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Original Paper

Inter-well Connectivity Mapping System Based on Production Dynamic Data

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Abstract

In the process of oilfield development, interwell connectivity is an important index for reservoir evaluation, but after most of the oilfields enter into the medium-high water content development stage, the evaluation of interwell connectivity becomes the key to improve the efficiency of injection and recovery development. In order to solve the problems of time-consuming and costly of the traditional dynamic connectivity research methods, a water-driven injection and recovery inter-well connectivity calculation model was established through the study of Liu76-60 well group. In the process of the study, the inter-well model was established by processing the data of the well group, and the inter-well connectivity between injection and extraction wells was calculated on the basis of this model, and the calculated results were verified by multivariate linear regression equations. The final results show that the model established in the study is more accurate in evaluating the inter-well connectivity, and the comparison can be confirmed to be consistent with the results of the production dynamics, so the model can be used to evaluate the inter-well connectivity, which has a positive effect on the effective improvement of the efficiency of injection and recovery development in the reservoir.

Keywords

Water drive, Injection and extraction well connectivity model, Well connectivity, Injection and extraction development efficiency

1. Introduction

China's current reservoirs have serious non-homogeneity, and the geological structure and physical characteristics of reservoirs locally have jumps, such as cusp out, faults, etc. (Su, 2013), and the process of water-drive development has also been faced with contradictions such as planar, interlayer, and intralayer, especially after entering the development stage of high water content and high extraction level, the problems of ineffective circulation of injected water, water-drive waves, and small volume have become increasingly prominent, resulting in low water-drive efficiency (Yi, 2019).

In reservoir evaluation work, reservoir connectivity is a very important indicator, which plays a crucial role in field development and program management. Currently, the commonly used methods for dynamic connectivity between reservoir wells mainly include tracer testing, pressure testing, well testing and numerical simulation. The implementation of these methods is complicated, expensive and can affect the normal production of the field, making connectivity monitoring face many challenges (Zhao, Li, Gao, et al., 2010). Currently, static and dynamic methods are commonly used in oilfield sites to evaluate inter-well connectivity. The static method is mainly used to evaluate the connectivity based on reservoir characteristics or parameters through cable logging stratigraphic comparisons, etc. However, in the process of reservoir development, the reservoir structure will change greatly, so this type of method can not accurately reflect the connectivity of the reservoir. Dynamic methods mainly include tracer testing, interference well testing, geochemistry, inter-well microseismic and other methods, but they have the disadvantages of difficult implementation, expensive cost, long interpretation period, and affecting the normal production of the oilfield, thus limiting their use and failing to satisfy the need for an overall understanding of the reservoir (Yi, 2019). The reservoir is a dynamical equilibrium system, and the fluctuation of fluid production from wells caused by the change of water well injection volume is the characteristic response of inter-well connectivity in the reservoir. By establishing the injection and extraction inter-well model and calculating the connectivity, and comparing it with the production dynamic results to prove its correctness and feasibility, which provides the basis for the subsequent water-driven injection and extraction inter-well connectivity (Song, 2023).

2. Fundamentals and Modeling of Interwell Dynamic Analysis

2.1 Basic Principle

Considering the production data of the production wells as the result of the injection data of all the surrounding injection wells, for an injection system consisting of production wells and injection wells, based on the multiple linear regression model, a multiple linear regression model can be used,The fluid production q_j from the jth production well can be expressed as (Yuan, Song, Ren, et al., 2023)

$$\hat{q}_j(n) = \beta_{oj} + \sum_{i=1}^{I} \beta_{ij} i(n) \ \ (j = 1, 2, ..., N) \tag{1}$$

where β_{oj} ——a constant term, which is the coefficient of injection and extraction imbalance in hydraulically driven reservoirs;

β_{ij} ——the weighting coefficients of the multiple linear regression for the jth production well and the ith injection well;

$i_i(n)$ ——injection volume of the ith injection well at time step n, m^3/d;

$\hat{q}_j(n)$ ——fluid production from the jth producing well at time step n, m^3/d;

