Study of the alkali concentration optimization in weak base Alkaline-Surfactant-Polymer flooding

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Abstract

In ASP (Alkaline-Surfactant-Polymer) flooding process, reasonable alkali concentration can reduce the interfacial tension of the ASP solution, and it can also be preferential adsorbed in the pore, which reduces the adsorption of surfactant. With a reasonable alkali concentration, the compound system could maintain ultra-low interfacial tension for a long time. Therefore, it is necessary to choose a reasonable alkali concentration. In this article, we combine the numerical simulation and physical experimental research together to solve the problem. Using CMG numerical simulation software to compare and screen the optimal alkali concentration in the main slug and vice slug, and then experimental research will be carried out to verify the simulation results. The results show that, along with the increase of the concentration of alkali, the recovery degree increases. The optimal alkali concentration in the main slug is 1.2%～1.4%,and in the vice slug is 1.0%. Indoor oil displacement experiment results validate the correctness of the numerical simulation results.

Keywords

ASP flooding; weak base; alkali concentration; numerical simulation; oil displacement experiment

1. Introduction

At present, some oilfields have entered high water cut period, which caused a lot of bad consequences, such as difficulties in the development process and poor economic benefits. Some recovery technologies must be carried out to improve recovery efficiency. ASP flooding is one of the most effective methods, which provides a guarantee for the production stable of the old oilfields and shows the broad prospects for enhanced oil recovery[1-2].

Adding alkali into the slug is very helpful to improve the recovery efficiency. Firstly, the alkali reacts with the organic acids, colloid, asphaltene and paraffin wax in crude oil. It can not only destroy the oil-water interface film but also generate surface active substance, which can reduce the interfacial tension between the water and oil phase. Secondly, the competitive adsorption of alkali and surfactant will reduce the wastage of the surfactant, and the alkali can also enhance the activity of oil-water interface through the synergistic process with surfactant. Finally, the alkali can promote the polymer molecules hydrolysis, which can increase the concentration of the polymer molecules in the system [3-5]. However, if the alkali amount is too large, the viscosity of the polymer solution will be reduced, and the convection control will be adversely affected [6].At the same time, the ionized Na^+ will compresses the diffusion electric double layer thickness of the oil-water interface, which do harm to the emulsion stability [7].Therefore, it is necessary to choose a reasonable alkali concentration. In this article, we combine the numerical simulation and physical experimental research together to screen the optimal alkali concentration in the main slug and vice slug.

2. Numerical simulation model

2.1 Geologic models

The Asp flooding experimental site is located in the west of Daqing oilfield, including SA II10- SA III10 blocks .The oil-bearing area of the site is 3.7km^2.The well pattern is five point area patterns, with a distance of 125m between the injection well and producing well. There are 230 wells in the area, including 99 injection wells and 131producing wells. The physical property parameters are as followed: Perforated sandstone thickness 23.4m; net pay thickness 14.7m; mean permeability 0.553 μm^2; Geological reserves 706.19 ×10^{4}t; Pore volume 1377.07 ×10^{4}cm^3.

2.2 ASP flooding model

Asp flooding numerical simulation is implemented by STARS module of the CMG software. A numerical simulation model, which is a multicomponent chemical flooding model, is intercepted in the center representative area of experimental zone. In the model, there are 50wells, including 28 injection wells and 22producing wells. Total grid numbers of the model is 51 ×44 ×53= 118932 and in the X and Y coordinate axis, the grid size are both 10 m. In the longitudinal axis, refined grid is used with a mean thickness of 0.5m.

3. Numerical simulation results

Based on past experience [8-9], when only the main slug is injected, the oil displacement effect is poor. However if pre-polymer slug, vice slug and rear-polymer slug are added, the recovery efficiency will be improved greatly. Therefore, in this article, pre-polymer slug, main slug, vice slug and rear-polymer slug are injected in order.

