Evaluation and Application of New Anti-expansion Unblocking Agent for Water-sensitive Oil Deposit

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Abstract. In water-injection development, water-sensitive oil deposits are prone to water injection pressure increase and water injection volume decrease, which makes it difficult to complete production and injection allocation. To solve this problem, on the basis of screening traditional anti-expansion unblocking agents, and combined with the performance evaluation of the formula and core experiment, a reasonable improvement scheme was proposed in this paper to develop a new type water-sensitive oil reservoir anti-expansion unblocking agent. The performance evaluation experiment shows that it has an applicable dissolution rate for oil rock samples and can dissolve inorganic salt scale; the anti-expansion rate is up to 90%; the core dynamic evaluation experiment shows that the core permeability can be increased more than double after the injection of the anti-expansion unblocking agent. The new type water-sensitive anti-expansion unblocking agent were used in 7 wells of the site, and all of them have a good effect of water injection pressure decrease and water injection volume increase.

1. Introduction

Unblocking is an important measure necessary to restore oil well production capacity and ensure stable production and high yield of oil deposits. In the past, the unblocking measures were less, and the unblocking agents commonly used were mainly hydrochloric acid, hydrofluoric acid, mud acid, formic acid, acetic acid, etc., but the unblocking effect was not good [1]. With the increase of water injection volume, there are often contradictions in the production and development of water-sensitive reservoirs, such as injection pressure increase and water injection decrease, which seriously restricts the development of water-sensitive reservoirs. The main reason is that, clay minerals are widely found in water-sensitive reservoirs. During the development of oil fields, clay minerals meet the low salinity water entering the formation, and hydration expansion and particle migration will occur, causing serious damage to the oil reservoir. [2]. Therefore, a new type of water-sensitive oil deposit anti-expansion unblocking agent was developed for the characteristics of water-sensitive oil reservoirs. The performance evaluation experiments show that it has an applicable dissolution rate and can dissolve inorganic salt scales in oil-bearing rock samples. Core dynamic evaluation test shows that the core permeability can be increased more than double after injecting the new anti-expansion unblocking agent. The field application practice shows that the application of the new anti-expansion unblocking agent of the water-sensitive reservoir can achieve the purpose of controlling the rising speed of the water injection pressure and improving the development effect of the well group.
2. Laboratory test evaluation

The formula of the new anti-expansion unblocking agent for water-sensitive reservoirs is: acidizing unblocking agent is used in an amount of 1.5-2.5%; the clay stabilizer is used in an amount of 2% to 3.5%; and the corrosion inhibitor is used in an amount of 0.5% to 3%.

2.1 Anti-expansion rate

The experimental method refers to the relevant provisions of the petroleum industry standard SY/T 5971-2016 "Calculation performance evaluation method for fracturing acidification and water injection clay stabilizer for oil and gas fields". After expansion with detonated water and core powder in deionized water, test sample was treated with 2% new anti-expansion unblocking agent to investigate the anti-expansion effect.

Weigh 0.50g bentonite powder or core powder, accurately to 0.01g. Put it into a 10ml centrifuge tube, and add 10ml, 2% mass fraction new anti-expansion unblocking agent., and place it at room temperature for 2h. Then put it into the centrifuge and the mixture was centrifuged at a speed of 1500 r/min for 15 minutes, and the expansion volume $V_1$ of the bentonite powder was read.

Repeat the above steps, replace the new anti-expansion solution with 10 ml of deionized water, and determine the expansion volume $V_2$ of the bentonite powder in water. Repeat, replace the new anti-expansion solution with 10ml of kerosene to determine the volume $V_0$ of bentonite powder in kerosene.

The anti-expansion rate is calculated according to the following formula.

$$B = \frac{V_1 - V_2}{V_2 - V_0} \times 100\%$$

Where:
- $B$ —— anti-expansion rate, %;
- $V_1$ —— expansion volume of bentonite powder (core powder) in anti-expansion solution, ml;
- $V_2$ —— expansion volume of bentonite powder (core powder) in deionized water, ml;
- $V_0$ — the volume of bentonite powder (core powder) in kerosene, ml.

