Numerical Simulation of Remaining Oil Distribution Based on Oil Field Data Analysis

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Abstract. In view of the narrow data source range of traditional residual oil distribution numerical simulation, a numerical simulation method of residual oil distribution based on oilfield data analysis is studied. Firstly, the principle of big data was put forward to complete the collection and analysis of oilfield information. Then, the three-dimensional simulation model of oilfield was designed by haiyan software. Then, the grid structure of oilfield saturation setting model was divided. By comparing the range of data sources, it is verified that the proposed numerical simulation method can effectively extend the range of data sources and improve the accuracy of numerical simulation.

Keywords: Data analysis · Residual oil distribution · Numerical simulation · Data fitting

1 Introduction

With the deepening of oilfield development, most of China's oilfields, especially the eastern onshore oilfields, have gradually stepped into the late stage of high water cut development [1, 2]. In the face of the shortage of reserves and national energy in the new area of the old oilfield, how to improve oil recovery and reverse the passive situation of oilfield development in the high water cut period has become a serious issue for oilfield development workers. A large number of studies have shown that the average recovery rate of secondary oil recovery is about 35%, and it is estimated that about 20% of movable oil is still not injected into water wave due to the heterogeneity of the reservoir, and this part of movable oil can be exploited by deepening reservoir understanding, changing oil production technology and other ways [3]. Therefore, in the stage of high water cut development, it is of great significance to carry out fine reservoir description and remaining oil distribution research, so as to provide technical support for the potential tapping adjustment of old oilfields. In order to solve the problems existing in the actual development of some oilfields, such as many oil-bearing

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series, small thickness of single oil layer, poor physical properties, low reserve abundance and different oil well productivity, further tap the potential of remaining oil, improve the level of reservoir development, deepen the understanding of reservoir geology, and design the numerical simulation method of remaining oil distribution based on the analysis of oilfield data.

In the study of oil field distribution, numerical simulation combined with oil data analysis can effectively improve the accuracy of distribution research results, improve the effect of oil field development, and further improve the recovery factor. The so-called oilfield data analysis refers to the process of using appropriate statistical analysis methods to analyze a large amount of collected oilfield data, extract useful information, form conclusions, and conduct detailed research and summary on the data [4]. This technique provides a basis for numerical simulation and ensures the validity of distribution results. It improves the precision of numerical simulation and provides technical support for the future development of petroleum industry.

2 Numerical Simulation Method of Remaining Oil Distribution Based on Oil Field Data Analysis

According to the past research on the distribution data of the remaining oil, in order to ensure that the simulation method of the remaining oil distribution can get more accurate simulation results, the oilfield data analysis technology is introduced into the method design.

2.1 Oil Field Data Collection and Analysis

Big data technology is used to obtain oilfield data. Oilfield data is the original data collected by oilfield enterprises for geological research and scientific management. It is a form of independent data storage and management for the original data collected from the source [6]. These data are one of the most important embodiment of oil field. Through digital transformation, data is transformed into the most important information, which is essentially the basic oil and gas materials. In order to ensure the accuracy and universality of the data source, the oil field data source is set as shown in Fig. 1 below:

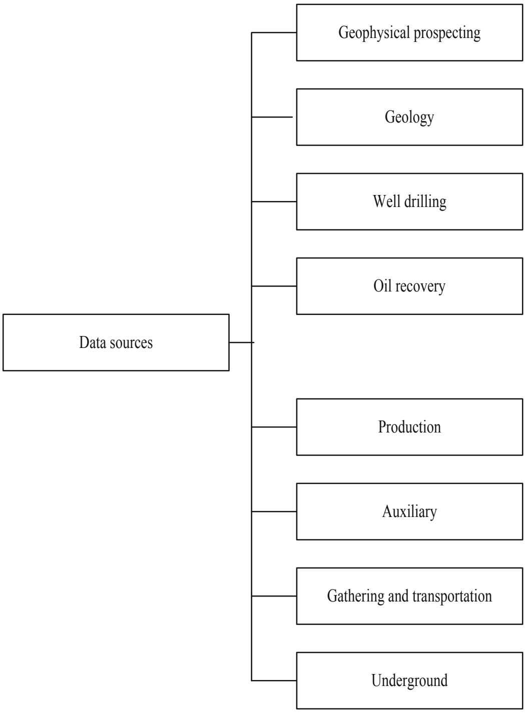


Fig. 1. Oil data sources

Through the above process to complete the acquisition of oilfield data. The data results are stored in the database and analyzed. In the process of analysis, using big data technology, in different types of data, cross analysis to obtain data value, promote the design of numerical simulation method. In the construction of numerical simulation method, flexible data analysis ability from multiple angles is needed. Taking the numerical model as an example, not only the development situation changes of different oil fields and different development units, but also the development situation changes of different types of reservoirs, different displacement modes, different recovery degrees and other angles, as well as the impact analysis of social factors and natural factors, etc. The results are applied to the numerical simulation. To ensure the design sequence, the design process is shown in Fig. 2 below:

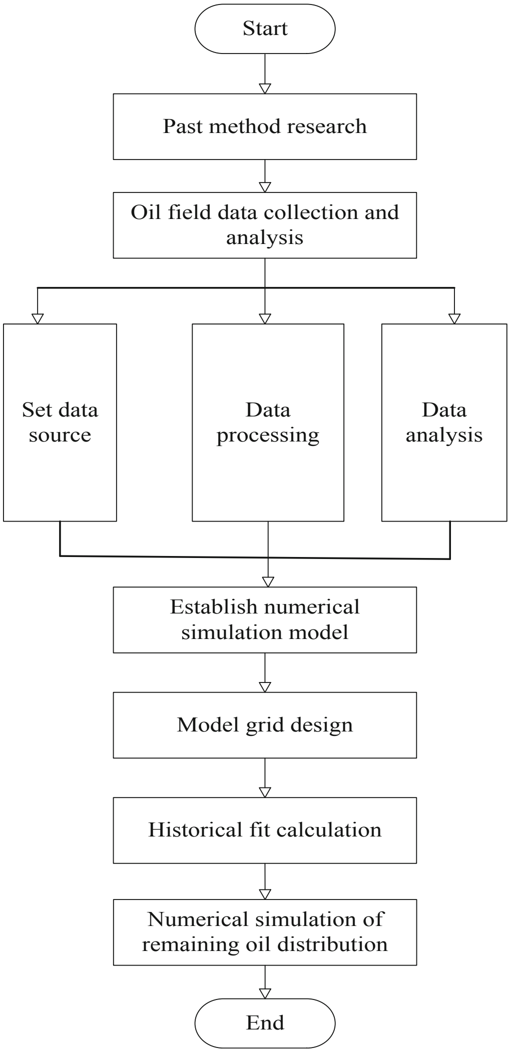


Fig. 2. Design flow of numerical simulation method for remaining oil distribution

Use the above process to complete the design process of numerical simulation method, introduce big data technology in the field data analysis [5], expand the data source, improve the accuracy of data simulation analysis results, and ensure the effectiveness of the method design.

2.2 Establish Numerical Simulation Model

Based on the above data collection and analysis results, a numerical simulation model is built. According to the interface provided by petrel software, the 3D fine geological model is transformed into the geological model required by VIP numerical simulation software. The specific model image is as follows (Figs 3 and 4).