3.1 Effects of alkali concentration in main slug on oil displacement results

The Numerical simulation is carried out with 0.04PV pre-polymer slug (1600mg\L polymer), 0.35PV main slug (0.3% surfactant + alkali + 1900mg\L polymer); 0.15PV vice slug (0.15% surfactant + 1.0% alkali + 1800mg\L polymer); 0.25PV rear-polymer slug (1600mg\L polymer). Alkali concentration in the main slug is 0.8%, 1.0%, 1.2% and 1.4%. Compare the results of experimental schemes and choose the optimal alkali concentration. The results are as followed:

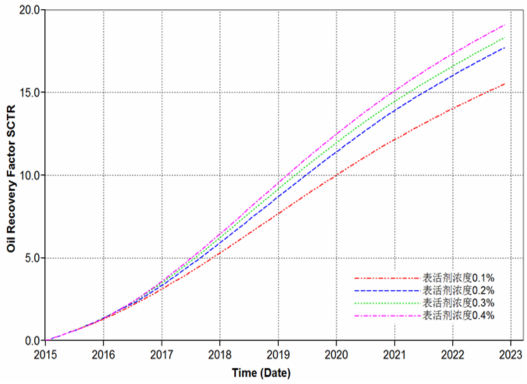

Fig3-1 recovery degree comparison of different experimental schemes

Table3-1 recovery degree percentage of different experimental schemes

scheme	alkali concentration （%）	recovery degree （%）	increased value of recovery degree（%）
scheme 1	0.8	16.21	--
scheme 2	1.0	17.62	1.41
scheme 3	1.2	18.33	0.71
scheme 4	1.4	18.91	0.68

Numerical simulation results are shown in Fig3-1and Table3-1.From the results we can find that along with the increase of the alkali concentration in the main slug, the recovery degree increases. The increased value of recovery degree reaches the highest value when the alkali concentration is 1.0%.After that point, increased value of recovery degree gradually decline. However, when ASP flooding solution flowing through the actual formation, alkali will react with organic acids in crude oil, ions in the formation, silicon dioxide in the rock and so on. At the same time, adsorptions can also wastage the alkali. All of these factors cause the alkali consumed and do harm to the compound system. So the alkali concentration in the main slug should be a little bit larger to ensure the stability of compound system. Considering that excessive alkali concentration is not conducive to the stability of the emulsion, so the alkali concentration in the main slug should be 1.2%-1.4%.

3.2 Effects of alkali concentration in vice slug on oil displacement results

The Numerical simulation is carried out with 0.04PV pre-polymer slug(1600mg\L polymer) ,0.35PV main slug(0.3% surfactant +1.2%alkali + 1900mg\L polymer);0.15PV vice slug(0.15% surfactant + alkali + 1800mg\L polymer);0.25PV rear-polymer slug(1600mg\L polymer). Alkali concentration in the vice slug are 0.8%, 1.0%, and 1.2% and 1.4%. Compare the results of experimental schemes and choose the optimal alkali concentration. The results are as followed:

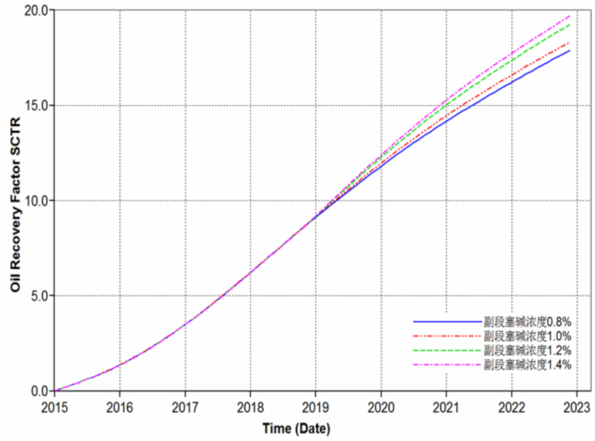

Fig3-2 recovery degree comparison of different experimental schemes

Table3-2 recovery degree percentage of different experimental schemes

scheme	alkali concentration （%）	recovery degree （%）	increased value of recovery degree（%）
scheme 1	0.8	17.49	--
scheme 2	1.0	18.33	0.84
scheme 3	1.2	18.85	0.52
scheme 4	1.4	19.32	0.47

Numerical simulation results are shown in Fig3-2and Table3-2.From the results we can find that along with the increase of the alkali concentration in the vice slug, the recovery degree increases. The increased value of recovery degree reaches the highest value when the alkali concentration is 1.0%.After that point, increased value of recovery degree gradually decline. When the vice slug flowing through the formation, the alkali in main slug has consumed, which will protect the alkali in vice slug from being expended. Considering the influence of economic factors, the alkali concentration in vice slug should be 1.0%.

