Study on Plugging Water Technology in Fractured Buried-Hill Reservoir of Heavy Oil

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Abstract
S1 heavy-oil buried hill belongs to bottom water massive reservoir with developed reservoir fractures. The main problem in development is that affected by bottom water coning, the comprehensive water cut of reservoir rises rapidly. At the beginning of 2018, the comprehensive water content of the block reached 93%. The field application shows that the plugging agent has high temperature resistance and high plugging rate. After the measures, the reservoir permeability can be partially restored. It is a better selective plugging agent.

Keywords
Study, Plugging Water Technology, Heavy Oil.

1. Introduction

According to the core analysis and statistics of coring wells, the fracture opening of S1 buried hill is generally 0.2 ~ 0.5 mm, the maximum is 0.75 mm, and the average is 0.38 mm. In the process of block development, with the increase of produced fluid, the reservoir pressure in the oil producing area decreases greatly, and a funnel-shaped local depressurization area is formed at each well point. Under the action of increasing flow pressure difference, the huge water body around the oil producing area protrudes upward along the high-angle fracture, resulting in the gradual flooding of the oil layer.

In the past, ordinary oil well cement was used to cut off the ash plug in the wellbore, and ultra-fine cement and fly ash were used to create a sealing zone near the well to inhibit the coning of edge and bottom water. However, due to the development of high angle fractures in the ancient buried hill, with the increase of recovery, the bottom water coning speed is accelerated and the plugging zone is quickly bypassed, and the effect of measures becomes worse year by year.

2. Study on Water Shutoff Agent

2.1. Plugging agent mechanism

The granular plugging agent used on site is mainly composed of plant fiber particles, tannin extract, oil-soluble resin, HPAM, Compound JB, etc. Its action mechanism is reflected in three aspects:

(1) After being squeezed into the oil layer under the carrier of polymer solution, the bulk swelling plant fiber particles expand with water and block the pore throat and fractures, so as to achieve the purpose of plugging the high permeability layer.

(2) Plugging effect of high strength gel produced by tannin extract and JB compound in alkaline plugging agent on high permeability layer.

(3) The temporary plugging agent composed of oil soluble resin dissolves or disperses with oil in the process of oil well pumping production to restore a certain reservoir permeability.
2.2. Performance evaluation of plugging agent

2.2.1. Particle size.

The compatibility between the particle size distribution of granular plugging agent and formation rock pore has a great influence on the plugging effect of plugging agent. If the particle size is too small, the plugging agent is not easy to form bridge plugging in the channel; If the particle size is too large, it is easy to form temporary plugging on the rock surface and cannot enter the depth of the pore, which has a great impact on the plugging effect (depth and validity period) of the plugging agent. According to the 1/3 bridging theory and considering the characteristics of serious reservoir heterogeneity in the block, it is determined that the particle size of plugging agent is controlled in the range of 0.05 ~ 0.15 mm.

2.2.2. Oil solubility.

Take 5g of plugging agent samples before and after high temperature (280 °C, 24 h) and place them in 50 ml kerosene. After constant temperature at 60 ~ 70 °C for 24 h, measure their dispersion and dissolution in kerosene at room temperature (Table 1).

<table>
<thead>
<tr>
<th>Sample</th>
<th>OR/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before high temperature</td>
<td>After high temperature (280 °C, 24h)</td>
</tr>
<tr>
<td>Sample 1</td>
<td>40.2</td>
</tr>
<tr>
<td>Sample 2</td>
<td>42.1</td>
</tr>
</tbody>
</table>

It can be seen from table 1 that the oil solubility of the granular plugging agent is greater than 40%, and the oil solubility decreases after constant temperature at 280 °C for 24 hours.

2.2.3. Temperature resistance.

Indoor experiment: prepare the plugging agent into 10% aqueous solution, take 100 ml and place it in a high temperature resistant container, and put it in a constant temperature oven at 150 °C and 280 °C respectively to test the temperature resistance of the plugging agent. It is found that the plugging agent solution has no obvious change after constant temperature at 150 °C for 24 and 48 hours; After constant temperature at 280 °C for 24 hours, the plugging agent solidifies and has no change on the surface. After constant temperature for 48 hours, the plugging agent has carbonized or degraded on the surface. The field application shows that after 2~3 cycles of huff and puff production, the injected plugging agent is basically produced with the pumping.

