The Research about Back Pressure and Permeability of Heterogeneous Core Affecting Fractional Flow Rate of Plugging Agent

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Abstract. In order to improve the selective plugging effect of high pressure layer which was during the process of commingled chemical water plugging in heterogeneous layer. This paper carried out the parallel core group experiment to research influence of back pressure and permeability contrast affecting fractional flow rate of acrylic plugging agent. The experimental results show that for parallel core group with different permeability contrast, with increased of pressure difference, fractional flow rate of the low pressure core gradually increased, indicating that inter-layer pressure difference in core group was main factor affecting fractional flow rate. With pressure difference increased from 0 MPa to 2 MPa, fractional flow rate of low pressure core gradually increased from 0 to 100% when permeability contrast is 12.55, fractional flow rate of low pressure core increased from 0 to 31.5% when permeability contrast is 105.5, fractional flow rate of low-pressure core increased from 0 to 10.5% when permeability contrast is 333.3. According to the experimental results, this paper proposed a proposal for selectively plugging high pressure layer in heterogeneous layer with inter-layer pressure difference and permeability contrast, that is, when permeability contrast was less than 105.5, temporary plugging agent should be injected to plug low pressure layer temporarily, and then water plugging agent was injected to plug high pressure layer. The lab experimental results show that after temporary plugging agent was injected, fractional flow rate of high pressure core increased from 0 to 98.8%, and fractional flow rate of low pressure core decreased from 100% to 1.2%, which achieved experimental purpose of selectively plugging high pressure core.
1. Introduction
At present, main methods for selective water plugging are use of selective water plugging agent and selective injection technology in China. First method is to inject the gel water plugging agent with the characteristic of unplugging oil. The characteristic of water plugging agent are used to effectively plug water flow channel. However, the agent generally has low plugging strength and short effective period, and its practical application effect is not ideal [1]. Second method is to use threshold pressure difference of high and low permeability layer to selectively plugging high permeability layer. High permeability layer has low threshold pressure. Low permeability layer has high threshold pressure. When water plugging agent is injected rapidly with the injection pressure below threshold pressure of low permeability layer, water plugging agent will have priority access into high permeability layer to achieve selective plugging [2]. However, this method doesn’t consider influence of inter-layer pressure difference on flow direction of water plugging agent. According to separated layer pressure measurement, liquid production profile test and injection water sweep law in old water flooding oilfield, permeability and layer pressure of high liquid production layer are high than that of low liquid production layer. However, high liquid production layer is the layer that needs to plug water and low liquid production layer. Commingled injection and pressure control injection can cause greater plugging and pollution to layer with low pressure and low liquid production, therefore water plugging effect is poor. This paper carried out the parallel core group experiment to research change law of different back pressure difference and different permeability contrast affecting fractional flow rate of plugging agent, which provides data support for selective entry of water plugging agent into layer with high pressure and high liquid production.

2. Experimental material and procedure

2.1. Experimental material
20-40 mesh, 40-60 mesh and 60-80 mesh quartz sand were mixed in accordance with the mass ratio of 1:1:1, and filled into the sand-filled pipe to produce cores with different permeability contrast. The cores data produced are as follows.

| Core group number | Permeability (mD) | Porosity (%) | Core size (diameter*length)(cm) | Permeability contrast |
|-------------------|-------------------|--------------|---------------------------------|----------------------|
| 1                 | 6.5               | 9.85         | 2.5*20                          | 105.5                |
|                   | 380               | 19.52        | 2.5*20                          |                      |
| 2                 | 4.5               | 10.37        | 2.5*20                          | 333.3                |
|                   | 1500              | 25.68        | 2.5*20                          |                      |
| 3                 | 105               | 15.4         | 2.5*20                          | 12.85                |
|                   | 1350              | 24.85        | 2.5*20                          |                      |

2.2. Experimental procedure
(1) Vacuumized the sand-filled pipe for 2 hours and then saturated it with formation water.
(2) Measured water-phase permeability and porosity of the sand-filled pipe by injecting formation water at a rate of 2 ml/min.
(3) Used the self-design parallel core group experimental procedure to test cores with different permeability contrast. Back pressure valve and manual back pressure device are connected at the outlet end of high permeability core.
(4) Commingled injected water plugging agent at the inlet end of parallel core group. Recorded fractional flow rate of water plugging agent under the back pressure when liquid production of outlet end reached 10 PV.
(5) Adjusted manual back pressure device to gradually improve back pressure of high permeability core, which was 0 MPa, 0.5 MPa, 0.75 MPa, 1 MPa, 2 MPa, respectively. And researched change law
of fractional flow rate of core group at the condition of same injection rate and different back pressure. The experimental flow is shown in figure 1.