4. Oil displacement experiment results

4.1 The experimental materials and equipments

(1) Core: epoxy resin cementation artificial heterogeneous cores, geometry size are: high × width × long. = 4.5× 4.5 × 30 cm

(2) Polymer: produced by Daqing refining factory and the molecular weight is 16-19 million and 25 million; Alkali: Na_2CO_3; Surfactant: alkyl benzene sulfonate.

(3) Experiment water: injected water from II injection allocation station of factory one,

4.2 Experimental procedure

(1) Acquire the pore volume of model by vacuumizing it and saturating it with underground water .All steps are operated at room temperature

(2) Under the condition of 45 ℃, saturate the model with 1.2PV oil, stop when the oil saturation is larger than 70%.

(3) Under the condition of 45 ℃, water flooding the model until the water cut is 98%.Obtained the pressure change value, liquid producing capacity, water rate and oil rate in each period, and then calculates the recovery degree.

(4) Under the condition of 45 ℃, conduct chemical flooding. Inject each slug according to the experimental scheme. Obtained the pressure change value, liquid producing capacity, water rate and oil rate in each period, and then calculate the recovery degree.

4.3 Experimental results

(1) Conduct the oil displacement experiments with a alkali concentration in main slug is 1%, 1.2%, 1.4% separately. The concrete schemes are shown in table 4-1.Fig 4-1to Fig 4-3 show the relation between injected PV number and pressure, water cut, recovery degree. Table 4-2 show the displacement results,

Table 4-1 concrete schemes of the oil displacement with different alkali concentration in main slug

scheme	pre-polymer slug	Main slug	Vice slug	rear-polymer slug
Scheme 1	slug size:0.04PV polymer 1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:1% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million
Scheme 2	slug size:0.04PV polymer 1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1.2% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:1% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million
Scheme 3	slug size:0.04PV polymer 1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1.4% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:1% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million

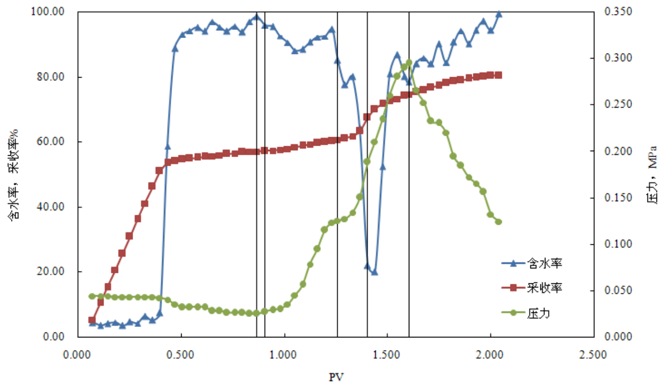

Fig 4-1oil displacement effect of scheme1(main slug CA=1.0%)

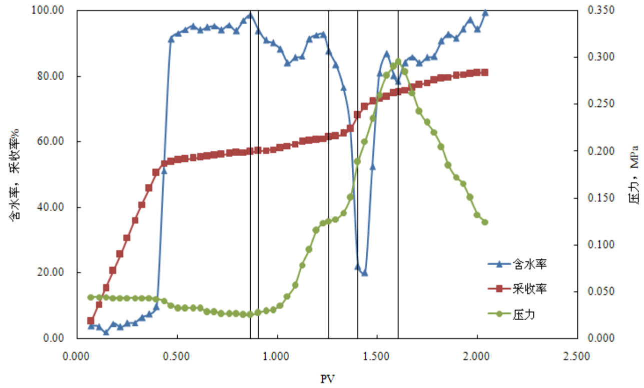

Fig 4-2 oil displacement effect of scheme 2(main slug CA=1.2%)

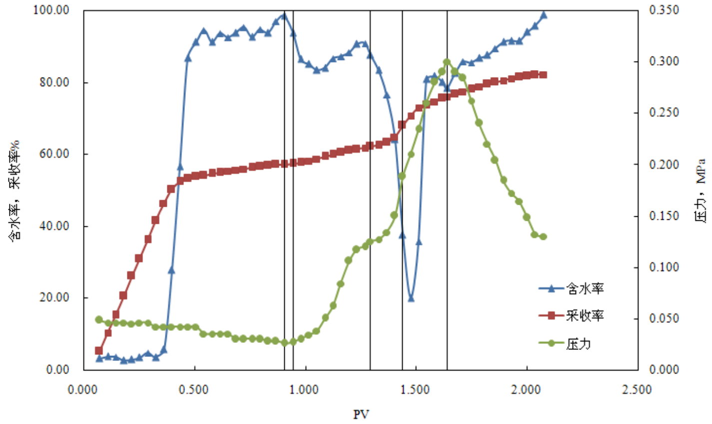

Fig 4-3 oil displacement effect of scheme 3(main slug CA=1.4%)

