Research on the Influence of Reservoir Physical Property Time Change on Reservoir Water Drive Development

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Abstract. With the continuous development of China's social economy, the total demand for energy in China's industrial production is constantly increasing, among which petroleum energy is an important energy type needed in industrial production. China's petroleum energy mainly depends on imports, which is very unfavorable to China's economic development and energy security strategy. Therefore, it is necessary to improve China's oil exploitation efficiency, increase oil production and alleviate China's energy shortage. In this paper, the influence of time variation of reservoir physical properties on reservoir water flooding development is deeply studied and analyzed, and some reasonable suggestions and measures are put forward to further promote the development of China's petroleum development engineering industry. In the oil field developed by water flooding, the long-term scouring force of water will lead to a series of complex physical and chemical changes in the microscopic space of oil reservoir, which will lead to certain changes in the physical parameters of oil reservoir. This phenomenon is called time-varying physical properties. Time-varying physical properties are the main factors affecting reservoir exploration and development, so it is necessary for staff to grasp the relevant technical key points, so as to make clear the changes and the changed reservoir physical parameters. According to the changes, the subsequent work will be adjusted accordingly. Time-varying reservoir will affect the movement law of oil and water in the reservoir, thus affecting the actual development effect of the reservoir, and also affecting the distribution of remaining reservoirs after reservoir development.

Keywords: Water drive reservoir, oil reservoir, physical property time variation, main influence, factor.

1. Basic characterization method of time-varying reservoir physical properties
Many scholars in China have studied the time-varying characterization methods of reservoir physical properties, and established many different numerical simulation techniques. For example, Liu Xian, a scholar, proposed a method to characterize the time-varying phenomenon of physical properties by the change of physical properties following the multiple of water. However, this method has some defects. Therefore, based on this characterization method, this paper improves it, and formulates an analysis method to characterize the time-varying reservoir physical properties by surface flux.
In the characterization method of over-water multiple proposed by scholar Liu Xian, over-water multiple refers to the ratio of the total amount of water passing through a core to the void volume between cores, and accurate results can be calculated by the proposed calculation formula. However, there are some defects in this method. For example, the size of the overflow multiple mainly depends on the length of the core, but the length of the core will cause some uncertainty in the calculation of the overflow multiple. In this paper, a new variable, namely surface flux, is added to the formula. The area flux refers to the volume of water phase in a certain area through which lightning strikes, and the calculation formula is \( M = \frac{QW}{S} \), where \( m \) is the area flux in cubic meters or square meters [1].

According to the formula, a three-dimensional grid is established, in which there are three flow directions, namely X, Y and Z, and water flows in or out of each flow direction. By calculating the total surface flux \( A_1 \) of the three-dimensional grid, which is equal to the sum of the surface fluxes of water flowing out in different directions of X, Y and Z, the total surface flux can be calculated, and the calculation formula is \( A_1 = \sum \frac{Md}{Sd} \), \( Md = \frac{Qdw}{Sd} \). In this formula, \( A_1 \) and \( Md \) are the total area flux and directional area flux, in cubic meters and square meters, respectively, and \( Sd \) is the cross-sectional area in each direction, in square meters. \( Qdw \) is the total volume of water flowed out by lightning in the \( d \) direction, in cubic meters. \( d \) is three different directions of x, y, and z. According to the calculation formula put forward by scholar Liu Xian and the calculation formula put forward in this article, we can get: \( M = \frac{Rl}{\phi c} \). By using this formula, the calculation of discharge multiple can be transformed into the calculation of surface flux. Using the surface flux calculation method, the physical property time-varying characterization method is more stable and the calculated results are more accurate.

Assuming that the cumulative water injection volume of the core in a certain oil reservoir is \( Sw \), the void volume of the core is \( Vp \), and the cross-sectional area is \( S \). Considering the core as a three-dimensional grid, the water flow multiple can be calculated by \( \frac{Sw}{Vp} \), and the surface flux is \( \frac{Sw}{S} \). If the core is equally divided into \( N \) three-dimensional grids, the water passing multiple of each grid is \( N \frac{Sw}{Vp} \), and the surface flux is still \( \frac{Sw}{S} \). There are many uncertain factors in the calculation method of the water flow rate, which causes the physical property parameters to change with the change of the calculation result of the water flow rate. Overwater multiple is a relative concept in itself and needs to be compared with the reference object. When the reference object changes, the overwater multiple will also change accordingly. In the past, when the water multiple was used to calculate the time variation of physical properties, researchers mostly regarded the core as a whole, thus making the core the default reference object, but ignored that the core reference object is also changing in the actual application process. Of. If the core is calculated as a three-dimensional grid, and the calculated physical property parameters are applied to the numerical simulation along with the change of the water flow rate, the problem of ignoring the actual changes of the three-dimensional grid will also occur. If the core in the same oil reservoir is divided into several three-dimensional grid patterns of equal size, the data change law of the water passing multiple will also change accordingly. This will lead to inconsistencies in the data results obtained through the simulation formula, and thus unable to obtain the most accurate time-varying parameters of physical properties. Therefore, the calculation result of the water-passing multiple characterization parameter is not stable enough and will be greatly affected by the meshing. However, by calculating the area flux, it will not be affected by the size of the mesh, and the calculation result is relatively stable, so it can be calculated by the area flux.

