Method of improving heterogeneous oil reservoir polymer flooding effect by positively-charged gel profile control

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Abstract. The project of polymer flooding has achieved great success in Daqing oilfield, and the main oil reservoir recovery can be improved by more than 15%. But, for some strong oil reservoir heterogeneity carrying out polymer flooding, polymer solution will be inefficient and invalid loop problem in the high permeability layer, then cause the larger polymer volume, and a significant reduction in the polymer flooding efficiency. Aiming at this problem, it is studied the method that improves heterogeneous oil reservoir polymer flooding effect by positively-charged gel profile control. The research results show that the polymer physical and chemical reaction of positively-charged gel with the residual polymer in high permeability layer can generate three-dimensional network of polymer, plugging high permeable layer, and increase injection pressure gradient, then improve the effect of polymer flooding development. Under the condition of the same dosage, positively-charged gel profile control can improve the polymer flooding recovery factor by 2.3~3.8 percentage points. Under the condition of the same polymer flooding recovery factor increase value, after positively-charged gel profile control, it can reduce the polymer volume by 50 %. Applying mechanism of positively-charged gel profile control technology is feasible, cost savings, simple construction, and no environmental pollution, therefore has good application prospect.

1. The influence of polymer volume on the effect of polymer flooding

In the practice of the polymer flooding development, polymer volume is expressed as the quality of polymer solution concentration and injection pore volume multiple product, usually using the polymer volume measures the relative size of the polymer powder usage in different development blocks. To evaluate positively-charged gel profile control reducing the effect of polymer volume, we study the influential regularity of polymer volume on the effect of polymer flooding. Experiments use heterogeneous core physical model [1], core size of 4.5 cm * 4.5 cm * 30 cm, high permeability layer effective permeability cores of 800 x 10^- 3μm^2, low permeability layer of 200 x 10^- 3μm^2. Experimental method is: the water drive to 95% water-bearing of produced liquid —polymer flooding (different dosage scheme)—subsequent water flooding to 98% water-bearing of produced liquid. Polymer flooding stage using polymer relative molecular mass is 1200 x 104, mass concentration of 1000 mg/L, viscosity of 20 mpa˙ s. The variation of polymer flooding recovery factor increase value with the polymer dosage is shown in Fig. 1

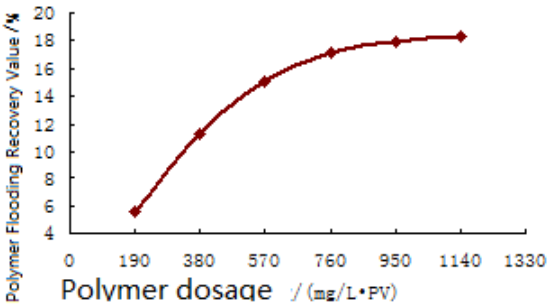

Fig. 1 The variation of polymer flooding recovery factor increase value with polymer dosage

2. Positively-charged gel introduction and profile control mechanism

Positively-charged gel refers to a molecular chain polymer with electricity. Appearance is gray grain, and relative molecular mass is 536. No viscosity after the product dissolved in water, the temperature of 0 ℃ to 70 ℃ has better solubility, and suitably apply to oilfield. Profile control mechanism of positively-charged gel is: cationic link contained in positively-charged gel with the carboxylic acid in polyacry lamide has chemical neutralization reaction and physical crosslinking reaction, generates a three-dimensional network polymer, the polymer network in the water phase, its molecular chain fully stretches to reach plugging high permeability layer, and reduces the effect of water phase permeability. Preparation conditions on the ground, appearance of the products of the reaction of the polymer with positively-charged gel are white floc, white floc object is shown in Fig. 2. By laser confocal microscopy, micro network structure form of the reaction products are shown in Fig. 3

