Study on Anti-scaling Performance of Scaling Inhibitor Used during Calcium Scaling Period of Oilwells in ASP Flooding

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Abstract The wellbore chemical anti-scaling technology is one of the effective ways to enhance the maintenance time of pump in the ASP flooding. This study investigated the different amount of calcium ion, silicon ion and scale inhibitor influenced the anti-scaling performance of the simulation system. The result indicated that the anti-scaling rate decreased when the content of calcium and silicon increased and the best concentration of scaling inhibitor existed. When the silicon content was 150 $mg \cdot L^{-1}$ or less, it could not influence the anti-scaling performance of scale inhibitor. When the content of calcium ion was 10-80 $mg \cdot L^{-1}$, the concentration of scale inhibitor increased with the increase of calcium ion content. There is a functional relationship between the calcium and scale inhibitor. According to empirical formula, the amount of scale inhibitor in the single well can reduce more than 20% and the average amount saved 31.05%.

Introduction

Strong base alkaline-surfactant-polymer flooding (ASP flooding), which is composed of sodium hydroxide, polymer and surfactant, is a composite oil displacement system. This technology can improve the oil recovery by 20%, but the problems of oil-wells scale expose in pilot tests [1-2]. With pilot tests of ASP flooding expand, the liquid which injects into the ASP flooding set off a chemical reaction with the reservoir fluid and rock. It will make the content of Ca^{2+}, Mg^{2+}, CO_3^{2+} and soluble silicon happened regular change. The main scale is $CaCO_3$ and $CaSiO_3$. The scale causes the pumps stuck frequently. It has a seriously influence on regular production and produces a hugh cost in oilfield [3, 4]. The peak of scaling in the ASP flooding is the period of calcium scale and silica scale. At present, the oil well scaling problem mainly adds the scale inhibitor in the wellbore and auxiliary anti-scaling measure. It has achieved well result in the oilfield application [5]. Nowadays, the amount of scale inhibitors in the oil well maintains at a high level. The concentration has no theoretical basis and the economy is bad.

According to investigating the concentration of scale inhibitor and the content of calcium ion and silicon ion influence the anti-scaling performance in the ASP flooding simulation system; we get the best concentration of scale inhibitor, and conclude the relationship between the concentration of scale inhibitor and the calcium ion, silicon ion in the produced liquid. It can reach the purpose of individualized design the ASP flooding in Daqing oilfield and reduce the production cost.

Experimental Details

Material and Equipment

Equipment: inductively coupled plasma spectrometer (PerkinElmer Inc. 2100DV), digital display (Brank Germany, precision 0.01mL), and thermostatic water bath (Guowang experimental instrument factory).

Experimental drug: Na_2CO_3, NaCl, $NaHCO_3$, Na_2SO_4, $Na_2SiO_3·9H_2O$, $CaCl_2$, $MgCl_2·6H_2O$, Calcium ion ICP standard solution (AR), Silicon ion ICP standard solution (AR), scale inhibitor (Lab-made), Ultrapure water.

Simulation of produced water: degree of mineralization (12067.52 $mg·L^{-1}$), NaCl (1300 $mg·L^{-1}$), CO_3^{2-} (1400 $mg·L^{-1}$), HCO^{3-} (2300 $mg·L^{-1}$), SiO_3^{2-} (100 $mg·L^{-1}$), Ca2+ (50 $mg·L^{-1}$), Mg^{2+} (10 $mg·L^{-1}$), SO_4^{2-} (100 $mg·L^{-1}$).

Evaluation Method

In the process of preparing the simulation of produced water, it was divided into two groups (A and B). The group A contained calcium ion and magnesium ion. Group B contained NaCl, HCO_3^-, CO_3^-, and $SiO32^-$. The specific operation referenced Q/SY DQ0830-2006.