Formula allows relative error to be no more than 5.0%

Experimental results:

| Index          | Test results |
|----------------|--------------|
|                | Bentonite powder | Core powder |
| Anti-expansion rate, % | 90.7         | 90.1        |

It can be seen from the test results that the new anti-expansion unblocking agent has a 90% anti-expansion rate for both bentonite powder and core powder. The anti-expansion effect is good.

2.2 Expansion rate

Experimental method: Weigh 0.50g bentonite powder or core powder, accurately to 0.01g, put it into a 10ml centrifuge tube, add 10ml deionized water and inject water respectively. Shake the mixture thoroughly, and place it at room temperature for 4h, and then put into the centrifuge and the centrifuge was centrifuged at 1500 r/min for 15 min, and the volume $V_1$ of the bentonite powder after expansion was measured.

Different concentrations of the shrinking agent solution were added to the above centrifuge tubes, placed in a centrifuge at room temperature for 4 hours, and centrifuged at a speed of 1500 r/min for 15 minutes to measure the volume $V_2$ of the bentonite powder after shrinking.

Calculation of shrinkage rate:

The shrinkage rate is calculated according to the following formula.

$$P = \frac{V_1 - V_2}{V_1} \times 100\%$$

Where: $P$ - shrinkage rate, %;
V₁ - the volume of expansion of bentonite powder in deionized water (or injected water), ml;  
V₂——the volume after the expansion of bentonite powder, ml;  

Experimental results:  

| Index               | Test results |
|---------------------|--------------|
|                     | Bentonite powder | Core powder |
| Expansion rate, %   | 57.6          | 57.5        |

It can be seen from the test results that the new anti-expansion unblocking agent has an anti-expansion rate of 50% for both bentonite powder and core powder. The anti-expansion effect is good.

2.3 Corrosion inhibition rate

The indoor static coupon test was carried out according to the SY/T0026-1999 "Water Corrosion Test Method" standard. The test steel sheet was made of N80 steel standard test piece, which was ground, sectioned, measured, degreased, weighed and hung into a 500 ml jar containing the test water sample. Two pieces of each bottle were used as parallel test. The experimental temperature was 80 °C. The indoor test pieces keep hanging for 4 to 7 days. Then the test piece is taken out for cleaning and weighing, and the average corrosion rate of the water sample to the test piece is calculated according to the formula according to the weight loss method.

\[ V = \frac{(m_0-m_1) \times 8.76 \times 10^4}{s \times t \times \rho} \]

In the formula:
- \( V \) ——— corrosion rate, mm/a;  
- \( m_0 \) ——— test piece quality before the test, g;  
- \( m_1 \) ——— test piece quality after the test, g;  
- \( s \) ——— test surface area, cm²;  
- \( t \) ——— hanging time, h;  
- \( \rho \) ——— test piece material density, g/cm³.

\[ \overline{V} = \frac{V_1+V_2}{2} \]

In the formula:
- \( \overline{V} \) ——— average corrosion rate, mm/a;  
- \( V_1 \) ——— test piece 1 corrosion rate, mm/a;  
- \( V_2 \) ——— test piece 2 corrosion rate, mm/a.

Corrosion inhibition rate refers to the SY/T0026-1999 "Water Corrosion Test Method" standard, and the static hanging method is used to calculate the corrosion rate and average corrosion rate of the water sample on the experimental steel sheet according to the formula. At the same time, the corrosion inhibition contrast experiment was carried out, and the concentration of the new anti-expansion unblocking agent was 100 mg/L. The corrosion inhibition rate was calculated according to the following formula.

\[ \eta = \frac{\overline{F}_0 - \overline{F}_i}{\overline{F}_0} \times 100 \% \]

In the formula:
- \( \eta \) ——— corrosion inhibition rate, %;  
- \( \overline{F}_0 \) ——— average corrosion rate of blank water sample, mm/a;  
- \( \overline{F}_i \) ——— The average corrosion rate of the corrosion inhibitor water sample, mm/a.
Experimental results:

| Agentia Corrosion rate, mm/a | Corrosion inhibition rate, % |
|-----------------------------|-----------------------------|
| Blank water sample           | 0.0313                      |
| New anti-expansion agent     | 0.0079                      |

According to the experimental results, the corrosion inhibition rate of the new anti-expansion agent is 74.8%, which is greater than 70%.