Fig. 2 Pictures of the reaction products of polymer with positively-charged gel

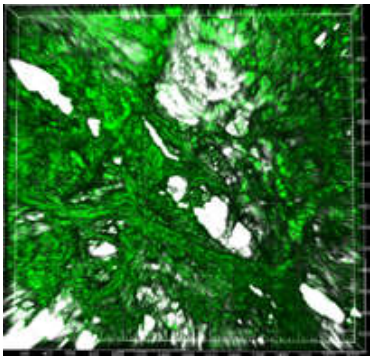

Fig. 3 Microstructure of laser confocal microscop reaction products

3. The determination of positively-charged gel profile control concentration

During the actual profile control operations, if positively-charged gel concentration is the lower, it will cause the insufficient reaction of positively-charged gel and residual polymer in oil reservoir and lead to the limited plugging effect; if positively-charged gel concentration is too large, although it has the reaction and the residual polymer in the oil reservoir sufficiently, but this can lead to waste of positively-charged gel and influences the economic effect. Therefore, under the condition of dispensing positively-charged gel and polymer solution on the ground, we studies the reasonable concentration of positively-charged gel. Firstly, dispensing polymer solution, then adds positively-charged gel to the fully dissolved polymer solution, after it fully dissolved tests solution viscosity. Concentration of the polymer preparation are 1000 and 1500 mg/L, positively-charged gel varied a variety of concentration.

The variation of viscosity of mixed liquid with concentration of positively-charged gel is shown in Fig. 4

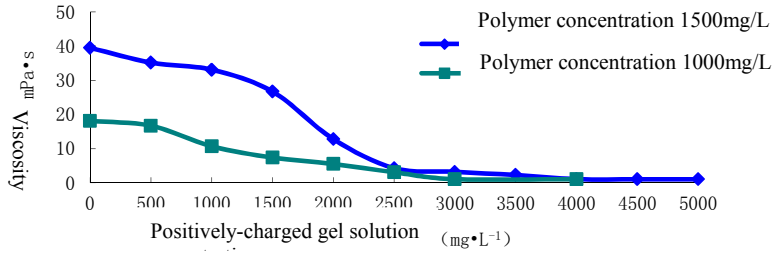

Fig. 4 Variation of positively-charged gel and the mixed polymer viscosity with concentration of positively-charged gel

4. Positively-charged gel profile control oil displacement experiment

4.1. The experimental scheme

The physical model in the experiment is the same as physical model described in part 1. Design three groups of experimental solutions: scheme one, the water flooding to 95% water-bearing of produced liquid — polymer flooding is 0.76 times the pore volume—Positively-charged gel profile is 0.1 times pore volume — subsequent water flooding to 98% water-bearing of produced liquid; scheme two, the water flooding to 95% water-bearing of produced liquid— polymer flooding is 0.57 times the pore volume—Positively-charged gel profile is 0.1 times pore volume— subsequent water flooding to 98%

water-bearing of produced liquid; scheme three, the water flooding to 95% water-bearing of produced liquid—polymer flooding is 0.285 times the pore volume —Positively-charged gel profile is 0.1 times pore volume — polymer flooding is 0.285 times the pore volume—subsequent water flooding to 98% water-bearing of produced liquid. The polymer dosage in scheme one is the same as that of scheme two, scheme two has the profile control after the polymer injection finishing, while scheme three has the polymer control in the intermediate process of polymer injection. 3 schemes using polymer relative molecular mass is 1200 x 104, mass concentration of 1000 mg/L, viscosity of 20 mpa * s, and mass concentration of injected positively-charged gel solution is 3000 mg/L.

4.2. The experimental results and discussion

The experimental results are shown in table 1. polymer volume of 760 mg/L* PV in scheme one, polymer dosage of570 mg/L*PV in scheme 2, polymer flooding recovery factor increase value in scheme two and three are 19.4% and 18.9% respectively. Fig. 1 shows that when polymer dosage is 760 mg/L*PV and 570 mg/L*PV, polymer flooding recovery factor increase value are 17.1% and 15.1% respectively on what condition the positively-charged gel profile control don't carried out. After positively-charged gel profile control, in the dosage of 2 kinds of cases, polymer flooding recovery factor increase by 2.3 and 3.8% respectively. You can also see from Fig. 1, the experiment scheme that the positively-charged gel polymer profile control isn't carried out and that polymer dosage is 1140 mg/l*PV, polymer flooding recovery factor increase value is 18.3%, and scheme two that positively-charged gel profile control is carried out the polymer flooding recovery factor increase value is 18.9%, two groups of experiment scheme polymer flooding recovery factor increase value is basically the same, but polymer dosage in scheme two is only 570 mg/L *PV, compared with the scheme that hasn't the profile control saves 50% of polymer dosage. Experimental data shows that the development effect of polymer flooding is further improved after positively-charged gel profile control. The reason is that polymer solution is inefficient and invalid loops in the middle and later periods of the polymer injection in high permeability layer, forms the advantage of seepage channel in the high permeability layer, at this time high permeability layer is filled with polymer solution, after filling it with low viscosity of positively-charged gel, polymer solution still along the advantage of seepage channel injects in the polymer injection, positively-charged gel react with residual polymer in the advantage of seepage channel, the reaction products reach the role of plugging preponderant seepage channel [2], thus raises the degree of use of low permeability layer.