When the injection and recovery equilibrium conditions are reached, the water-driven reservoir shows that the average values of injection and recovery of water and oil wells are approximately equal, so the constant term β_{oj} in Eq. (1) is zero. At this time, the multivariate linear regression model established in Eq. (1) is transformed into another form, i.e., into a multivariate linear regression model (BMLR) for water-driven reservoirs in the case of equilibrium injection and extraction:

$$\hat{q}_j(n) = \sum_{i=1}^{I} \beta_{ij} i(n) \ (j = 1, 2, ..., N) \tag{2}$$

And in the process of water drive, there is usually a situation of one injection and multiple recovery, when it is one injection and multiple recovery, the summation sign in equation (2) can be deleted. And in the process of water drive, various production dynamic data of the oilfield will also affect the fluid production of the wells, with reference to the principle of fire-driven injection and extraction inter-well connectivity modeling, the water drive model also considers the influence of the main characteristic variables, and obtains the following formula:

$$\hat{q}_j(n) = \beta_{ij} i(n) + \sum_{m=1}^{M} (\lambda_m A_m(n)) \tag{3}$$

In Eq. (3): λ_m denotes the multiple regression weights of the mth main feature of the fluid production volume of the jth production well; $A_m(n)$ denotes the data of the main feature of the fluid production volume of the jth production well at the time length of time n; and M is the number of main features of the fluid production volume of the jth production well.

According to the principle of modeling by multiple linear regression, the connectivity coefficient used to represent the dynamic connectivity is the weight coefficient β_{ij}. Then the formula for calculating the connectivity between injection and extraction wells in the case of water-driven can be obtained by further analyzing equation (3):

$$\beta_{ij} = \frac{\hat{q}_j(n) - \sum_{m=1}^{M}(\lambda_m A_m(n))}{i\ (n)} \quad (4)$$

2.2 Computational Modeling of Water-driven Injection and Recovery Connectivity

First of all, for the existing data processing calculations, remove the abnormal values in the data, calculate the average value of all the samples, and fill in the vacant values in the data using the calculated average value, after completion of the data screening, select the main characteristics of the data, the selected data into the formula (4) to get the formula for water-driven injection and extraction of the connectivity between the wells, and finally, through the production dynamics of the results of the model to validate the model, with the results of the validation of the model to analyze the reliability of the model obtained, the specific process shown in Figure 1.

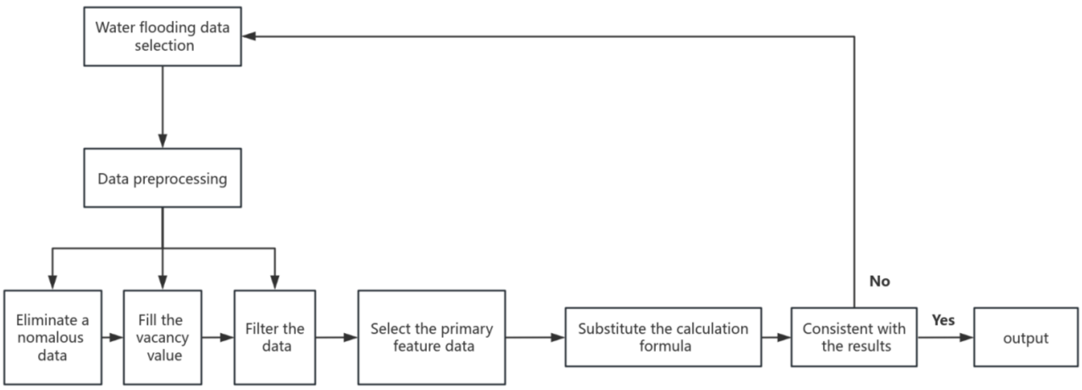

Figure 1. Flowchart of Model Building

3. Model Experiment and Result Analysis

3.1 Model Experiment Object

Jing'an Oilfield Wuliwan Area 1 is located in the oil and gas superposition enrichment zone in the Ordos Basin of northern Shaanxi, western China, and is a large-scale low-permeability oil and gas field development block, the structure is in the middle part of the slope in northern Shaanxi, and it is a group of axial nearly east-west nose-like uplift tectonics developed on the backdrop of the westward-tilted monoclinic with the dipping angle of less than 1°. The main oil layer Triassic Long 6 reservoir is a lakeside deltaic deposition, and the petrographic overall characteristics of the mineral maturity is relatively low. The overall lithology is characterized by low mineral maturity, low porosity and low permeability clastic feldspar sandstone (Wang, Shen, Qiu et al., 2019), which is characterized by low permeability, low pressure and low abundance, and is a lithological reservoir with "three lows" characteristics.

In order to verify the feasibility of the model, we select the well group Liu76-60, which has more complete dynamic monitoring information, to carry out the application and calculation, and verify the feasibility of the model by combining with the dynamic testing results.