![Experimental flow graph](image)

**Figure 1.** Experimental flow graph.

3. Analysis of experimental results

3.1. Change law of fractional flow rate in medium-low permeability parallel core group

For 380-6.5 mD parallel core group, the permeability contrast was 105.5. With increased of back pressure, fractional flow rate of low permeability core gradually increased, while fractional flow rate of high permeability core gradually decreased (figure 2). Two curves had no intersection, indicating that within range of this permeability, most of injected water plugging agent entered into high permeability core and a few into low permeability core. Lab experimental results shown that, under the condition of 2 MPa back pressure, the amount of water plugging agent entered into low permeability core was 31.5%, the core plugging rate was 99.5%, and the breakthrough pressure gradient reached 22 MPa/m. Therefore, this paper considered that if water plugging agent is commingled injection, it will cause serious plugging pollution to low permeability core.

![Fractional flow rate curves of core group 1](image)

**Figure 2.** Fractional flow rate curves of core group 1.

3.2. Change law of fractional flow rate in medium-high permeability parallel core group

For 1350-105 mD parallel core group, the permeability contrast was 12.85. Two curves had intersection at around of 0.55 MPa back pressure. With increased of back pressure, fractional flow rate of low permeability core gradually increased, while fractional flow rate of high permeability core gradually decreased. After back pressure reached 0.75 MPa, fractional flow rate of low permeability core was stable at 100%, while that of high permeability core was stable at 0 (figure 3). Therefore, this paper considered that, for this permeability contrast core group, if water plugging agent was commingled injection, all of agent entered into low permeability core, while high permeability core cannot be plugged. In addition, for selective water plugging in this type of layer, temporary plugging measures should be adopted to temporarily protect low permeability and low pressure parts of layer.
3.3. Change law of fractional flow rate in high-low permeability parallel core group
For 1500-4.5 mD parallel core group, the permeability contrast was 333.3. With increased of back pressure, fractional flow rate of high permeability core gradually decreased, while fractional flow rate of low permeability core gradually increased, but change of curves was small (figure 4). Lab experimental results shown that, under the condition of 2 MPa back pressure, the fractional flow rate of high permeability core was 95%, that of low permeability core was 5%, the core plugging rate of low permeability core was 10.5%, and the breakthrough pressure gradient was 0.56 MPa/m. Therefore, this paper considered that, for this permeability contrast core group, if water plugging agent was commingled injection, most of agent entered into high permeability core, while a few into low permeability core.

3.4. Comparison of parallel core group with similar low permeability core
Comparative analysis of core group 1 and group 2 shown that in the condition of similar low permeability core, the larger permeability of high permeability core was, the larger fractional flow rate of that was.
3.5. Change law of fractional flow rate in medium-high permeability parallel core group after temporary plugging

According to the analysis result of 3.2, parallel core group 3 was firstly injected with a temporary plugging agent that can be plugging and break to temporarily protect core with low pressure and low permeability, and then injected with water plugging agent. Through such measures, this paper researched the change law of fractional flow rate after temporary plugging. Experimental results are shown in figure 6.

Figure 6. Comparison of before and after temporary plugging.

For 1350-105 mD parallel core group, the permeability contrast was 12.55, and back pressure of high permeability core was 0.75 MPa. Before temporary plugging, fractional flow rate of high permeability core was 0, while that of low permeability core was 100%. In the process of temporary plugging agent injection, fractional flow rate of high permeability core was 2.86%, while that of low permeability core was 97.14%. After temporary plugging, fractional flow rate of high permeability core was 98.8%, while that of low permeability core was 1.2%. Experimental results shown that injection of temporary plugging agent reversed flow direction of water plugging agent, and had an obvious selective plugging effect. Therefore, this paper considered that when temporary plugging agent was injected before water plugging agent injection, most of temporary plugging agent can preferentially enter into core with low pressure and low permeability, while a few into core with high pressure and high permeability. Meanwhile, temporary plugging agent cannot plug core with high pressure and high permeability, so there was no plugging pollution. After injection of temporary plugging agent, temporary plugging agent had a good plugging effect on core with low pressure and low permeability, which can obviously improve breakthrough pressure and play a temporary protection role. Therefore, most of subsequent injection of water plugging agent can enter into core with high pressure and high permeability, so as to achieve selective plugging.

4. Conclusion

Flow direction of water plugging agent was affected by back pressure and permeability contrast of high permeability core. For core group with high back pressure and low permeability contrast (contrast is 12.85), water plugging agent was easy to enter into low permeability core, so it can cause plugging pollution. Therefore, in order to achieve selective water plugging for this type of layer, it is need to use temporary plugging measures to protect the low pressure and low permeability position of layer.

For core group with high back pressure and high permeability contrast, water plugging agent rarely entered into low permeability of core, so it caused less pollution. Therefore, in order to achieve selective water plugging for this type of layer, it can adopt commingled injection instead of temporary plugging measures.
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