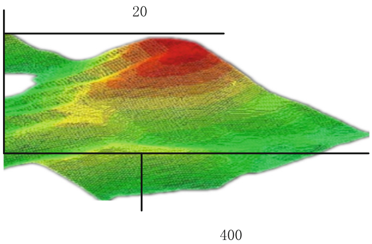


Fig. 3. 3D model of oil field

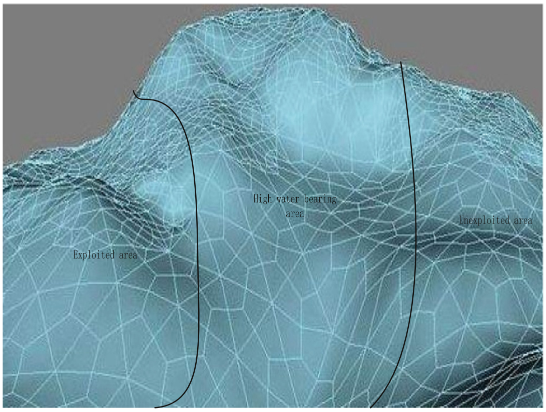


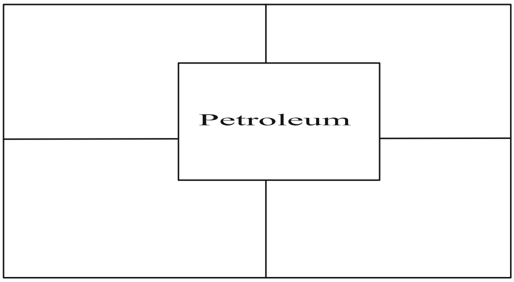
Fig. 4. Oilfield geological model

In this data simulation, it mainly includes: reservoir geological parameters [7], including reservoir depth, sand thickness, effective thickness, permeability, porosity, etc.; physical property constant of balance area, including original reservoir pressure, original saturation pressure, oil-water interface and capillary pressure corresponding to the interface, etc. special core analysis data [8], including oil-water and gas-water relative permeability curve, rock compression coefficient; PVT data of high pressure physical properties of crude oil, including curves of oil phase volume coefficient, oil phase compression coefficient, oil porosity and other changes with pressure; physical properties constant of formation water, including water porosity, density, compression coefficient, etc.; dynamic data, including well location, well type, completion data, production and injection volume, pressure, etc.

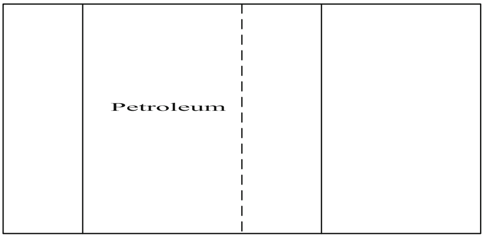
The parameters involved in the numerical simulation include matrix porosity, matrix permeability, matrix initial oil saturation, effective thickness, fracture porosity, fracture permeability and so on. By using the geological parameters of the corresponding intervals of each well point in the study area and using petrel software [9], the data field of the actual reservoir geological parameters is established. Based on the data field, the model grid is divided and data simulation is realized.

2.3 Model Grid Design

Using the model set above, the mesh generation is completed. It is assumed that there is a residual oil accumulation area in the reservoir, which is square in shape and relatively high in oil saturation. If the square area is taken as the plane size of the numerical simulation grid, the following situation may occur after grid division, that is, no complete grid falls on the remaining oil area. As the saturation displayed in the grid is the average value of the grid, the saturation on the remaining oil area is allocated to four or two adjacent grids, the simulated remaining oil will be dispersed, and the oil saturation will drop. Even in the simulation results, it is difficult to see that the oil saturation is relatively high for the enriched remaining oil, and the shape and center position of the simulated remaining oil will also change. Obviously, this kind of grid division is not consistent with the actual situation. If a production well is designed to exploit the remaining oil on this basis, it may lead to class failure (Fig. 5).



(a) Remaining oil is divided into 4 grids



(b) Remaining oil is divided into 2 grids

Fig. 5. Schematic diagram of remaining oil being meshed

The above method has poor control power. In order to improve the control power of the grid on the model, at least one grid is set at the center of the enriched remaining oil, then the area and center position of the enriched remaining oil can be determined, and the area and oil saturation of the remaining oil can also be controlled. The larger the area of remaining oil enrichment is, the more grid control will be obtained under this grid size, and the better the control result will be; however, if the grid size is too large, the remaining oil enrichment will not get more grid control, and the remaining oil in numerical simulation will be dispersed, and the oil saturation will decline, so that it is difficult to find the existence of the remaining oil enrichment. Conventional numerical simulation of remaining oil area requires that the grid size should meet the requirements of no less than three grid nodes between two well points. If the number of grid junctions between two well points is less than three, the accuracy of calculation and the characterization of oil saturation will be affected. Therefore, the total number of grid nodes in the model is 800000, including 400 in the east-west direction (X direction), single grid step of 30 m, 100 in the north-south direction (Y direction), and single grid step of 30 m. There are 20 layers vertically. The total number of nodes is 400 * 100 * 20 = 800000. According to the operation speed of the existing computer and the effective area of the actual simulation, the fault is selected as the closed boundary, and the invalid area is cut as the simulation area. The number of effective grids in the simulation area is 400000 to ensure the normal operation of the model.

2.4 Historical Fit Calculation

As the geological model changes with the development stage, the differences of geological models in different stages need to be considered, so the stage fitting method is used in the fitting. Due to the limitation of data, the change of infiltration curve is not considered in this simulation. The fitting of the comprehensive indicators of the unit in each stage is as follows. On this basis, a better dynamic fitting is carried out. Historical fitting is to use the actual dynamic data to verify the geological model [10], so that the simulated dynamic production data is basically consistent with the actual data. When fitting the production data of the model, it takes one month as a time point, and adopts the fixed oil production mode, which is fitted from four aspects: fault block index, well group index and single well index. The difference equations of the model are solved by the full implicit method. The maximum time step of the iteration is 10, and the maximum number of iterations is 100. In this way, the convergence of the iterative calculation and the stability of the model are guaranteed. The specific fitting results are as follows (Tables 1 and 2).

