Core Simulation Research of Oil Soluble Resin-Dual Crosslinked-Gelatinous Selective Water Shutoff Agent (ORG)

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Abstract. As most oilfields of China turn into the later stage of high water cut, Water shutoff has been an important means to increasing and maintaining oil output in the oilfield. Oil soluble resin-dual crosslinked-gelatinous selective water shutoff agent (ORG) is a good choice. After the formula of ORG is determined, the plugging ability of plugging core and plugging performance of plugging agent are simulated. This paper clarifies the role of ORG plugging agent in the formation, provides support for the application of ORG plugging agent and provides technical support for high and stable oil production.

1. Oil-soluble resin oil-soluble experiment
In order to better evaluate its oil-soluble properties, experiments were divided into two groups to do parallel experiments. One group at room temperature, respectively, the resin I and II particles placed in a large test tube with kerosene, plug the stopper, according to the experimental process experiment; the other group at 85°C, will be equipped with resin and The large test tube of the solvent is placed in a constant temperature water bath at 85°C and the stopper is plugged [1-3]. The same experiment is carried out according to the above experiment. The experimental results are shown in Table 1 and Table 2.

| Table 1. Solubility data of two resins in kerosene over time at room temperature |
| --- |
| Time (h) | I Resin |  | II Resin |  |
|  | Weight after dissolving (g) | Solution state | Oil solubility (%) | Weight after dissolving (g) | Solution state | Oil solubility (%) |
| 1 | 19.5 | clear | 2.5 | 19.3 | clear | 3.5 |
| 7 | 14.7 | clear | 26.5 | 14.4 | clear | 28.0 |
| 24 | 7.3 | clear | 36.5 | 6.7 | Micro-turbidity | 66.5 |
| 48 | 0.1 | clear | 99.5 | 0.0 | Micro-turbidity | 100.0 |
| 72 | 0.0 | Micro-turbidity | 100.0 | 0.0 | Micro-turbidity | 100.0 |
### Table 2. Dissolution data of two resins in kerosene over time at 85°C

| Time (h) | I Resin | II Resin |
|----------|---------|----------|
|          | Weight after Dissolving (g) | Weight after Dissolving (g) | Solution state | Solution state | Oil solubility (%) | Oil solubility (%) |
| 1        | 13.4    | 12.9     | clear   | clear    | 33.0     | 35.5    |
| 7        | 7.7     | 6.4      | clear   | clear    | 61.5     | 68.0    |
| 24       | 0.3     | 0.1      | clear   | clear    | 98.5     | 99.5    |
| 48       | 0.1     | 0.0      | clear   | Micro-turbidity | 99.5 | 100.0 |
| 72       | 0.0     | 0.0      | Micro-turbidity | Micro-turbidity | 100.0 | 100.0 |

Experimental Results Analysis: Here kerosene, for example, lists the oil-soluble resins at room temperature and 85°C, respectively, in the solvent dissolution changes, the same temperature, with the increase of time, the remaining solid mass is reduced; and As the temperature increases, the quality of the solid decreases faster[4-6].

At the end of the experiment, it was found that almost all of the four test tubes formed a substantially clear solution with no visible particles, i.e., very few oil-insoluble materials, indicating that the sample had a high solubility in the refined oil. As a result, oil-soluble resins entering the formation quickly dissolve when in contact with oil well production fluids or cleaning fluids (kerosene, diesel), loses blockage, does not cause difficulties in flowback or plugging, and does not permanently cause formation Sexual damage. Thus, it can be said that the oil-soluble resin is an excellent selective blocking agent. Oil-soluble resin is one of the most important indicators of plugging agent. After being soaked in aqueous solution, the resin is insoluble in water. Therefore, it is also an ideal oil-soluble selective plugging agent from the viewpoint of oil solubility [7-8].

### 2. Oil-soluble resin sealing simulation experiment

1. Core selection: Artificial core: with diameter of 177-200μm of quartz sand, mixed with 3% of the epoxy resin / ethylenediamine mixture as a binder, under the pressure of 8-16MPa diameter 25mm, about 50mm long core, in 90°C curing 16h, you can use. Number 1#, 2#. Natural core: No. 3#, 4#.

2. After the core is selected, the core flow pressure gauge is used to evacuate the artificial core or the natural core from the saturated water. After the water is positively driven at a concentration of 2% KCl solution at room temperature, the core plugging capacity can be measured Water phase permeability $K_{w1}$.

3. Dry the core, the experiment again. Kerosene was injected into the core at room temperature and the oil phase permeability $K_{o1}$ was measured before plugging.

4. Similarly, using a dried core, soak in a xylene solution containing saturated YC oil-soluble resin for 72-120 hours. After considering that the oil-soluble resin has completely blocked the core, kerosene forward drive is applied to determine the oil core permeability $K_{o2}$ after plugging.