2.4 Core permeability recovery rate

The core plugging rate recovery experiment was used to evaluate the plugging effect. Take the core of Q oilfield, and measure the initial permeability of the core after cleaning and drying. Under the pressure difference of 0.17 MPa, the formation water, oil and wax were injected into the core to establish fluid blockage. After the injection was completed, the core damage was recorded for 6 hours. Finally, after the three kinds of unblocking agents were injected under the same pressure difference, the core was tested for permeability recovery. The experimental results are shown in the table below.

| Plugging removal agent       | Formula                  | Initial permeability, $10^{-3}\mu m^2$ | Post-pollution permeability, $10^{-3}\mu m^2$ | Permeability after plugging removal, $10^{-3}\mu m^2$ | recovery rate (%) |
|-----------------------------|--------------------------|---------------------------------------|-----------------------------------------------|--------------------------------------------------|------------------|
| Conventional soil acid permeation | 10%HCl+1%HF              | 12.41                                 | 1.57                                          | 8.45                                             | 68.1             |
| Fluoroboric acid penetration | 10%HCl+4%HBF4            | 9.42                                  | 0.66                                          | 6.57                                             | 69.7             |
| New anti-expansion unblocking agent | 1.5% 1.5%               | 8.78                                  | 0.57                                          | 8.01                                             | 91.2             |

From the above experimental results, the recovery rate of conventional soil acid permeation was 68.1%, the recovery rate of fluoroboric acid penetration was 69.7%, and the recovery rate of new anti-expansion unblocking agent was 91.2%, which was better than conventional soil acid and fluoroboric acid.

2.5 Dissolution rate

Experimental method: the natural core was crushed, and then passed through a 110-mesh sieve, and baked at 100 °C for about 2 h, then 1 g of dry natural rock waste powder was added to a 10 mL slow-speed acid system, and the reaction was heated at a constant temperature of 40 °C water bath. After 4 h, the rock sample was taken out. After filtered, rinsed with 1% aqueous HCl solution, then dried and weighed to calculate the dissolution rate. Calculated as follows:

\[
\text{Dissolution rate} = \frac{(m_1-m_2)}{m_1} \times 100\%
\]

Where $m_1$ is the mass of the cuttings powder before the reaction, g; $m_2$ is the mass of the cuttings powder after the reaction, g.

| Core sample | $m_1$, g | $m_2$, g | 8-hour dissolution rate, % |
|-------------|----------|----------|---------------------------|
| A           | 2.0031   | 1.4389   | 28.2                      |
| B           | 2.0098   | 1.4334   | 28.7                      |

It can be seen from the experimental results that the new anti-expansion unblocking agent has a moderate dissolution rate for the oil layer rock sample and does not cause damage to the rock layer skeleton.
3. Field Application

3.1 Filed design
The new anti-expansion unblocking agent injection process can be divided into concentrated injection and dispersed injection.

The concentrated injection process is to build the water injection station in the joint station or the oil transfer station. The system outside the station is a high-pressure pipe network. The source water is adjusted and distributed by the water distribution valve group and then transferred to the water injection wellhead. In the concentrated injection process, the injection pump has a large displacement, a small number and concentrated construction, and the number of wells is generally more than two. For the newly built production area with large development area and centralized water injection Wells, the concentrated injection process should be adopted.

The dispersed injection process builds the water treatment part into the oil transfer station, and uses low-pressure water supply between the transfer station and the injection station. The injection station uses high-pressure water injection line to transfer the source water to the injection wellhead. Dispersed injection is a single well injection process, the displacement of the water injection pump is small, the quantity is large, and the construction is dispersed. The scattered well and the expanded well project should use a dispersed injection process.

3.2 Filed effect
The new anti-expansion unblocking agent applied a total of seven wells in the Q oilfield application reaches a 100% efficiency and the effective period is 4-8 months.

4. Conclusion
For the water-sensitive reservoir, the new anti-expansion unblocking agent developed by screening has an applicable dissolution rate and can dissolve inorganic salt scale. It is verified by experiments that the anti-expansion rate of the new anti-expansion unblocking agent reaches 90%. The core dynamic evaluation test shows that the core permeability can be increased more than double after the anti-expansion unblocking agent is injected, which has a positive effect for the reservoir protection of the water-sensitive reservoir. Seven wells were used in the field test, and all of them have a good effect of water injection pressure decrease and water injection volume increase.

References
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