Table 4-2 oil displacement results with different alkali concentration in main slug

scheme	oil saturation (%)	water flooding recovery degree	chemical flooding recovery degree	added value by chemical flooding	amplification of recovery degree
scheme 1	72.0	49.0	72.31	23.31	--
scheme 2	73.5	48.8	72.97	24.17	0.86
scheme 3	73.5	49.1	73.89	24.79	0.62

From the results, we can find that along with the compound system injected into the sand column, the water cut will decrease obviously and the pressure will increase at the same time. Compared with water flooding, the recovery degree increased obviously. By contrasting the three schemes, we can know that recovery degree increases with the alkali concentration increasing in the main slug, but the amplitude decreases gradually, which is consistent with the results of numerical simulation.

(2) conduct the oil displacement experiments with a alkali concentration in vice slug is 0.8%, 1.0%, 1.2% separately. The concrete schemes are shown in table 4-3.Fig 4-4to Fig 4-6 show the relation between injected PV number and pressure, water cut, recovery degree. Table 4-4 show the displacement results.

Table 4-3 concrete schemes of the oil displacement with different alkali concentration in vice slug

scheme	pre-polymer slug	Main slug	Vice slug	rear-polymer slug
Scheme 4	slug size:0.04PV polymer1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1.2% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:0.8% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million
Scheme 5	slug size:0.04PV polymer1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1.2% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:1.0% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million
Scheme 6	slug size:0.04PV polymer1600mg/L molecular weight 25 million	slug size:0.35PV alkali:1.2% surfactant:0.3% polymer 1900mg/L molecular weight 16-19 million	slug size:0.15PV alkali:1.2% surfactant:0.15% polymer 1800mg/L molecular weight 16-19 million	slug size:0.2PV polymer 1600mg/L molecular weight 16-19 million

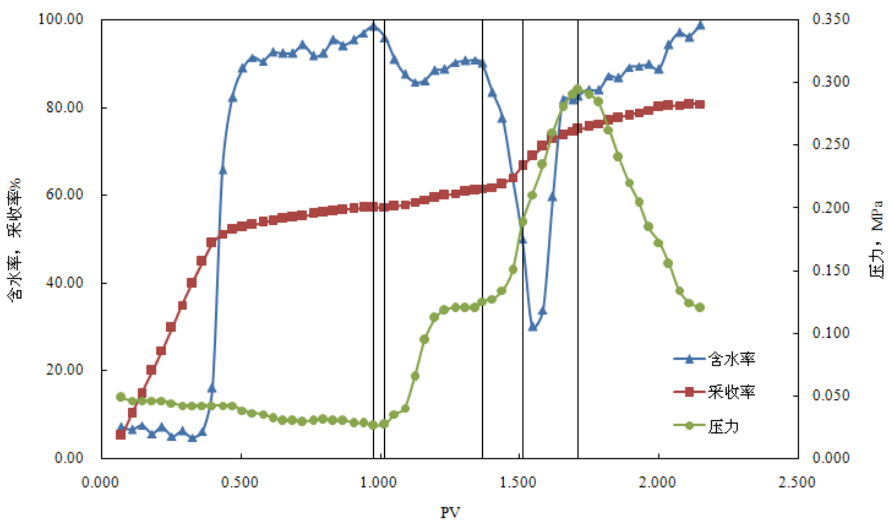

Fig 4-4 oil displacement effect of scheme 4(vice slug CA=0.8%)