Results and Discussion

Effect of Scale Inhibitor Concentration on Anti-scaling Performance

In the simulation system, the content of silicon ion and calcium ion is 50 $mg·L^{-1}$. The anti-scaling performance of the scale inhibitor is measured by the concentration under the 10-70 $mg·L^{-1}$. The experimental result is shown in Fig.1.

In the Fig.1, the anti-scaling rate increases with the increased scale inhibitor concentration. When the concentration of scale inhibitor is 60 $mg·L^{-1}$ or less, the anti-scaling rate increases rapidly. When the concentration of scale inhibition is more than 60 $mg·L^{-1}$, the anti-scaling rate is over 85%. According to the law of definite composition, chelating groups of anti-scaling system and calcium ion in the simulation system generated the stable soluble chelating. When the concentration of scale inhibitor increases, the chelate calcium ion also increases. Anti-scaling rate curve appears rising trend with the increase of concentration of scale inhibitor. The scale-forming cation and chelating ligand exists the upper limit. When the scale inhibitor concentration is more than 60 $mg·L^{-1}$, it cannot have enough calcium ions to react with the scale inhibitor, so the curve flats. The best concentration of the scale inhibitor is 60 $mg·L^{-1}$ in the simulation system. It can effectively prevent 50 $mg·L^{-1}$ calcium ion from producing the scale.

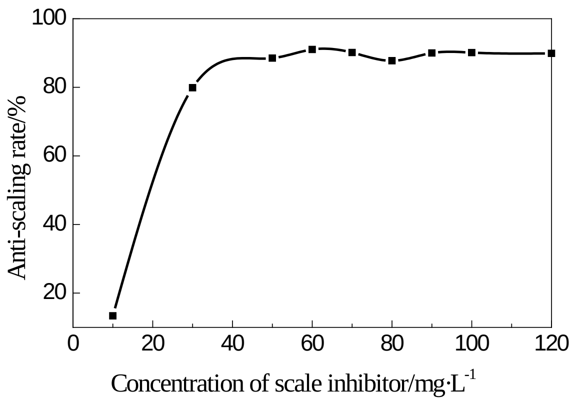

Figure1. Effect of scale inhibitor concentration on anti-scaling

Effect of the Calcium Ion Concentration on Anti-scaling Performance

In the simulation system, the content of the silicon ion is 50 $mg·L^{-1}$ and scale inhibitor is 60 $mg·L^{-1}$. The anti-scaling performance is influenced by the 10-140 $mg·L^{-1}$ calcium ion. The experimental result is shown in Fig.2.

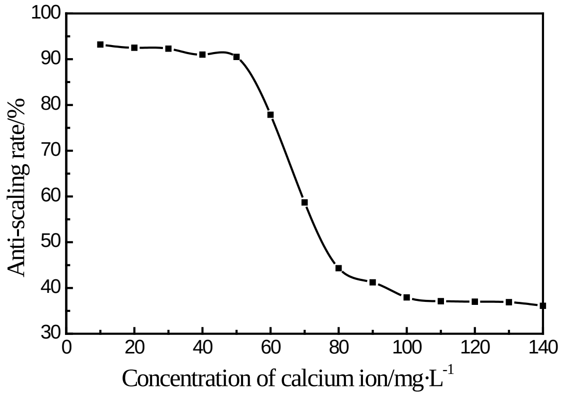

Figure2. Effect of the calcium ion concentration on anti-scaling

When the concentration of calcium ion is 50 mg·L^{-1} or less, the anti-scaling rate could maintain the 90%. When the concentration of calcium ion is 50-80 mg·L^{-1}, the anti-scaling rate will decrease. The higher concentration of calcium ion makes the anti-scaling performance worse. When the content of calcium is higher than 80 mg·L^{-1}, the anti-scaling performance will disappear. When the concentration of calcium ion is 50 mg·L^{-1} or less, the system of chelating groups could provide enough calcium ions and express good anti-scaling effect. Overall the anti-scaling performance is closely related to the calcium content in the simulation system.

