Evaluation of the development effect of polydynamic drive in Class IIB oil reservoir of Lamadian Oilfield

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Abstract. With the continuous deepening of oilfield development, the target of oilfield development is gradually shifting towards reservoirs with poor physical properties, and polymer flooding can better utilize such reservoirs. The heterogeneity of Class II B oil layer in Lamadian Oilfield is severe, and polymer flooding takes effect later, with a small decrease in watercut. A study was conducted on the evaluation of polymer flooding development effectiveness for Class II B oil layers through reservoir numerical simulation. Research has shown that when the initial watercut is constant, a lower injection pressure can increase the utilization degree of remaining oil in the middle and high permeability layers of Class II B oil layers. With the increase of injection pressure, the response time is shortened, and the decrease in watercut is reduced; As the watercut increases, the injection pressure should gradually increase in order to improve the recovery of low permeability reservoirs; As the watercut increases, the injection pressure should gradually increase in order to improve the recovery of low permeability oil layers; At a watercut of 95% and injection pressure of 7MPa, a field experiment was conducted with a molecular weight polymer of 12 million, and the response time was 6 months. The cumulative oil increase was 14675m³, achieving good polymer flooding effect.

1. Introduction
At present, Most oilfields in China are dominated by terrestrial deposits, and after a long period of water injection development, the water drive development effect deteriorates and the oil production decreases, so the polymer enhanced recovery technology becomes the preferred choice[1-2], and it has been widely applied in the mines[3]. The final recovery of water-driven in type II reservoirs can reach 45.3%, and the recovery of polymer-driven can be increased by 13.32%[4-6]. For some blocks, the development of Class II B oil formation using the production conditions of Class II A, there is a phenomenon of poor results. So the polydynamic recovery conditions of extensive Class II oil reservoirs are not applicable to Class IIB oil reservoirs.

The depth of the Sa III4-10 oil layer in the North-North Block I of the Lamadian Oilfield is 990 m~1100 m. After the boundary adjustment of the subdivided sedimentary unit, the upper and lower units show a better distribution of the compartments. Class I compartments are widely distributed in patches, and class II, III, IV, and V compartments are set in class I compartments in the form of stars and dots.

Analyzing the stratigraphy of North North Block I, it is found that its oil layer thickness is thin, permeability is low, the proportion of the thickness of Class I oil layer connection is low, and the proportion of the thickness of Class I connection is 13.5% lower than that of Class I oil layer. According to the field data, it was found that the proportion of Class II oil layers accounted for about 23.8% of the overall oil layer distribution, of which the Class IIB oil layer accounted for about 40% of the Class II oil layers. The permeability planar abruptness coefficient is larger, the horizontal non-homogeneity is stronger, and the planar coefficient of variation is also higher reaching 0.79.

Statistical data on the formation permeability of the block found that the permeability distribution of wells with ineffective injection polymerization was concentrated in three permeability intervals of 0.2~0.4 μm², 0.4~0.6 μm², and 0.6~0.8 μm², as shown in Figure 1.

![Permeability distribution in response areas](image)

**Figure 1.** Permeability distribution in response areas
In this paper, based on the research block, numerical simulation research is carried out to optimize and preferably select the poly injection parameters of Class II B oil formation, and clarify the characteristics of the
2. Characterization of oil reservoirs in Class II-B reservoirs

Table 1. Changes in permeability and porosity of Class II B core before and after water flooding

<table>
<thead>
<tr>
<th>Reservoir Layer Number</th>
<th>Permeability (×10^{-3}μm²)</th>
<th>Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before water drive</td>
<td>After water drive</td>
</tr>
<tr>
<td>GII 1</td>
<td>207.43</td>
<td>195.8</td>
</tr>
<tr>
<td>SI 7</td>
<td>452.32</td>
<td>501.52</td>
</tr>
<tr>
<td>GII 3</td>
<td>267.34</td>
<td>254.72</td>
</tr>
<tr>
<td>PII 5</td>
<td>776.69</td>
<td>825.34</td>
</tr>
</tbody>
</table>

The experiments show that the porosity value of PII and SI formations is found to increase during long-term water injection, with an average change rate of roughly 0.53 %. Due to the high permeability of the core in this formation, the degree of cementation is relatively loose, the mud content is low, and the particles in the pore space are transported by scouring, but the pore channels are not blocked, thus leading to a larger porosity value.

At permeability lower than 260×10^{-3}μm²², the permeability decreases by about 5% after water drive. The main reason is the high content of clay minerals in this layer, and particle transportation plugs the pore channel, resulting in permeability decrease.

After the reservoir characterization of the Lamadian Class II-B formation, the geological model was developed using Eclipse. The model is a three-layer homogeneous model. The permeability is 200×10^{-3}μm²², 400×10^{-3}μm²², and 600×10^{-3}μm²² from bottom to top. The specific model is shown in Figure 2 and Table 2.

