Research and Application of Precision Characterization Technology for Numerical Simulation of Side Bottom Water Reservoir

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Abstract. In this paper, according to the technical requirements of accurate characterization of middle and bottom water reservoir model in reservoir numerical simulation, three technical means have been used to solve the difficult problem that puzzles the technicians. The first is to establish a mixture of analytical and numerical water bodies to accurately characterize the side water energy and at the same time to reduce the effective grid to improve the operation speed of the model; the second is to solve the problem of oil reservoir simulation in long time and stratified injection wells. The application of these characteristic technologies has played a good technical support role in the high water cut development period.

1. Introduction
One of the difficulties in the numerical simulation of edge-bottom water reservoirs is how to describe the energy of edge water more accurately in line with the development characteristics of the reservoir itself. Firstly, the Petrel software is used to model the block geology. The Flogrid module of Eclipse software is used to describe the oil boundary and side-bottom water. In this process, several characteristic techniques are summarized to promote the potential of residual oil in reservoir during ultra-high water cut development period.

2. Study on Numerical Simulation Technology of Border Water Reservoir

2.1. Overview of Yangsanmu Oilfield
The Yangsanmu oilfield belongs to the normal pressure system, the saturation pressure is lower than the original formation pressure, the elastic energy is insufficient, there are broad side water and bottom water, and the oil thick gas is less. According to the reservoir characteristics, the driving mode is developed by combining artificial water flooding with natural water flooding.

2.2. Mixed water technology
Yangsanmu Oilfield is a heavy oil reservoir (the viscosity of underground crude oil is 113 mPa. s) and has active side water. Its function is the main energy in the development process. Active side bottom water is a double-edged sword in oil field development, especially heavy oil reservoir. On the one hand, it provides sufficient water drive energy; on the other hand, it is easy to form a pointing phenomenon in
the plane, which makes the production well flooded prematurely. Reduce reservoir recovery. The water body size of the bottom water reservoir is determined by numerical simulation method, and the three-dimensional numerical model of the bottom water reservoir is established. The numerical simulation of side water reservoir is carried out.

There is a reservoir with active side and bottom water. Because of the large side and bottom water area, if all the side and bottom water areas are included in the modeling range, the effective grid number of reservoir numerical simulation will be huge, and the simulation time will be greatly increased. In this case, in order to reduce the number of grid nodes and speed up the operation of the model, and at the same time reflect the energy characteristics of the side and bottom water of the reservoir, a mixed water body is established to understand the combination of body and numerical water body. The whole reservoir bottom water system is treated as two subsystems, one is the side water system (such as the light blue boundary in figure 1), which is the effective numerical water body in numerical simulation, and the other part establishes the analytical water body. Connect the analytical water with this part of the water (light blue in figure 2) rather than directly with the oil-bearing area. This can effectively improve the convergence of the model in the operation process. By using the FLOGRID module, the combination of numerical water body and analytical water body can not only effectively characterize the energy of edge and bottom water, but also reduce the number of grid nodes involved in the operation, so the speed of numerical simulation model operation is greatly improved.

![Figure 1. Initial Effective Grid](image1.png)

![Figure 2. Establishment of mixed water bodies](image2.png)

3. Accurate numerical simulation techniques for fine injection
In order to accurately simulate the history of oilfield water injection development and improve the reliability of reservoir utilization and the simulation results of residual oil stratification distribution, the method of "one well is more empty" is used in reservoir numerical simulation mode.

Applying the Eclipse software to establish the black oil model to carry out the stratified simulation of the sub-injection well using the method of "one well and more vacuity ", combining with the water absorption profile data of different periods, the injection quantity of each layer is fitted separately. First, the accuracy of water injection in each layer is greatly improved. By adjusting the single of the sub-injection well is realized by adjusting the single-layer injection of the sub-injection well, which not only reflects the mechanism of the sub-injection, but also can track the history of the sub-injection and improve the reliability of the simulation results; Second, the numerical simulation of stratified water injection improves the simulation accuracy of the extraction degree of each layer. Because of the large difference of cumulative water injection in the simulation layer, the extraction degree of each layer is obviously different. The prediction accuracy of vertical residual oil can be improved.

4. Precision Simulation and Characterization of Residual Oil Distribution
Difference of water-flooding degree in different parts of reservoir in ultra-high water-bearing period means great difference of oil-water distributary ability, which exacerbates the [4] of inter-layer, intra-layer and planar interference. Considering the significant nonlinear relationship between residual oil diversion capacity and water saturation, the concept —— dominant potential abundance suitable for
quantitative characterization of residual oil potential distribution in ultra-high water-bearing reservoirs are proposed. The quantitative characterization is realized by numerical simulation.