3.2 Evaluation Results of Inter-well Connectivity

According to the size of the connectivity coefficient, the dynamic connectivity is divided into four categories, the connectivity coefficient greater than or equal to 0.6 is regarded as a class of connectivity, good connectivity; connectivity coefficient between 0.4-0.6 is regarded as a class of connectivity, general connectivity; connectivity coefficient between 0.2-0.4 is regarded as a class of three connectivity, poor connectivity; connectivity coefficient of less than 0.2 is regarded as class of four connectivity, considered as non-connectivity (Guo, 2023).

The Liu76-60 well group is located in the east of the block and was put into production in September 2001, and the results show that there exists a dynamic connectivity relationship between the injection well 76-60 and the production wells Liu75-59, Liu75-60, Liu76-59, Liu76-61, Liu77-59, Liu77-60, Liu77-61, and the production wells Liu75-60, Liu75-60, Liu75-60, Liu75-60, Liu75-60, Liu75-60, Liu75-60, Liu75-60, Liu75-60 and Liu75-61. The results are shown in Figure 2.

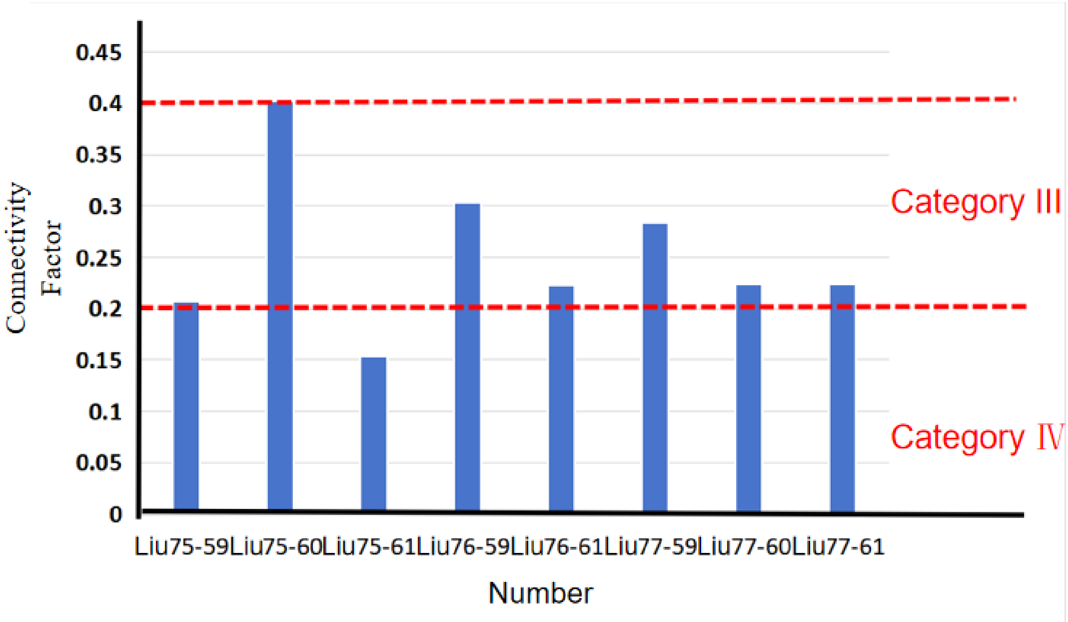

Figure 2. Histogram of Average Values of Connectivity Coefficients of Production Wells

4. Discussion and Prospect

In this study, the author proposes a connectivity inscription system between injection and extraction wells based on production dynamic data, and verifies the feasibility of the system through calculation and analysis. There are still some problems in this study: for example, the calculation and experiment can not be well combined, and the algorithm composition is not mature.

Generally speaking, it can be seen that the inter-well connectivity modeling system based on production dynamic data has shown good performance and broad application prospects in many aspects. Through the computational discussion of the model, the author expects to provide a more advanced and reliable connectivity detection method for the petroleum industry and to promote the further development of oilfield production management and optimization.

5. Conclusion

(1) This study applies dynamic injection and extraction production data to verify the connectivity by comparing the establishment of mathematical model with multivariate linear regression, which can well avoid the shortcomings of other research means that require high cost and complex procedures.

(2) The connectivity of the Liu76-60 well group is studied in depth by calculating the inter-well connectivity through comprehensive analysis, and the results obtained from the comprehensive analysis show that the inter-well connectivity of injection and extraction wells in this well group is poor under the conditions of the current injection and extraction well spacing.

Fund Project

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