Table 1. Reserve matching data of numerical model reservoir (excluding fuzzy layer)

The layer number		XI	XII	XIII	XIV	Total
Modified reserves (10^4t)		170.50	259.70	225.0	58.0	713.2
Fitting	Matrix reserves (10^4t)	141.50	228.25	201.50	52.0	623.25
	Fractured reserves (10^4t)	27.0	28.0	20.20	3.60	78.8
	Total (10^4t)	339	515.95	446.7	113.6	1415.25
	Percentage of fractured reserves (%)	16.0	11.0	9.0	6.5	10.625
Error (%)		−1.0	−1.5	−1.2	−5.0	2.175

Table 2. Reserve matching data of numerical model reservoir (including fuzzy layer)

The layer number		XI	XII	XIII	XIV	Total
Modified reserves (10^4t)		170.50	259.70	225.0	58.0	713.2
Fitting	Matrix reserves (10^4t)	150.50	235.25	201.50	52.0	639.25
	Fractured reserves (10^4t)	28.0	28.0	20.20	3.60	9.8
	Total (10^4t)	349	522.95	446.7	113.6	1432.25
	Percentage of fractured reserves (%)	16.0	11.0	9.0	6.5	10.625
Error (%)		5.0	2.0	−1	−2	1

The actual reserves of this area after the reserves are changed are 14 million tons. The calculated reserves of the model are compared by stratified reserves. As the actual calculated reserves do not include fuzzy layers, 30 stratified reserves are deducted, and the error is controlled between 5%, the overall reserves are relatively small, with a total error of 2%, in which the fracture reserves account for 10.0% of the total reserves, the stratification ratio is between 6.0% and 12.0%, and the vertical distribution of fractures from top to bottom becomes poor. According to the fitting results of the overall reserves, the geological model has high accuracy and can meet the needs of numerical simulation.

2.5 Numerical Simulation of Remaining Oil Distribution

Through the above fitting data combined with the remaining oil distribution standard to complete the design of data simulation. According to the current classification standards of remaining oil in domestic major oil fields, the remaining oil in the model is divided into the following five types: structural factor control type, interlayer interference type, incomplete injection production type, single well drilling type and water flooded type. Among them, water flooded type is the most, accounting for 38.0%, followed by structural factor control type, accounting for 27.5%. This is because of the development of underwater distributary channels in this area, and the distribution of oil fields is mostly positive rhythm and compound rhythm. The general trend is that the bottom is thick and the top is fine, and the physical properties are good and bad. The coarse-grained sandstone in the lower part has good physical properties, and it can see water quickly after waterflooding development, which is the main part that causes the injection water to rush rapidly and forms the short-circuit cycle of injection production. But the physical properties of the upper and middle parts are poor, forming more remaining oil. The specific distribution of remaining reserves is shown below (Table 3).

Table 3. Distribution of remaining recoverable reserves

Type of remaining oil	Remaining recoverable amount/10^4t	Proportion/%
Structural factor control type	8.60	27.5
Interlayer interference type	3.65	11.5
Incomplete injection production	4.25	14.0
Single well drilling type	2.90	9.0
Watered out type	12.50	38.0
Total	31.9	100

According to the category distribution in the above table, combined with the data simulation model, the data model is displayed in the form of formula, and the specific formula is as follows.

$$A_{t-o} = A_{\mathrm{i}}, B_{t-o} = B_{\mathrm{i}} \tag{1}$$

$$\frac{\partial A}{\partial n} = 0 \tag{2}$$

$$\frac{\partial}{\partial x}\left(\frac{A * A_{\mathrm{i}}}{\partial} * \frac{\partial A}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{A * A_{\mathrm{i}}}{\partial} * \frac{\partial A}{\partial y}\right) + \partial = \frac{\partial B_{\mathrm{i}}}{\partial i} \tag{3}$$

In the above formula, formula (1) and formula (2) represent the boundary conditions of the numerical simulation model, A is the result of grid transformation, B is the final result of grid division, $_{\mathrm{i}}$ is the set grid number, n is the cell boundary, x, y are the coordinates of cells, and ∂ is the distribution coefficient of remaining oil. Through the above formula to complete the research on the distribution of remaining oil, the actual oil field data is brought into the formula, and the design method of this paper is used to complete the research on the distribution of remaining oil in the oil field. According to the prediction results of data simulation, the actual oil volume is exploited to improve the exploitation and utilization efficiency of the remaining oil volume. In order to verify the effectiveness of the numerical simulation method of remaining oil distribution based on the analysis of oil field data, the experimental links are set up to obtain the research results.

