Research on water driving state evaluation and adjustment technology based on streamline

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Abstract: The general reservoir engineering method is the injection volume and production between the regular injection-production well pattern (five-point method, seven-point method, nine-point method, etc.), geometric average calculation or kh method. The accuracy of the calculation results is low and it is difficult to reflect the political enemy dynamics of reservoir heterogeneity and correctly evaluate the water characteristics of reservoir development and characteristics. Problems of water injection, distribution and well efficiency are not solved. We can intuitively understand the dynamic flow characteristics of fluid in underground by using the oil-first device technology, and combined with the basic principles of reservoir engineering, a method of hydraulic reservoir dynamic evaluation is proposed. Using this method, many variables such as drainage area of oil well, flooding velocity, flooding swept area between oil Wells can be evaluated quantitatively, and the development effect of oil field can be evaluated accurately. According to the analysis of the characteristics and factors of the distribution of the wire, the corresponding adjustment measures are taken to make the dominant wire weaker and the weak wire stronger, and finally achieve the purpose of improving the recovery rate.

Key words: water drive evaluation; Streamline numerical simulation; Development adjustment

1. Introduction

In order to accurately understand the law of underground fluid in water drive reservoir and improve the ultimate oil recovery, the evaluation model of water drive state was established on the basis of flow line numerical simulation technology, and the evaluation method of water drive state was proposed. On this basis, the corresponding adjustment and optimization technology was studied. Through the dynamic evaluation of flow line, the relationship between injection-production Wells can be evaluated quantitatively, which can guide the development and adjustment of reservoir. Using low cost adjustment techniques such as hierarchical subdivision recombination, dynamic deployment and well pattern thinning, good development results have been achieved.

2. Research on water driven state evaluation technology

2.1 Use oil - well distribution coefficient

Well Allocation Factors are the amount of fluid that a well receives (or contributes) to other Wells [1]. For an oil well, the oil well distribution coefficient is the relative contribution of the surrounding Wells to its liquid production, oil production and water production.

2.2 Establishment of water-driven state evaluation model

The traditional methods in reservoir engineering adopt regular well pattern design, and the production distribution is usually fixed geometric average method. The percolation area of the reservoir is limited in the specified well pattern unit, and the boundary is artificially fixed, which has great blindness and does not conform to the actual seepage condition of underground reservoir. Therefore, a new calculation method is proposed, which takes the oil well as the center and establishes the dynamic well pattern between the oil well and the surrounding water injection well by streamline simulation, and realizes the distribution coefficient calculation by the variable well pattern flow method. In this way, the distribution of the surrounding water injection well and the actual dynamic injection volume of the water injection well are taken into account. The streamline model is realized by the "five-step method". The first step is to clarify the cumulative production, cumulative injection and related production and water injection time of oil and water Wells. The second step marks the existence of injection-production relationship and establishes the historical injection-production flow line; The third step is to use the superposition analysis of production injection, new well, measures and monitoring data to evaluate the nature of streamlines and judge the strong, sub-strong and weak streamlines. The fourth step is to remove the weak streamlines such as short corresponding time, ineffective injection and production, weak flooding of new Wells and less cumulative production and cumulative injection, so as to dilute the complex streamline network, and analyze and calculate the streamline water flooding swept area. The fifth step is to describe the flooded area and the remaining oil-rich area by synthesizing the strength of various flow lines, corresponding time, injection and production efficiency, and cumulative production and cumulative injection.

2.3 Dynamic evaluation method

Since the established streamline model fully considers the heterogeneity of the reservoir, the irregular form of well pattern and the dynamic variation characteristics of injection-production Wells, it can realize the dynamic evaluation of the water drive characteristics of the reservoir, the water injection efficiency, the connectivity degree of injection-production Wells and the effectiveness of the well. Main evaluation indexes: (1) Cumulative water drive contribution oil production-cumulative water injection relationship curve; (2) The relation curve of current water drive contribution to oil production-current water injection; ③ Flow distribution diagram of well pattern unit. After selecting relevant parameters, the corresponding dynamic evaluation method can be established. Firstly, the cumulative deficit diagram of the oilfield or block is drawn to analyze the overall injection-production situation within the oilfield or block, including the injection-production ratio of the oilfield, formation pressure maintenance level, injected water loss, etc., so as to preliminarily evaluate the water flooding effect of the oilfield. Secondly, a typical well group is selected for detailed analysis, and the flow distribution diagram within the well pattern unit is drawn to evaluate the contribution of water flooding in a single well, as well as the connectivity between oil and water Wells and zones. Finally, the Wells with poor development effect (injection well and production well) are selected and corresponding adjustment schemes are formulated to improve the water flooding effect.