3. Characterization of polydynamic drive in Class IIB oil reservoirs

Numerical simulation analyses were performed with different injection pressures at the same polymer concentration, dosage, and molecular weight, using a five-point method well set. Under the actual well history conditions, wells were defined and production data were attached for three formations. Water was injected at injection wellhead pressures of 7MPa, 8MPa, 9MPa, 10MPa, and 11MPa, and transconcentrated at water contents of 95%, 96%, 97%, and 98%. History fitting of the well history was performed to obtain the relationship between recovery rate, water content, and the oil production contribution of each layer under different initial conditions with the injection volume, respectively, as shown in Figures 3-6 and Table 3.
Figure 3. Variation of recovery rate with injection volume in polymer flooding driving under different injection pressures when the initial watercut is 95%

Figure 4. The variation of recovery with different injection pressures and injection volume at initial watercut of 95%

Figure 5. The variation of watercut with injection volume under different injection pressure when the initial watercut is 95%

Figure 6. The effect of oil production in each layer under different injection pressure

Table 3. The changes of parameter under different injection pressure

<table>
<thead>
<tr>
<th>different pressure (MPa)</th>
<th>Injection rate (PV/a)</th>
<th>Initial water content 95%(a)</th>
<th>Water content after polymerization 95%(a)</th>
<th>Productive response time (Month)</th>
<th>Minimum water content(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.15</td>
<td>5.42</td>
<td>5.96</td>
<td>6.48</td>
<td>87.92</td>
</tr>
<tr>
<td>8</td>
<td>0.18</td>
<td>4.67</td>
<td>5.16</td>
<td>5.88</td>
<td>88.06</td>
</tr>
<tr>
<td>9</td>
<td>0.19</td>
<td>4.32</td>
<td>4.84</td>
<td>5.04</td>
<td>88.39</td>
</tr>
<tr>
<td>10</td>
<td>0.21</td>
<td>3.92</td>
<td>4.33</td>
<td>4.92</td>
<td>88.36</td>
</tr>
<tr>
<td>11</td>
<td>0.28</td>
<td>3.09</td>
<td>3.41</td>
<td>3.84</td>
<td>88.45</td>
</tr>
</tbody>
</table>

Under the initial water content of 95%, the injection pressure of 7MPa has the greatest impact on the overall recovery rate. For the polydynamic recovery, the highest polydynamic recovery was achieved at 7 MPa pressure.

Figure 7. Permeability distribution in inresponse areas

Figure 8. Variation of recovery with injection volume under different injection pressure when the initial watercut is 96%
However, the polydynamic effect time becomes shorter with the increase of injection pressure, and the decrease of water content decreases (shown in figure 7). When the injection pressure increases, judging from the cumulative oil production of each layer, the cumulative oil production of the polydrive in the high-permeability layer decreases obviously, and the cumulative oil production in the middle and low permeability layer increases gradually; the contribution rate of the high-permeability layer to the final oil production decreases, and the contribution rate of the middle and low permeability layer increases; the change of the contribution rate of the oil production in each layer decreases, as shown in Figure 8.

The overall recovery is the highest when the initial water content is 96% and 97% and the injection pressure condition is 7MPa, and the polydynamic recovery decreases sequentially under the injection pressure conditions of 8MPa, 10MPa and 11MPa. The high permeability layer is highly exploited at an injection pressure of 8MPa, and the middle and low permeability layers can also be mobilized, but the high permeability layer is still the main oil layer. When the injection pressure is 10MPa, 11MPa, the contribution rate of the middle and low permeability layer rises, and it can be well utilized, and then the middle and low permeability layer is the main oil layer. The lower the water content decline the higher the polydynamic recovery. The production as well as the contribution rate of the middle and high medium and low permeability layers still satisfy the law when the initial water content is 95%, see Figure 9.

![Figure 9. Variation of recovery rate with injection volume under different injection pressure when the initial watercut is 98%](image)

When the initial water content is 98%, the recovery rate of polydynamic drive reaches the maximum value at 11MPa, because the production at this time mainly depends on the middle and low seepage layer. The polydynamic recovery time is characterized by accelerated recovery as the injection pressure increases, and at this time, the water content decrease increases with the increase of pressure.

4. Conclusion

(1) At the stage of injection polymerization when the initial water content is low, the low injection pressure can make the degree of mobilization of the remaining oil in the high-permeability layer in the Class IIIB oil reservoir increase. At this time, the high permeability layer has the highest contribution rate of oil production and the highest overall oil production; the contribution rate of each layer's oil production decreases with the increase of injection pressure under the condition of the same initial water content and increases with the increase of the contribution rate of the high permeability layer and the contribution rate of the low permeability layer. The change value of contribution rate shows a decreasing trend with the increase of injection pressure.

(2) For Class II-B oil reservoirs, lower injection pressure should be adopted in the early stage to fully utilize the residual oil in the high-permeability layer, and with the increase of water content, the injection pressure should be elevated to exploit the low-permeability layer, so as to give full play to the development potential of the oil reservoir.

(3) Under the same initial water content condition, with the increase of injection pressure, the injection effect time will be shortened, and the decrease of water content will be lowered, and the value of the lowest water content will be smaller.

References


