Research and Countermeasures of interlayer interference in main reservoir of ASP flooding

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Abstract. According to the recognition of the industrial production of ternary compound flooding in a development zone, it is believed that the development mode of ASP flooding can expand the sweep efficiency, improve the development effect of a class of oil layers and further improve the recovery. However, the contradiction between AⅠ33 and upper AⅠ1-32 layers is prominent, which leads to uneven oil production, rapid rise of water cut in the production wells, short time of low value period and so on. In order to reduce the interlayer contradiction, the interlayer contradiction coefficient is introduced to study the interlayer interference law in different development stages of ASP flooding in combination with reservoir type and vertical heterogeneity of an oilfield, and the technical countermeasures for layered system development are put forward. The straight joint development technology is adopted in some potential areas of an ltest area to exploit AⅠ3 reservoir, and the ideal development effect is achieved. The production degree of the reservoir is 88.3%, and the enhanced oil recovery is 26.23%.

Key words: vertical well productivity formula; interlayer contradiction coefficient; layered system development; straight joint.

1. Overview of research block
The main oil layers of AⅠ1～3 in Xings block are divided into seven sedimentary units, AⅠ1, AⅠ12, AⅠ21, AⅠ22, AⅠ23, AⅠ32 and AⅠ33 vertically. On the plane, the sand body deposition types are divided into distributary channel sand, distributary river sand, off surface reservoir and sandstone pinch out area. The original formation pressure is 11.36mpa, saturation pressure is 8.35mpa, original saturation pressure difference is 3.01mpa, surface crude oil density is 0.8517g/cm3, viscosity is 13.86mpa. S, formation crude oil viscosity is 7.4mpa. S. It has good combination relationship of source reservoir, reservoir and cap rock, and good structural trap conditions. The block is an anticline sandstone reservoir, which not only has a unified pressure system, but also has a unified oil-water contact surface. Bottom water and edge water are not active. It was put into operation in July 2014, and the injected water infiltrated along the large channel AⅠ3 in the blank water drive stage, with high water cut. After the injection of ternary liquid, due to the influence of bottom viscosity, all units were effectively produced, but the ratio of producing AⅠ3 reservoir was high, and that of AⅠ1～2 reservoir was relatively low.
According to the statistics of continuous profiles of 41 injection wells in Xings block, it can be seen that the production ratio of each main layer is uneven, which leads to the rapid rise of water cut and the decrease of injection production index in the late development period. In order to improve the oilfield development effect, it is necessary to study the interlayer interference law of the main oil layers in an oilfield, so as to provide technical guidance for tapping the potential of remaining oil in the future.

![Fig. 1 water absorption in different mining stages of each sedimentary unit](image)

2. The inter layer interference law of AⅠ1～3 oil layers in each slug stage of ASP flooding

2.1. Interlayer interference coefficient of vertical well multi-layer commingled production

In order to more intuitively describe the influence of interlayer contradiction on oilfield development, variable interlayer interference coefficient is introduced in combination with the characteristics of tertiary oil recovery development, which can objectively show the variation law of interlayer contradiction in AⅠ1～3 oil layers, and then study the influence of interlayer contradiction on production, so as to provide technical guidance for the sustainable development of oilfield in the future.

According to the reference [1], it is known that the interlayer interference coefficient of heterogeneous reservoir is related to single layer oil production index and oil production index when participating in combined production.

\[ \alpha = \frac{\sum J_{di}}{\sum J_{hi}} \]  

(1)

Among them: \( \alpha \) - inter layer interference coefficient, \( J_{di} \) - oil production index of layer I in single production, \( J_{hi} \) - oil production index of layer I participating in combined production.

Compound flooding in an oilfield is mainly to produce a kind of reservoir, and vertical well is often used. Reference [2] gives: when the production well is imperfect, the productivity calculation formula of vertical well is as follows:

\[ Q_0 = \frac{542.87 \frac{K_i h \Delta p}{\mu_i B_o}}{\ln(R_{w,0}/R_{w,c}) + S_c} \]  

(2)

When multi-layer commingled production, the productivity formula of interference coefficient between layers is derived:

\[ Q_0 = \frac{542.87(1 - \alpha) \sum \frac{K_i h \Delta p}{\mu_i B_o}}{\ln(R_{w,0}/R_{w,c}) + S_c} \]  

(3)

According to formula (3), the formula of interlayer variation coefficient is deduced.
\[ \alpha_i = 1 - Q \frac{\ln(R_i / R_{cm}) + S_i}{542.87 \sum_{\text{ev} \text{ wv} v \text{n} \text{hi} i \text{in} o i \text{o} \text{RR} \text{SQ} \text{Kh} p} \mu B} \]

(4)