Effect of Silicon Ion Concentration on Anti-scaling Performance

For the period of the produced water with calcium scale in Daqing oilfield, the silicon ion contented between 0-100 mg·L^{-1}. We investigate the anti-scaling performance with the different content of silicon ion and scale inhibitor. When the calcium ion content is 50 mg·L^{-1} and the scale inhibitor content is 60 mg·L^{-1}, the silicon ion will influence the anti-scaling performance, and the result is shown in Fig.3.

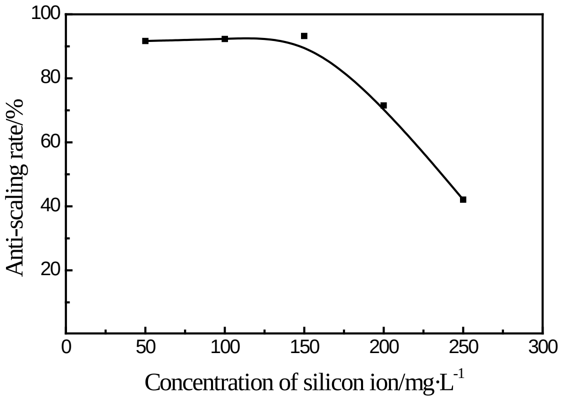

Figure3. Effect of silicon ion concentration on anti-scaling

When the concentration of silicon ion is 150 mg·L^{-1} or less, the anti-scaling rate will remain above 90%. The content of the silicon ion could not influence the performance of scale inhibitor in the system. When the concentration of silicon ion is more than 150 mg·L^{-1}, the rate of anti-scaling will decrease. The main reason is that the soluble silicon has many forms under the different concentrations. It exists in four states: SiO_3^{2-}, $SiO_2(OH)_2^{2-}$, $SiO(OH)_3^-$ and $Si(OH)_4$ [6,7]. When the concentration of silicon ion is 150 mg·L^{-1} or less, the soluble silicon exists $SiO(OH)_3^-$ and $Si(OH)_4$. It could not react with HCO_3^-, therefore the content of CO_3^- could not increase in the system. There is no influence to the anti-scaling performance. The scale inhibitor suits that the content of silicon content is less than 150 mg·L^{-1} in the produced liquid.

Design the Effective Concentration of the Scale Inhibitor

In the Fig.4, it is shown that the concentration of scale inhibitor influences the anti-scaling performance in the simulation system. The content of calcium ion is 50-80 mg·L^{-1} and the content of silicon ion is 100 mg·L^{-1}.

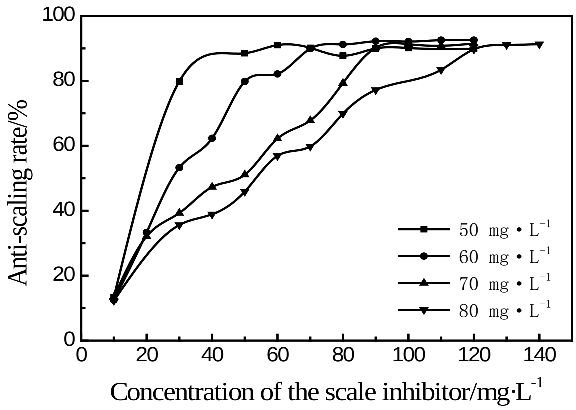

Figure 4. Different concentration of scale inhibitor effect the anti-scaling in different content of calcium ion

In Fig.4, when the content of calcium ion is 60 mg·L^{-1}, 70 mg·L^{-1} and 80 mg·L^{-1}, the effective concentration of scale inhibitor is 70 mg·L^{-1}, 90 mg·L^{-1} and 120 mg·L^{-1}. In Daqing oilfield ASP flooding, the calcium ion is 10-80 mg·L^{-1}. The relationship of calcium ion and scale inhibitor is shown in Fig.5.

