of the injected amount of profile control agent is 3.62. So the influence of permeability, the injected amount and the concentration of profile control agent on the oil sweep efficiency is larger, and the oil saturation takes the second place.

(2) For a core with certain permeability and oil saturation, plugging rate can be improved by adjusting injection amount and concentration of profile control agent. When the profile control agent concentration is 1%, the plugging rate can reach more than 68%. This means that the profile control agent has good water plugging performance.

(3)The best dosage of profile control agent is 0.2PV and the best injected concentration is 1% for the artificial core with $2000\times10^{-3}\mu m^2$ gas permeability.

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