5. According to the size of $K_{w1}$ and $K_{w2}$, we can calculate the decrease of water permeability $\eta_w$, which can evaluate the blocking agent blocking strength.

6. Based on the sizes of $K_{o1}$ and $K_{o2}$, we can calculate the recovery value $\eta_0$ of the oil phase permeability, from which the permeability recovery can be evaluated. The results of the analysis are shown in Table 3.

### Table 3. Core simulation results

| number | Radius cm | Length cm | Water phase | Oil phase |
|--------|-----------|-----------|-------------|-----------|
|        | Before $K_{w1}\times10^{-3} \mu m^2$ | After $K_{w2}\times10^{-3} \mu m^2$ | Plugged Rate $\eta_w$% | Before $K_{o1}\times10^{-3} \mu m^2$ | After $K_{o2}\times10^{-3} \mu m^2$ | Recovery Rate $\eta_0$% |
| 1#     | 1.25      | 4.85      | 136.1       | 1.322     | 99.2      | 113.8    | 104.2     | 91.6 |
| 2#     | 1.25      | 4.79      | 683.2       | 4.681     | 99.3      | 576.4    | 530.1     | 92.0 |
| 3#     | 1.25      | 7.90      | 30.4        | 0.029     | 90.3      | 24.7     | 22.1      | 89.5 |
| 4#     | 1.25      | 7.92      | 40.1        | 0.034     | 99.9      | 32.8     | 30.1      | 91.8 |
As can be seen from Table 3, through the comparative experiments on four cores, it is found that the permeability of the water phase has been significantly reduced, with the plugging rates exceeding 90%, indicating that the plugging effect is good. The recovery of oil phase permeability is low at the beginning, but with time, the permeability is slowly recovered.

Since the experiment was conducted at room temperature, the temperature was lower, so the permeability recovery value did not reach the ideal state. Considering that under high temperature conditions, the oil solubility of the resin increases with increasing temperature, so the recovery of the oil phase in the field test is also worth the wait.

It is concluded that the oil recovery rate and the water phase plugging rate of oil-soluble resin plugging agent in indoor core experiments are quite high. Due to the limited conditions, the core may not be completely blocked even after being soaked in xylene solution for a long time. However, the experimental data are still very satisfactory. The actual sealing effect depends on the field test.

3. Comparative experiment of oil soluble resin and active heavy oil

In order to compare different plugging agents, active thick oil plugging agents, water-based plugging agents, and oil-soluble plugging agents were formulated. Specific experimental steps are as follows:

(1) 100g of degassed heavy oil with a viscosity of 1.07Pa • s at a temperature of 50°C, 2g of Span-80 was added as an active heavy oil plugging agent;
(2) Take 2.0 g of partially hydrolyzed polyacrylamide with viscosity average molecular weight of 4.8 × 10^6 and degree of hydrolysis of 30% and dissolve in 200 mL of water;
(3) Using hydrochloric acid to adjust the pH until reaching 5 o'clock;
(4) Adding 12mL of chromium nitrate solution (concentration of 0.04mol/L) while stirring, as a water-based gel blocking agent. With the above experimental method, the plugging rate and permeability recovery rate of different plugging agents on core were measured. Comparison of blocking test results in Table 4.

Table 4. Different plugging capacity of the comparative analysis of data

| Plugging agent type | Water phase | Oil phase |
|---------------------|-------------|-----------|
|                     | $K_{w1}$ ($\mu m^2$) | $K_{w2}$ ($\mu m^2$) | $\eta_w$ (%) | $K_{o1}$ ($\mu m^2$) | $K_{o2}$ ($\mu m^2$) | $\eta_o$ (%) |
| Oil-soluble resin   | 1.61        | 0.04      | 97.09      | 1.18        | 1.07      | 90.68      |
| Active heavy oil    | 1.57        | 0.09      | 94.31      | 1.15        | 0.99      | 86.09      |
| Water-based plugging agent | 1.58    | 0.11      | 92.81      | 1.13        | 0.83      | 73.20      |

From Table 4, it can be seen that the water-blocking ratio and oil recovery rate of oil-soluble resins are significantly higher than those of water-based plugging agents and active heavy oil plugging agents under the same flow pressure, temperature and consistent core conditions Plugging agent, the choice of water plugging superior performance. Thus, oil-soluble resin as a selective plugging agent, its performance is superior.

4. Summary

(1) For cores with different permeability, the ORG plugging agent has a water blocking rate of more than 90% and a plugging rate of less than 30%, showing good selectivity.
(2) For heterogeneous reservoirs, ORG plugging agent will preferentially enter the reservoir with high permeability and will block the reservoir with high permeability.
(3) The selectivity index $SI = FRL / FRH$ of an ORG plugging agent is introduced. The larger the SI value, the stronger the ability of the ORG plugging agent to selectively enter the high permeability oil layer.

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