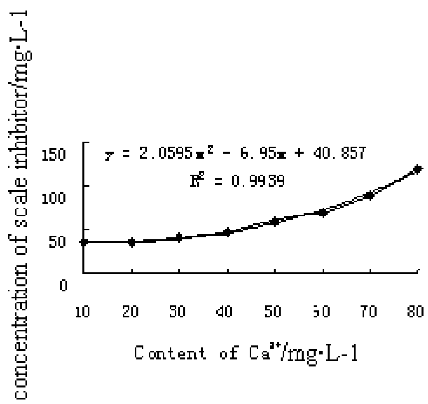

Figure5. Relationship of Ca^{2+} content and scale inhibitor concentration in scaling system

It will illustrate the Ca^{2+} content and scale inhibitor concentration has a functional relationship in scaling system. The equation is as follows:

$$Y = 2.0695\left(\frac{C}{10}\right)^2 - 6.95\left(\frac{C}{10}\right) + 40.857$$

Which Y is the effective concentration of scale inhibitor; C is the Ca^{2+} content in scaling system.

We select eight ASP flooding wells in Daqing oilfield. The content of calcium ion is in the range of 10-80 mg·L^{-1}. According to the equation, we could calculate the corresponding concentration of scale inhibitor. The relationship of the experimental concentration and actual concentration is shown in Table 1.

Table 1 Analytical data

Calcium ion ($mg \cdot L^{-1}$)	10	20	30	40	50	60	70	80	average
Effective concentration ($mg \cdot L^{-1}$)	35	35	40	45	60	70	90	120	61.88
Concentration in design ($mg \cdot L^{-1}$)	35.98	35.24	38.63	46.17	57.84	73.66	93.61	117.71	62.35
Deviation ($mg \cdot L^{-1}$)	0.98	0.23	(-1.37)	1.17	(-2.16)	3.66	3.61	(-2.29)	1.93
Concentration in oilfield ($mg \cdot L^{-1}$)	60	60	60	60	80	100	120	200	92.5
Adjustive concentration ($mg \cdot L^{-1}$)	36	36	40	47	58	75	95	120	63.38
Saving (%)	40.00	40.00	33.33	21.67	27.50	25.00	20.83	40.00	31.04

Note: The concentration in oilfield was the actual concentration in the ASP flooding.

It is shown that the average deviation of the calculated concentration and the effective concentration in the experiment is 1.93 $mg \cdot L^{-1}$ or less. According to the equation in individualized design, the amount of scale inhibitor could save more than 20% and the average amount is 31.05%. Therefore, the empirical formula can be used in individualized design at Daqing oilfield. It can get effective anti-scaling performance and reduce the production cost.

Conclusions

(1) The scale inhibitor had the best concentration in the ASP flooding oil well. The best concentration was closely related to the content of calcium ion and silicon ion in the simulation system.

(2) When the silicon content was 150 $mg \cdot L^{-1}$ or less, the anti-scaling performance in the calcium scale period had no relationship to the silicon ion content in the simulation system.

(3) In the ASP flooding oilfield, the anti-scaling performance in the calcium scale had relationship with the calcium ion content. With the increased calcium ion content, the concentration of scale inhibitor increased. When the content of the calcium ion was 10-80 $mg \cdot L^{-1}$, the effect of the anti-scaling was more than 85% and the concentration of scale inhibitor was 35-120 $mg \cdot L^{-1}$.

(4) In the period of calcium scale with the ASP flooding oilfield, when the content of the calcium ion was 10-80 $mg \cdot L^{-1}$, and the silicon content was 150 $mg \cdot L^{-1}$ or less, the calcium content had functional relationship with the effective concentration of the scale inhibitor. The function was $Y = 2.0695\left(\frac{C}{10}\right)^2 - 6.95\left(\frac{C}{10}\right) + 40.857$. It could guide the oilfield to individualized design and save the amount of scale inhibitor more than 20%.

Acknowledgment

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Reference

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