2.2.4. Core plugging test

The six action experimental device is mainly composed of pressure source (hydraulic pump, nitrogen cylinder), intermediate container and core tube. Take 2 artificial cores and number them 1 and 2 respectively. The saturated water is pumped out of the artificial core and replaced with tap water until it is stable, and the water phase permeability $K_{w1}$ and $K_{w2}$ before plugging are measured. Prepare the plugging agent into 6% and 10% aqueous solutions, squeeze them into cores 1 and 2 respectively on the core flow tester, the extrusion amount is 5 times the pore volume, and the extrusion pressure is 0.5~1.0 MPa. Then take out the core, put it into high-temperature and high-pressure containers filled with 6% and 10% plugging agent solution respectively, keep the temperature at 280 °C for 24 hours, take it out and cool it to room temperature, and then measure the water phase permeability $K_{w1}$ and $K_{w2}$, and then calculate the water shutoff rate $\eta_{w1}$, $\eta_{w2}$ (Table 2).
Table 2. Core plugging test results

<table>
<thead>
<tr>
<th>Core</th>
<th>WPP before plugging / μm²</th>
<th>WPP after plugging / μm²</th>
<th>PR / %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core 1</td>
<td>2.195</td>
<td>0.038</td>
<td>98.2</td>
</tr>
<tr>
<td>Core 2</td>
<td>2.314</td>
<td>0.011</td>
<td>99.5</td>
</tr>
</tbody>
</table>

It can be seen from the core plugging test results that the plugging rate of the plugging agent is more than 98%, indicating that the plugging agent has good water plugging effect, and the higher the concentration and extrusion amount of the plugging agent solution, the better the water plugging effect.

3. Field application and effect analysis

3.1. Site implementation

From 2018 to the end of 2020, granular plugging agent was applied in 31 wells for water shutoff, increasing oil by 15280t and increasing oil by 493t per well on average. According to the statistics of 18 measure wells whose cycle has ended, the average periodic water production of a single well decreased by 7548t and the water cut of a single well decreased by 11.6%.

3.2. Effect analysis of measures

(1) On the premise that the steam displacement can be compared, the steam injection pressure of the measure well generally increases, the large fracture channel is effectively blocked, and the steam injection pressure after the oil well measure increases by 0.54MPa on average compared with that before the measure.

(2) After the implementation of water shutoff process, the daily oil production in the block has increased steadily, and the comprehensive water cut shows a downward trend. It can be seen from Figure 1 that with the decrease of the total number of wells opened in the block, the total liquid volume of oil wells in the block decreased year by year, and basically remained at about 1000t by 2019.

Table 3. Daily oil production and water cut curve of the block

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of wells opened</th>
<th>Daily liquid/t</th>
<th>Daily oil production/t</th>
<th>Rate of water content/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>51</td>
<td>1884</td>
<td>134</td>
<td>93</td>
</tr>
<tr>
<td>2019</td>
<td>38</td>
<td>1235</td>
<td>126</td>
<td>89.7</td>
</tr>
<tr>
<td>2020</td>
<td>40</td>
<td>1015</td>
<td>134</td>
<td>86.7</td>
</tr>
</tbody>
</table>

In 2018, the granular plugging agent was popularized and applied in the block to implement the water plugging process, and obvious oil increase and precipitation effect was seen. Since 2003, the daily oil production of the block has increased significantly, and the comprehensive water cut of the block has decreased from 93% at the beginning of 2018 to 86.7% at the end of 2020.

(3) The comprehensive decline and natural decline of the block show an obvious downward trend. In 2003, the comprehensive decline and natural decline decreased from 33.6% and 51.44% in 2018 to 8.09% and 41.53% respectively, with a decline of 25.51% and 9.91%; In 2020, the comprehensive decline and natural decline were - 11% and 24.84% respectively, realizing the comprehensive negative decline of the block.
4. Conclusion

(1) The granular plugging agent has good temperature resistance and plugging performance, and is suitable for water plugging and profile control in heavy oil thermal recovery wells.

(2) The main raw material (plant fiber particles) of the granular plugging agent has wide sources and low price. It can greatly reduce the cost of single well measures and is suitable for large-scale popularization and application.

(3) After 2~3 cycles of huff and puff production in measure wells, squeeze injection plugging agent is basically produced with pumping, which can restore reservoir permeability to a great extent.

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References


