Research on Methods of Improving Historical Fitting Accuracy in Transitional Zone Area

Jiahui Li
Geological Brigade of the Second Oil Production Plant of Daqing Oilfield Co., Ltd., Daqing, China
lijiahui@petrochina.com.cn

Abstract. The transitional zone of X Oilfield has a large development area, many oil and water wells, and the historical fitting accuracy is relatively low. The historical fitting accuracy of single wells in the whole area is only 62%. With the needs of oilfield development, it is inevitable to improve the historical fitting accuracy in the transitional zone. Therefore, this paper studies the method of improving the historical fitting accuracy in the 350m transitional zone of X Oilfield, and the historical fitting accuracy has increased by 13 percentage points.

Keywords: Transition zone; History fitting; High pressure physical properties; water body.

1. The raising of questions
X oilfield transitional zone still has great potential because of low well pattern density and relatively low recovery degree. However, the historical fitting accuracy of the whole numerical simulation in the transitional zone is low, and the average single well fitting accuracy is only 62%, far below the average level. The main reason is that the historical fitting method of pure oil area in X Oilfield is not suitable in the transitional zone, which is characterized by low comprehensive water cut and low pressure of fitting. Analyze the main reasons: First, the high-pressure physical parameters of the pure oil area for application are not suitable for the transition zone area; Second, the special relative permeability curve in the transition zone is not used; Third, no water body is added to simulate the transitional zone, which leads to low fitting pressure.

2. Method for improving historical fit accuracy in transitional zone area

2.1. Application of relative permeability curve in transition zone area
The relative permeability curve is a key parameter that affects the comprehensive water cut of historical fitting. Each block and strata have different relative permeability curves. According to the application methods of relative permeability curves in recent years, combined with the sedimentary characteristics of transitional zone areas, the application template of relative permeability curves in transitional zone areas is established: According to the first-class reservoir (YⅠ1-4), the second-class reservoir (XⅡ7-12, Y15-7, YⅡ2-3) and the third-class reservoir, in combination with five types of sand bodies, i.e., river channel, main body, non-main body, off-table and mudstone, 15 relative permeability curves are applied.
In the choice of relative seepage rate curve, due to the difference of physical properties between transition zone and pure oil area. Therefore, the normalized oil-water relative permeability curve of coring wells in the whole plant is applied, and the relationship between relative permeability curve and water saturation and recovery degree in percolation mechanics is combined. According to the permeability grade of different oil layers, the most suitable relative permeability curve in the transitional zone of X Oilfield is selected for historical fitting (see Figure 1).

In addition to selecting suitable relative permeability curves, there are some cases where the initial water cut of some wells is higher than 0 in the transitional zone. In this case, it is necessary to specify a relative permeability curve for the well, and then adjust the relative permeability value of the initial saturation of the relative permeability curve according to the initial water cut, and carry out a certain degree of trial calculation until the fitting requirements are met (see Figure 2).

Figure 1. X6- check the relative permeability curve of well 48

Figure 2. Setting of single well relative permeability curve with initial water cut not 0

2.2. Setting of high-pressure physical parameters of fluid in transitional zone
The transitional zone oil layer is controlled by anticline structure, and gradually enters the water layer from bottom to top from one zone to four zones. Because the transitional zone area is close to the oil-water boundary line, the setting of fluid high-pressure physical properties is quite different from that of
pure oil zone, which is mainly manifested in the deep buried depth of reservoir and high viscosity of formation crude oil. Therefore, in the process of reservoir numerical simulation, PVT parameters should be personalized according to block physical properties.

In the process of reservoir numerical simulation, oil viscosity, as an important physical parameter, affects the fitting of oil production and water cut. Due to the lack of new physical property data in transition zone, if the physical property parameters in pure oil area are used for historical fitting of numerical simulation, the water cut will rise slowly and the fitting result will be poor. Therefore, according to the rising law of water cut, the viscosity of crude oil in transitional zone is 9~10 MPa·s.

2.3. Application of water body
The setting of water body is necessary for reservoir numerical simulation in oil-water transition zone, and the first thing to consider is the size of water body.

1. Determination of water body size
According to the geological structure characteristics of the transition zone of X Oilfield, the water invasion is closely related to the water supply area of this block. The method of determining water body size in edge water reservoir can be applied to reservoir engineering method.

According to the principle of material balance, the reservoir engineering method uses the data of reservoir fluid, rock properties and production performance to solve the water body size by linearization. When the pressure is P, the volume of formation crude oil is equal to the sum of residual oil volume, elastic expansion volume of rock and irreducible water, cumulative water injection and edge water invasion, and the material balance equation is as follows

\[ N_p B_o + W_p B_w = (N_o B_{oi} C_o + N_w B_{wi} C_w) \Delta P + W_i + W_e \]  

Type, \( B \) for water invasion coefficient, \( B = 2\pi \phi \delta \varphi C_i r_o^2 \); Volume coefficient of crude oil and formation water in \( B_o \) and \( B_w \) formations; \( B_{oi} \), \( B_{wi} \) original formation crude oil and original formation water volume coefficient; \( C_o \), \( C_w \) and \( C \) are crude oil, formation water and comprehensive compressibility, \( \text{MPa}^{-1} \); Geological reserves of crude oil \( N_o \), \( 10^4 \) m\(^3\); Accumulated oil production of \( N_p \), \( 10^4 \) m\(^3\); \( W_p \), \( W_i \) cumulative water production and injection, \( 10^4 \) m\(^3\).