4.1. Dominant potential abundance reservoirs

In high water-bearing period, the conventional method to characterize residual oil reserves is to calculate the abundance of residual oil reserves or the abundance of recoverable reserves of residual oil. To some extent, this method reflects the remaining oil reserves per unit area of the block, and the abundance of the recoverable reserves of the remaining oil is simply not considered when the bound oil is not considered. However, the flow capacity of the remaining oil under the current development state is ignored. [3] is the formula for calculating the abundance of residual oil reserves and recoverable reserves of residual oil.

\[
\Omega_{o1} = \frac{100h\Phi S_o \rho_o}{B_o}
\]

\[
\Omega_{o2} = \frac{100h\Phi(S_o-S_{or})\rho_o}{B_o}
\]

Where \(\Omega_{o1}\) is Abundance of residual oil reserves, \(10^4\)t/km²; \(h\) is Effective reservoir thickness, m; \(\Phi\) is porosity; \(S_o\): Oil saturation; \(\rho_o\) is Surface crude oil density, t/m³; \(B_o\) is Crude oil volume facto, m³/m³; \(\Omega_{o2}\) is Abundance of recoverable reserves of residual oil, \(10^4\)t/km²; \(S_{or}\) is Residual oil saturation.

The difference between the abundance of residual oil reserves and the abundance of recoverable reserves of residual oil lies in the understanding of the saturation of residual oil. The definitions of the two indicators are treated as follows, Orde R1=So, R2=Sor. Coefficient a1 and a2 linear relationship with oil saturation. In fact, the distribution capacity of crude oil and water saturation are nonlinear. According to the literature [11], the relationship between oil-water relative permeability ratio and oil saturation can be expressed as:

\[
\lg \frac{K_{ro}}{K_{rw}} = a + bS_w
\]

In the formula: \(K_{ro}\) is elative permeability of oil; \(K_{rw}\) is Relative permeability of oil; a and b respectively \(\lg \frac{K_{ro}}{K_{rw}}\) and \(S_w\) Intercept and slope of relation curve. Define dominant potential abundance [3] as:

\[
\Omega_{o3} = \frac{100Rh\Phi\rho_o}{B_o}
\]

\[
R = \frac{K_{ro}\mu_w}{K_{rw}\mu_o}S_o
\]

In the formula: \(\Omega_{o3}\) is Advantage potential abundance, \(10^4\)t/km²; \(R\) is Abundance coefficient of dominant potential; \(\mu_w\) is Formation water viscosity, mPa. s; \(\mu_o\) is Formation crude oil viscosity, mPa. s.

The abundance of dominant potential can more accurately reflect the real residual oil dominant field than the abundance of residual oil reserves and the abundance of recoverable reserves of residual oil, which can not only represent the size of recoverable reserves of residual oil. It can also indicate the difference of oil-water distributary reservoir during high water-bearing period.

4.2. Numerical simulation of dominant potential abundances

The abundance distribution of recoverable reserves and distribution of residual oil recoverable reserves in this layer are quantitatively characterized by numerical simulation. When the residual oil recoverable reserves abundance is used to describe the residual oil distribution, the recoverable reserves abundance of A, C, two points B relatively high, but all three points belong to the dominant position of residual oil. When the dominant potential abundance is used to describe the distribution of residual oil, the dominant
level of residual oil is clear. The comparison is not difficult to find that the residual oil potential abundance of B point is not as good as that of A point, but it has high movable oil saturation, which is also worthy of consideration. At A point, the abundance of recoverable reserves of residual oil is high, but it can be seen from the dominant potential abundance map that the movable oil saturation is relatively low, which can be used as the potential area, but it is difficult to produce the extract. since the dominant potential abundance takes into account both the residual oil abundance and the shunt capacity of the remaining oil, the description of the residual oil distribution by the dominant potential abundance has the advantage that the residual recoverable reserve abundance can not be replaced, and can guide the adjustment of the injection and mining well network more accurately and scientifically.

Example verification: five wells have been put into production in A well area since 2015, Average daily production of 5.6 tons, Daily liquid 10, All are low speed production wells. Hole 1067-4 was put into production in A well area in April 2019, Initial production of 4.7 tons, 9.4 square meters, The combined water content is 50. B well area 2 wells, the liquid production is above 20 square meters, Average daily output of 8 tons, the average water cut is 60%.

Figure 3. Abundance of remaining oil reserves  Figure 4. Potential of Surplus Oil

5. Conclusions
On the basis of the numerical simulation model of fine water drive, the numerical simulation study of edge water reservoir is carried out. Through the sensitivity analysis and optimization comparison of multiple parameters, the adjusted conductivity is selected for historical fitting. Effectively improve the fitting accuracy and improve the efficiency of fitting. The establishment and application of fine numerical simulation model of side water drive is of great significance to the reservoir which has entered the ultra-high water-bearing period.

Applying the Eclipse software to establish the black oil model to carry out the stratified simulation of the sub-injection well with the method of "one well and more empty ", which can effectively improve the reliability of the stratified use condition and the simulation results of the remaining oil. Effectively solve the problem of fine stratified water injection simulation in ultra-high water-bearing period.

The numerical simulation method is used to realize the quantitative characterization of the dominant potential abundance, and the two characterization methods of the residual oil recoverable reserve abundance and the residual oil distribution are fully combined to effectively highlight the dominant potential position of the residual oil. The potential direction of residual oil is defined.

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