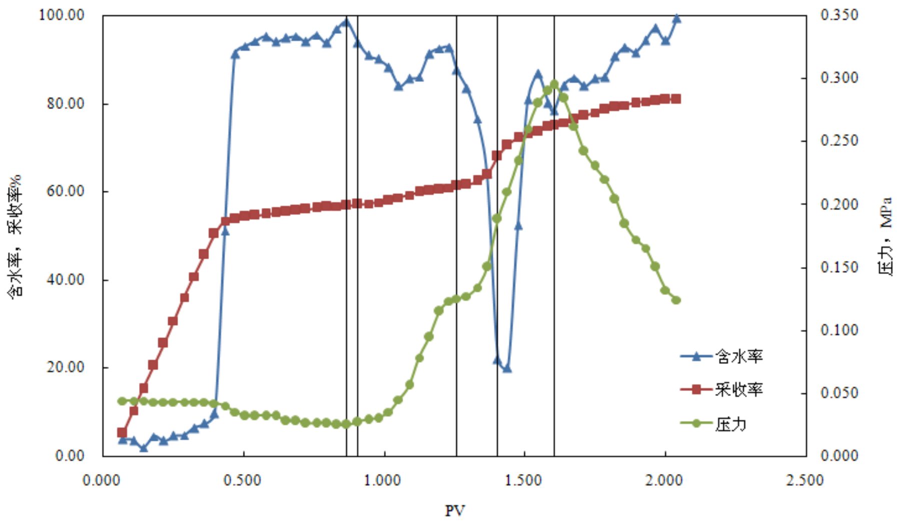

Fig 4-5 oil displacement effect of scheme 5(vice slug CA=1.0%)

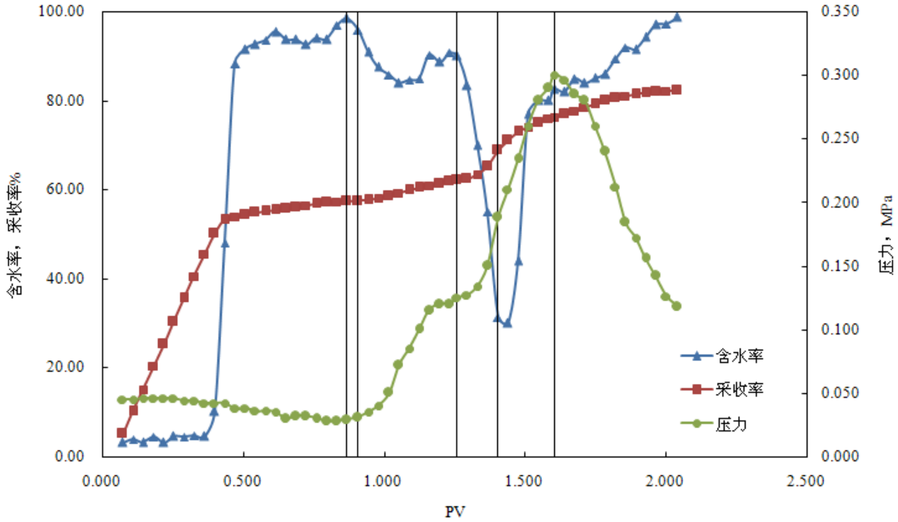

Fig 4-6 oil displacement effect of scheme 6(vice slug CA=1.2%)

Table 4-4 oil displacement results with different alkali concentration in main slug

scheme	oil saturation（%）	water flooding recovery degree	chemical flooding recovery degree	added value by chemical flooding	amplification of recovery degree
scheme 1	74.0	49.1	72.73	23.63	--
scheme 2	73.5	48.8	72.97	24.17	0.54
scheme 3	74.1	49.3	73.98	24.68	0.51

From the results, we can find that along with the compound system injected into the sand column, the water cut will decrease obviously and the pressure will increase at the same time. Compared with water flooding, the recovery degree increased obviously. By contrasting the three schemes, we can know that recovery degree increases with the alkali concentration increasing in the vice slug, but the amplitude decreases gradually, which is consistent with the results of numerical simulation.

5. Conclusion

(1) When implementing weak base ASP flooding in the west part of Daqing oilfield, the recovery degree increases gradually when the alkali concentration increases in the main slug. The optimal alkali concentration in main slug is 1.2%-1.4%.

(2) When implementing weak base ASP flooding in the west part of Daqing oilfield, the recovery degree increases gradually when the alkali concentration increases in the vice slug. The optimal alkali concentration in vice slug is 1.2%-1.4%.

(3) Compared to increasing the mass fraction of alkali in vice slug, the increased value of recovery degree is bigger when increase the mass fraction of alkali in the main slug. It demonstrates the amount of alkali in the main slug plays a more important role in displacing oil from the formation.

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