Make \( Y = (N_p B_o + W_p B_w - W_i) / \Delta P \), \( X = W_i / \Delta P \), \( C = N_o B_{oi} C_o + N_w B_{wi} C_w \)

When the linear relation \( Y = C + X \) is satisfied, it is the appropriate water body size, which can be expressed as,

\[ W = r_{oi}^2 \frac{H}{h_e} - 1 \]  

In the formula, \( w \) water volume multiple; Dimensionless water radius: \( r_{oi} = r_o / r_e \); Average effective thickness of H water layer, m; Average effective thickness of \( h_e \) reservoir, m;

2. Establishment of water body model
In ECLIPSE numerical simulation software, there are two commonly used water types, namely numerical water and analytical water. Numerical water is similar to virtual well, which is defined by defining redundant grid blocks or grids below oil-water interface as water grids. However, its disadvantage is that when there is no injection in the reservoir, water will be injected into the reservoir from the water area, and the reservoir pressure will drop until it reaches equilibrium. This will increase the error of numerical simulation, so we choose to analyze the water body when building the water body model. FK water body is commonly used in analytic water body. FK water can effectively represent a wide range of water types. Select the water model as analytical water body by using AQUDIM keyword
under RUNSPEC; Use AQUFET keyword to set an independent water body connected to one surface of the reservoir; Keyword AQUANCON specifies the connection parameters of water body.

![Setting of water body model](image)

**Figure 3.** Setting of water body model

Among many blocks in the transition zone, the western transition zone of Sartu has a large contact area with water and is obviously affected by water because of its small block area and strip shape. Therefore, the water model is widely used in the western transition zone of Sartu.

### 3. Application and effect

#### 3.1. Establishment of model

X oilfield has a development area of 25.70km² in the transition zone of 350m, and its geological reserves are 5566.00×10⁴t, accounting for 43.20% of the total geological reserves in the transition zone. In 1970, the four-point well pattern with a well spacing of 350m was put into development. It has experienced one infill adjustment of one to three zones, comprehensive tapping of potential of four zones and tertiary oil recovery in one local well area. At present, there are 730 oil and water wells, including 652 water flooding wells and 78 tertiary oil recovery wells, with a recovery rate of 43.99%. In order to ensure the speed of numerical simulation, the block north of Row 31 of X6 Zone in the transition zone of 350m is selected as the test area for modeling and numerical simulation work area. There are 406 oil and water wells in the study area, with water cut of 96.31% at present.

According to the situation of the block, a three-dimensional geological model based on subdivision of sedimentary units in the vertical direction and sedimentary microfacies in the plane is established. A total of 78 simulation layers are divided in the vertical direction, and the phase constraint attribute modeling method is carried out by Petrel software. The corner grid is adopted, with a grid step length of 30m. On the plane, 105 grids are divided in the east-west direction, 132 grids in the north-south direction and 1081080 geological model summary points. According to the actual production system of the block, the working mode of constant daily fluid production of oil wells and constant pressure of water injection wells is adopted.
3.2. **Application effect**

By adjusting PVT attribute parameters and relative permeability curves, and adding edge water to the edges of the four strips of the model, the volume coefficient of edge water is calculated to be 4 through formula operation. The fitting accuracy of cumulative oil production and water cut in the whole region is 1.86% and 1.71%, respectively, and the fitting rate of single well reaches 75%, increasing by 13 percentage points.

![Figure 4](image1.png)

**Figure 4.** Fitting curve of water cut and cumulative oil production in the whole region

![Figure 5](image2.png)

**Figure 5.** Comparison of water cut and daily oil production curves of well X5-1-B65

![Figure 6](image3.png)

**Figure 6.** Comparison of water cut and daily oil production curves of well X6-2-B63
4. Conclusion and understanding
1. Transition zone is not suitable for high-pressure physical parameters in pure oil zone, so PVT parameters in numerical simulation should be set according to buried depth conditions and reservoir viscosity in transition zone.
2. It is necessary to select the relative permeability curve suitable for the transitional zone according to the sedimentary microfacies and permeability grade in order to improve the accuracy of historical fitting.
3. The introduction of water body has great influence on the fitting of water cut in transitional zone. It is more appropriate to use FK to analyze water body.
4. The setting of high-pressure physical properties, the selection of suitable relative permeability curves and the reasonable addition of water bodies are the keys to improve the accuracy of historical fitting in transitional zone areas. The application of this method can obviously improve the historical fitting accuracy of numerical simulation. The historical fitting results of the 350m area in the transition zone of X Oilfield show that the final single well fitting rate is increased by 13 percentage points.

5. References
[1] Han Dakuang. Basis of reservoir numerical simulation. Beijing: Petroleum Industry Press, 1993.
[2] Li Xingxun. Basic principles of rational and efficient development of edge and bottom water reservoirs. Petroleum Geology of Xinjiang, 1998.
[3] Qin Tongluo, Li Yan, Chen Yuanqian. Practical reservoir engineering method [M]. Beijing: Petroleum Industry Press, 1989.
[4] Liao Yuntao. Regression formula for calculating natural water invasion [J]. Petroleum Exploration and Development, 1990, 17 (3): 71-75.