2.4 Quantify the relationship between injection-production Wells

For the whole oilfield, the key of water driving state evaluation should be specific to a single well. By calculating the distribution coefficient of each well in the well pattern unit, the connectivity degree of each well and the actual injection-production distribution can be described quantitatively. Similarly, the distribution coefficient of each phase fluid in a single well can be calculated to clarify the flow characteristics of each phase fluid in the reservoir, so as to guide the dynamic allocation of oil and water Wells [2].

The larger the distribution coefficient of the injection well corresponds to the well, the more water injected into the well. If the flow field is not adjusted in time, the premature flooding of the well will be caused.

As can be seen from the flow line distribution of the one-injection and two-production theoretical model, a large amount of injection water flows to well P2 from the injection well I1, and it can be seen from the pie chart of distribution coefficient that the water volume accounts for 82%, forming the main channeling channel. However, in the direction of well P1, the water volume is less, resulting in poor or even ineffective water flooding effect.

Similarly, if the distribution coefficient of an oil well to a certain injection well is larger, it indicates that the production volume contributed by the oil well is mainly from the direction of the injection well. According to the flow line distribution of well P2 in the two-injection and one-production theoretical model, it can be seen that the fluid production of the well mainly comes from the contribution of injection well I1, and the pie chart of distribution coefficient shows that the contribution rate reaches 86%.

3. Study on water drive adjustment and optimization technology

Based on the evaluation results of water driving state and the analysis of the characteristics and factors of flow line distribution, targeted adjustment measures are taken to change the dominant direction of underground fluid, increase the water drive intensity in the direction of weak flow line, improve the overall sweep coefficient, and improve the oilfield development effect.

3.1 Increase the sweep volume of injected water

The injection water in the early stage is used to advance evenly outward in the formation around the bottom hole. First, the injection water advances along the high permeability section with low seepage resistance. When the formation pressure in the higher permeability section increases, the injected water is forced into the very low permeability section, which increases the formation pressure in the low permeability section, reduces the pressure difference between the two, and effectively improves the swept volume of the injected water. See Figure 1.

$$q_o = \frac{2\pi k_o h_o \Delta p}{u_o\left(\ln\frac{r_e}{r_w} + S\right)}$$

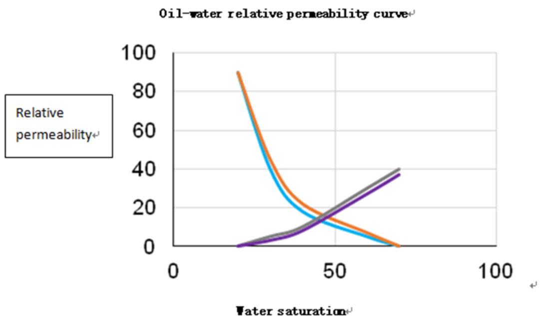

FIG. 1 Relation between injected water and volume

3.2 Dynamic vector allocation, optimize fixed streamline

The vector dynamic deployment is carried out by streamline numerical simulation. Combining with the results of streamline dynamic simulation, the following technical ideas of dynamic deployment are formulated for the purpose of improving the waterflood sweep sweep: (1) Based on the water-driven state evaluation model, the waterflood sweep sweep coefficient of a single well and the average sweep coefficient of a block are calculated. ② Optimization of water injection and liquid extraction. By comparing the sweep coefficient of single-well waterflooding with the average sweep coefficient of block waterflooding, if the sweep coefficient of single-well waterflooding is small, the water injection will be increased, and the oil well in the direction of weak flow line will be extracted, while the oil well in the direction of strong flow line will be shut down. On the contrary, the water injection should be reduced and combined with measures to control the rise of water in the well. ③ Use the optimized water injection to simulate the production effect after a certain period of time. Repeat the above steps until you optimize the best solution for improving the sweep efficiency of water drive.

3.3 Improve the injection-production well pattern and add new flow lines for potential exploitation

By perfecting the injection and production well pattern in the area where reserves are out of control, a new flow line is established to excavate the remaining oil. There are two ways to establish a new flow line: one is to deploy a new well, and the other is to adjust the flow field (including diversion or diversion). The main forms include: (1) deploying new Wells in uncontrolled well pattern areas or using old Wells to sidetrack and establish new injection-production well pattern; (2) The original strong flow line direction of the oil well after flooding, forming a row or cut water injection, change the original water drive direction; (3) The Wells with low production are diverted to form multi-directional water flooding, and the Wells with less cumulative water injection are diverted to pumping combined with the optimization of well pattern. (4) Combined with profile control, drive control, water sticking and other measures, weaken the strong streamline, promote the addition of other directions of the streamline.