Table 1. data of experimental results in driving oil

Experimental scheme	Water displacement Recovery efficiency/	polymer flooding recovery efficiency increase value/%	total recovery efficiency/%	polymer volume/%
Scheme 1	37.5	19.4	56.9	760
Scheme 2	37.2	18.9	56.1	570
Scheme 3	36.9	22.5	59.4	570

Polymer flooding recovery efficiency increase value in scheme two is basically the same as that in scheme one, but polymer dosage is lower 190 mg/l* PV than scheme one. The development of positively-charged gel profile control under the reasonable polymer dosage, can greatly save polymer dosage under the condition of guaranteed polymer flooding effect; polymer flooding recovery factor increase value in scheme 3 was higher 3.6% than that of scheme 2. The reason is that after positively-charged gel profile control in the process of polymer injection in scheme 3, effectively blocks the high permeability layer, subsequently the injected 0.285 times pore volume of polymer is more into the low permeability layer, and more fully performs the function of low permeability layer improving recovery factor [3-4]. And positively-charged gel solution is injected at the end of the polymer injection, although this can play a role in profile control, but subsequent injection of low permeability layer of

liquid is water, and the expansion of the micro wave, the ability of volume and improving oil displacement efficiency is limited for the low permeability layer. Therefore, in the process of injecting polymer flooding it is the best to carry out positively-charged gel in the field practice.

In order to study the effect of positively-charged gel profile control of injection pressure, drawing injection pressure curve of scheme two, at the same time compare it with the profile of the polymer flooding injection pressure curve (Fig. 5)

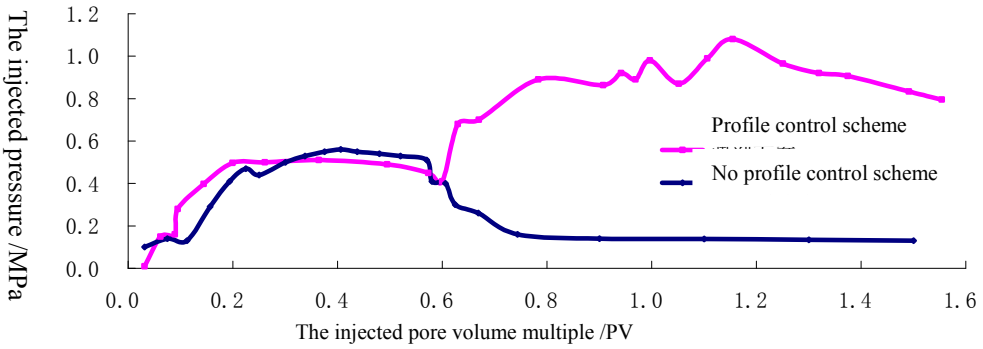

Fig. 5 Variationally relation of injection pressure with injection pore volume multiple

5. Conclusion

Researches show that there is the best range for polymer dosage, exceeding the range increase recovery factor is limited, and causes the waste polymer. Therefore, we need to study a method that can not only the most greatly enhance oil recovery factor, but also save the polymer dosage. The polymer physical and chemical reaction of positively-charged gel with residual polymer in oil reservoir can generate three-dimensional polymer network, adjustably plugging high permeable layer. The profile control mechanism determines that the profile control timing must proceed in the process of polymer injection or after polymer flooding finishing.

References

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