3 Experimental Results and Analysis

In order to verify the validity of the numerical simulation method of remaining oil distribution based on the analysis of oil field data designed in this paper, a comparative test is set up to complete the research on the difference between the original numerical simulation method and it. In this experiment, the comparative amount is set as the range of data source of numerical simulation.

3.1 Experiment Preparation Process

In order to ensure the effectiveness of the experiment, the oil field in the same area is selected to complete the data simulation research, and the numerical simulation method designed in this paper and the original numerical simulation method are used to carry out the simulation. In order to ensure the order and consistency of the experimental process, the experimental equipment and samples are set as follows (Table 4).

Table 4. Setting of experimental equipment

Direction of use	Equipment	Parameter
Model processing software	Petrel	
Data storage	Data base	SQL2013
Image processing software	Remote sensing image processing system	
Analog computation	CPU	Intel
Comprehensive treatment	Operating platform	Microsoft

Using this equipment to complete the numerical simulation process, and set its range sample, compare the original method and the data source of this method numerical simulation to complete the experiment process, the data sample is as follows (Table 5).

Table 5. Experimental samples

Number	Sample
Y1	Geophysical prospecting
Y2	Geology
Y3	Well drilling
Y4	Oil recovery
Y5	Production

The above samples are used to complete the experiment, and the experimental results are represented by images, based on which the experimental results are analyzed.

3.2 Simulation Experiment Results and Analysis

Set the experimental results of this method as the experimental group, the results of the original method as the control group. The specific experimental results are as follows:

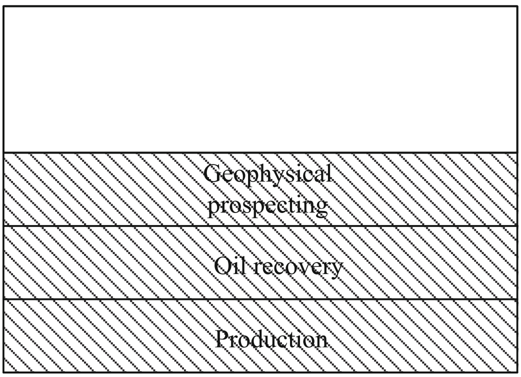


Fig. 6. Original method data source

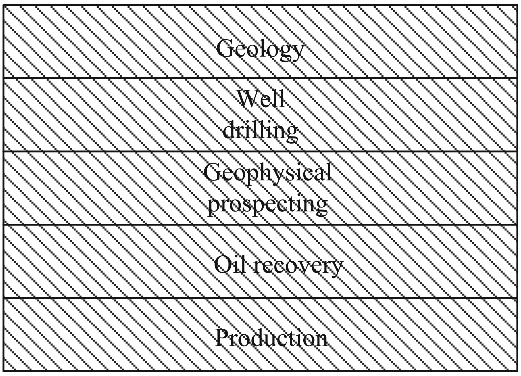


Fig. 7. Data sources of this method

In the above experimental results, the overlapped part between the original method and the data source range of the method in this paper and the experimental sample is shown in shadow. From Figs. 6 and 7, we can see that the data source and sample of the design method in this paper have always been, and the data source of the original method is different from the experimental sample. It can be seen from the above that in the case of the same experimental target, the richer the data source, the higher the accuracy of the numerical simulation results, and the more persuasive. Therefore, the accuracy of the numerical simulation method designed in this paper is higher than that of the original method.

The experiment shows that the accuracy of remaining oil numerical simulation can be effectively improved by using oil field data analysis in remaining oil distribution. The application of this design method in life can effectively improve the research effect of oil industry on oil field reserves, and deal with the rapid development of oil enterprises.

4 Conclusion

For the simulation of remaining oil distribution in the oil field, the total grid number is used to control the accuracy of the simulation results. The computer with appropriate row energy and speed is selected to support the calculation process, so that the numerical simulation can not only describe the distribution of remaining oil, but also meet the requirements of calculation speed. It can be seen from the distribution simulation of remaining oil in most oilfields at present that the remaining oil mainly exists in the edge of the oilfields, the layers with low permeability and the areas with imperfect well pattern. Because the remaining oil in these areas has a large accumulation, a reasonable grid number is set to control the remaining oil characterization results of its distribution, so as to complete the numerical simulation research of remaining oil distribution. In the research, the data processing part is added to improve the accuracy of numerical simulation and provide technical support for the future development of petroleum industry.

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