3.4 Optimize injection-production well spacing and control plane streamline

Based on a clear understanding of reservoir heterogeneity and sedimentary microfacies, the spacing of injection-production Wells is changed to establish a reasonable displacement pressure gradient between the injection well and the well, and control the flow line is too strong or too weak, so as to maximize the development of the reservoir, improve the development effect and increase the water drive recovery factor. The main methods are as follows: (1) In the main river channel or the area with good physical properties, dilute the well pattern, widen the injection-production well spacing, reduce the displacement pressure gradient, and control the strong flow line. (2) In the lateral edge of the river channel or the area with poor physical property, well spacing should be filled, the distance between injection and production Wells should be reduced, and the displacement pressure gradient should be improved, so that appropriate flow lines can be established between oil and water Wells, and water injection can be effective. (3) In the joint area of the main river channel and the side edge, change the well pattern, water injection in the river channel, oil recovery in the side edge, combined with the measures of increasing injection and extraction, increase the flow line, expand the water drive sweep.

3.5 Subdivide and reorganize layers to improve three-dimensional streamline

Based on Darcy's formula, the seepage resistance term R 'is defined as pseudo seepage resistance coefficient, representing the oil-water two-phase seepage capacity varying with saturation. The larger the pseudo drag coefficient difference is, the more serious the interlayer interference is.

Aiming at injection Wells with prominent interzonal contradictions, the four-stage optimization method of layer subdivision and recombination is adopted to improve injection profile and balance interzonal operation. The four-stage optimization method of hierarchical subdivision and recombination is mainly as follows: the first step is to screen the pseudo-seepage resistance level difference. The pseudo-seepage resistance level difference limit in the adjustment zone is determined to be 5.5. According to the calculation method of the pseudo-seepage resistance coefficient, the pseudo-seepage resistance level difference of each scheme is calculated and the scheme with the pseudo-seepage resistance level difference less than 5.5 is screened out. In the second step, schemes with single control reserves less than 4.5×104t are excluded. The third step is to predict the development index and select the higher degree of recovery at the end of 15 years after the implementation of the program. The fourth step is to optimize the economic indicators, to optimize the scheme with the highest economic indicators. Through the stepwise screening of the four-stage optimization method, the hierarchical division scheme with small

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pseudo seepage resistance difference, a certain reserve base and the best development economic index is optimized.

4. Application Effect

The technology has been applied to W2 and G7 blocks in Jiangsu oilfield, and the recovery efficiency has been increased by 1.8% and 1.3% respectively, while the natural decline rate has decreased by 9.8% and 10.9%.

5. Cognition and Conclusion

(1) The conventional water drive reservoir evaluation usually considers the static geological model, which is unable to quantitatively evaluate the water drive state of the reservoir and the effect of the well. The reservoir dynamic evaluation method based on streamline simulation can realize the quantitative evaluation of the relationship between injection-production Wells, and can better guide the reservoir development adjustment.
(2) In the late stage of high water cut development, flow line adjustment and optimization is an important means to slow down production decline and further improve reservoir recovery efficiency. According to the different distribution characteristics of streamline, the corresponding streamline adjustment measures can effectively improve the development effect.

Reference

1. Wu Junlai. A new method for water drive reservoir dynamic evaluation based on 3D streamline simulation [J]. Journal of Xi 'an Shiyou University (Natural Science Edition),2011,26(2):43-47.
2. Wang Hongguang. Simulation study on characteristics of reservoir physical properties in high water cut period [J]. Acta Petrolei Sinica,2004,25(6):53-58.
3. Zhang Yingzhi. Practice and Understanding of Oilfield Development Adjustment in Sabei Development Zone of Daqing Oilfield: Petroleum Industry Press, 2012
4. Liao Guangzhi, Niu Jingang. Industrial Polymer Flooding Effects and Main Practices in Daqing Oilfield [J]. Daqing Petroleum Geology and Development, 2004:2-3
5. Wang Demin. Developing New Theory and Technology of Tertiary Oil Recovery to Ensure the Sustainable and Stable Development of Daqing Oilfield (Part 1) [J]. Daqing Petroleum Geology and Development, 2001:3-7
6. Liu Xiang'e. Collection of papers on overall water plugging and profile control technology in oilfield blocks [M]. Petroleum Industry Press. 1994