2. Time varying law of reservoir physical properties

When calculating the time-varying law of reservoir physical properties, if the core volume is small, it cannot represent the whole area, so this paper chooses the method of well test to calculate the time-varying law of reservoir physical properties. In this paper, the middle A8 well area of H oilfield is selected, and the permeability of A8 well area in different periods is calculated by well test method. Use relevant software to carry out fitting processing, thus obtaining the corresponding surface flux in A8 well area. The functional relationship between permeability change multiple and surface flux is obtained by fitting processing. Figure 1 is the specific fitting processing result.
In terms of time-varying law of relative permeability curve, it is difficult to determine the relationship between relative permeability curve and surface flux by experiment, so this paper uses the change of reservoir saturation and corresponding water relative permeability to show the change. After using the relevant software, we can get the corresponding change relationship [2].

3. Research and Analysis on time-varying numerical simulation of reservoir physical properties

3.1. Application of mathematical model
In the study of numerical simulation of reservoir physical properties with time variation, mathematical model is a common way, which can accurately simulate the time variation of physical properties through the corresponding data model. The commonly used mathematical model is black oil model. Black oil model can calculate the absolute permeability customization, but the relative permeability is greatly influenced by the original relative permeability curve, which can not accurately describe the basic time-varying phenomenon of physical properties, and has certain limitations and defects [3]. Therefore, this paper improves the black oil model, and replaces the calculation methods of absolute permeability and relative permeability with the area flux correlation calculation function, thus obtaining a new mathematical model. The mathematical model includes the oil output or injection amount, water volume (m/s), gravity acceleration (m/s²), depth (m), time (t) and porosity (%) calculated for a certain reference area in a certain state and time.

3.2. Model application and software use
After the black oil model is optimized, the change rule of physical parameters can be calculated. The model solution method chosen in this paper is the finite difference method, which can discretize the differential equation and calculate the pressure and saturation by combining with the fully implicit calculation method. In addition, the absolute permeability curve and relative permeability curve of each step can be calculated. According to the mathematical calculation model, the author developed the corresponding numerical simulator by using software. This simulator is based on the function of black oil model simulator, and adds corresponding functions, so that it can accurately calculate the time-varying laws of reservoir physical properties. Compared with the commonly used black oil model numerical simulation simulator, the numerical simulation developed by the author has a higher matching degree with the total mathematical model. The model software has the following functions: (1) Based on the pressure and saturation, it can calculate the flow rate of water phase in each three-dimensional grid in different directions, thus it can accurately calculate the area flux in different directions and the total area flux in each three-dimensional grid. (2) The permeability and conductivity in multiple three-
dimensional grids can be calculated based on the change law of permeability. (3) The relative permeability curve can be calculated and updated based on the saturation and variation law of participating oil.

4. Analysis of the specific application of the model
After determining the analysis method with area flux as the core, and establishing a perfect mathematical analysis model, it is necessary to test the application effect of the model check. First, establish a conceptual model of numerical simulation. In the research process of this paper, a grid with a scale of $30 \times 30 \times 10$ was established, with a grid length of 15m in the x and y directions, and a grid length of 4m in the z direction. The porosity is 0.20, the permeability in the x and y directions is $100 \times 10^{-3}\mu m^2$, the permeability in the z direction is $10 \times 10^{-4}\mu m^2$, the initial oil saturation is 0.670, and the initial residual oil saturation is 0.320. The injection-production unit adopts a coordinated method of one injection and one production. The water injection rate is 40m³/d, and the oil well fluid production rate is 38m³/d. After the completion of the model construction, in order to obtain the accurate structure of the influence of the time-varying reservoir physical properties on the development of reservoir water drive, it is necessary to simulate the relationship and variation law between permeability, relative permeability curve and surface flux in the software developed by the author. Thus, four different curves are obtained, which do not consider the time variation of physical properties, include the comprehensive time variation of permeability and relative permeability curves, and only include the time variation of permeability and relative permeability. When the water drive development is 20 years, the corresponding recovery degrees of four different curves are 42.7%, 51.0%, 42.4% and 51.5% respectively.

According to further tests and analysis, after comprehensive time-varying permeability and relative permeability curves are included, the remaining oil is mainly concentrated on the two sides of the main production line which is close to the oil well, and the emergence degree is increased by 8.2% compared with that without physical properties. But at the same time, the influence of time-varying permeability is small, and the change of relative permeability curve is not obvious enough. Compared with the model without time-varying, the model with only time-varying permeability can reduce the degree by 0.2%. The long-term filling effect of injected water makes the permeability of submerged reservoir increase, and the flow rate along the main production line is larger, which leads to the early meeting of oil wells, and the water injection efficiency decreases to a certain extent, which leads to the decline of output degree. Only the model with time-varying relative permeability curve has the highest degree, which is 8.7% higher than the model without time-varying physical properties. Under the long-term scouring action of water, the saturation degree of residual oil in the area affected by water injection is gradually reduced, and the development efficiency of water flooding is continuously improved, so that the development effect is continuously improved.

5. Experimental conclusion analysis of the influence of reservoir physical properties change with time on reservoir water flooding development
After the complete experiment in this paper, the following conclusions are drawn:

It is unstable to describe the time variation of physical properties by the multiple of water flow, which will be affected by the change of reference object, while the time variation of physical properties by the surface flux will not be affected by the change of reference object, so the calculation results are stable and accurate. Therefore, it is necessary to use the area flux calculation method to measure and calculate.

After comprehensive time-varying of permeability and relative permeability curves, the remaining oil is mainly concentrated on both sides of the main production lines of oil wells, and the recovery degree of oil reservoirs has increased by 8.7%. The influence of time-varying permeability is small, which will slightly reduce the development effect of water flooding, while the influence of time-varying relative permeability curve is obvious, which can effectively improve the development effect of water flooding.
6. Conclusions
To sum up, this paper adjusts and innovates the way of calculating the influence of time variation of reservoir physical properties on reservoir water drive development, hoping to play a certain reference role for China's oil development industry.

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