Among them: - interlayer interference coefficient, - oil production of combined production, \( t \); - supply radius, \( m \); - wellbore effective radius, \( m \); - vertical well skin factor, dimensionless, - production pressure difference, MPa; - effective permeability of the first layer, \( \mu \) m\(^2\); - effective thickness of the layer, \( M \); - viscosity of the first layer, MPa; - Underground volume coefficient of the first layer. Mobility \( \lambda_e = K_e / \mu_e \)

2.2. interlayer interference law in each slug stage of ASP flooding

The production well spacing of a block \( s \) is 125m. According to well test data, the supply radius is 7.05m. Single wells with different permeability levels are selected as the analysis object, as shown in table 1. According to the literature [3], it can be seen that the ternary composite system with different mobility has different

Therefore, according to formula (4), the oil displacement efficiency is different

The statistics of interlayer interference in different injection slugs of ASP flooding under permeability gradient are as follows:

**Table 1.** Statistics of single well with different permeability difference

| JH  | permeability | permeability ratio | effective thickness |
|-----|--------------|--------------------|---------------------|
| X1  | 542          | 6.4                | 13.9                |
| X2  | 386          | 4.3                | 8.3                 |
| X3  | 398          | 3.5                | 9.0                 |
| X4  | 350          | 2.8                | 10.2                |

**Fig. 2** Variation Law of interlayer interference in different development stages

It can be seen from Figure 2 that: (1) the interlayer interference of multi-layer commingled production runs through the whole stage of oil well development. In the blank water flooding stage, the interlayer interference is large, which is mainly the fluid displacement of high permeability layer, and the low or no production ratio of medium and low permeability layer; the interlayer interference decreases gradually in the injection stage, and increases with the increase of water content. It is suggested to take measures or scheme adjustment in the later stage of ASP main slug to reduce or reduce
the interlayer interference. (2) For wells with small permeability difference, interlayer interference is small, and multi-layer commingled production can be achieved; in the later stage of ternary main slug, with the increase of water content, interlayer interference is intensified, so it is suggested to separate mining or implement layered transformation measures. (3) In the late stage of tertiary oil recovery, the interlayer interference is more serious with reservoir plugging, scaling and formation pressure changes.

2.3. measures to reduce interlayer interference and development effect.

2.3.1. Slicing system mining. In the process of industrial tertiary oil recovery in a development zone, there is a serious problem of interlayer contradiction in the production of a set of strata series in A Ⅰ 1 ~ 3 oil layer, so it is necessary to optimize the combination of strata. Considering the development and productivity scale of the first kind of reservoirs, the A Ⅰ 1 ~ 3 reservoirs can be divided into two sets of A Ⅰ 1 ～ 2 and A Ⅰ 3. In order to avoid the interference of A Ⅰ 3 Reservoir on A Ⅰ 1 ~ 2 oil layer, the suitable injection system can be selected for two sets of formation series, so as to improve the producing degree of A Ⅰ 1 ～ 3 oil layer, and then enhance the recovery factor. At the same time, the surface scale of ASP flooding preparation station and injection station can be reduced correspondingly.

2.3.2. Flat joint is adopted. The injection production well spacing of vertical well is 141m, and the designed injection production well spacing of two horizontal well groups is 200m. Among them, horizontal well group can ensure that high quality sand body is drilled; at the same time, horizontal well group is deployed in vertical structure contour line of fault edge to control remaining oil at fault edge.

2.3.3. Development effect. The field test of strong alkali ASP flooding for horizontal wells was carried out in unit A Ⅰ 33 of a l test area. As of December 2014, the staged enhanced oil recovery was 26.23 percentage points, which was 8.06 percentage points higher than that of vertical well ASP flooding. According to the test results, the ASP flooding development mode of A Ⅰ 3 oil layer with straight joint single production has expanded the oil drainage area and the production degree of the reservoir reached 88.3%, which improved the control degree and was conducive to mining the remaining oil at the top of thick oil layer. It has the characteristics of strong injection and production ability and light scale formation, and has the prospect of popularization in the first class reservoir of a development zone.

3. Conclusion

(1) According to the difference of producing status and recovery degree of different development layers in an oilfield, the development difficulties caused by interlayer contradictions are studied. The interlayer interference coefficient is introduced, and considering the influence of starting pressure gradient of heterogeneous reservoir, the vertical well productivity formula suitable for multi-layer combined production of heterogeneous reservoir is established, and the quantitative characterization relationship of interlayer interference coefficient is obtained.

(2) Combined with the reservoir heterogeneity of an oilfield, the variation law of interlayer interference in different development stages of ASP flooding is studied. The results show that the more serious the vertical heterogeneity is, the higher the interlayer interference degree is, and the more serious the interlayer contradiction is in the middle and late stage of tertiary oil recovery.

(3) Based on the above theoretical and practical development demonstration, the straight joint production mode is adopted in A Ⅰ 3 reservoir, which makes the production ratio of oil layer reach 88.3%, and the stage enhanced oil recovery rate is 26.23 percentage points, which is 8.06 percentage points higher than that of ASP flooding in A Ⅰ 1-3 vertical wells.
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