Full multi-dimensional dynamic comprehensive optimization stochastic simulation is the sustainable trend of future petroleum reservoir description

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Abstract. Being an important and sustainable approach in future petroleum reservoir description as well as a new frontiers subject in information optimization decision making of today’s oil/gas field development, multi-information stochastic dynamic comprehensive optimization simulation bears profound research significance and broad application prospect. The present paper is an introduction to theoretic performance and characteristics of multi-dimensional stochastic dynamic comprehensive optimization simulation, to classification, steps of model establishment, frequently-adopted approaches and problems to be considered in stochastic simulation. The paper, based on the author’s years of profound study and practice, also indicates the trend and latest application progress of stochastic simulation.

1. Theoretical performance and characteristics of full-dimensional dynamic comprehensive optimization stochastic simulation

Scientific and rational petroleum reservoir description is an important part of scientific development and reconstruction of oil and gas reservoirs. Its purpose is to deepen the understanding of oil and gas reservoirs through dynamic comprehensive analysis and prediction of oil and gas reservoirs based on scientific theories, methods and optimization methods. Furthermore, the adjustment and perfection of oilfield development plan should be done well to develop oilfields scientifically and rationally from the beginning.

In the future, most of China’s onshore oil fields will enter a high water-cut period, and some will enter a very high water-cut period. Moreover, with the deepening of the degree of exploitation, the relationship between underground oil and water will become more and more complex, and it will be more and more difficult to stabilize and adjust the production potential of oilfields. However, at present, the proportion of reserves and production of old oilfields still accounts for more than 70% of the total land reserves and production. Therefore, how to make a deep petroleum reservoir description of the old oil fields in the future and find out the relative enriched areas of the remaining oil to the maximum extent has become the primary task of the future petroleum reservoir development research [1]. However, in petroleum reservoir description, especially in the study of reservoir heterogeneity and spatial distribution of petroleum reservoir attribute parameters, it is found that under the condition of given limited data, the models established by traditional interpolation methods often have been limited without considering the spatial correlation of the estimated values. Therefore, in the future reservoir description, special attention should be paid to the overall dynamic correlation and dynamic comprehensive optimization of the results, and the reservoir property space should be described in a comprehensive and dynamic manner. In order to overcome the shortcomings of traditional methods, we should pay special attention to the stochastic simulation method and means of multi-dimensional dynamic synthesis optimization under the condition of insufficient information of future petroleum reservoir description and distribution of underground reservoirs.
We should conduct in-depth search, excavation, dynamic filtering and optimization of many complex information flows in the objective reality of underground oil and gas reservoirs, and then obtain a series of practical random models for accurate description of all-round multi-information reservoirs and oil and gas. Therefore, it provides a new theory, method and approach of intelligent full-dimensional simulation for stochastic information optimization modeling and computer simulation application software development of various complex petroleum reservoirs. So people will have a deeper understanding of petroleum reservoirs. Thus because we can determine the distribution of oil and gas reservoirs and their remaining oil more effectively in this way, the well pattern development mode can be determined more reasonably and the maximum development benefit can be obtained with less investment. The above-mentioned in-depth research on the series optimization theory, method, model and intelligent application software development of petroleum reservoir description in the future will play a very positive role in promoting the development of the future dynamic development analysis of oilfields and the industrialization of digitalization, informatization, computerization and decision-making analysis of oil and gas field benefits by vigorously tapping the petroleum reservoir potential and improving the overall recovery of various types of reservoirs [2].

2. Classification, steps and methods of the full multi-dimensional dynamic comprehensive optimization stochastic simulation

The full multi-dimensional dynamic synthesis optimization stochastic simulation is based on in-depth search and full exploitation of various complex information flows, and uses modern stochastic analysis, modern information quantification analysis and stochastic simulation in an all-round and multi-perspective manner to establish an optional A stochastic dynamic comprehensive optimization model with equal probability and high precision reflecting the spatial distribution of variables.

2.1. Classification of the full multi-dimensional dynamic comprehensive optimization stochastic simulation

According to different classification criteria, stochastic simulation of full multidimensional dynamic synthesis optimization has different classification. According to whether the simulation results are faithful to the constraints, stochastic simulation of full multi-dimensional dynamic synthesis optimization can be divided into conditional simulation and unconditional simulation. The model generated by unconditional simulation only needs to reproduce the correlative structure of spatial dynamic distribution of reservoir parameters, while the model generated by conditional simulation requires not only to reproduce the correlative structure of spatial dynamic distribution of reservoir parameters, but also to be consistent with the known well observation position.

The stochastic simulation of the full multi-dimensional dynamic comprehensive optimization stochastic simulation can also be divided into discrete and continuous types. The discrete stochastic simulation of full multi-dimensional dynamic synthesis optimization mainly describes the geological characteristics of discrete nature in an all-round way. The continuous stochastic simulation of full multi-dimensional dynamic synthesis optimization mainly describes the spatial distribution of continuously changing reservoir parameters in an all-round way.

2.2. Steps of the full multi-dimensional dynamic comprehensive optimization stochastic simulation

The discrete stochastic simulation of the full multi-dimensional dynamic comprehensive optimization stochastic simulation is closer to geological dynamic interpretation and more suitable for reservoir dynamic simulation of discontinuous and large-scale heterogeneity, while the continuous stochastic simulation of full multi-dimensional dynamic synthesis optimization is more suitable for spatial dynamic distribution simulation of continuous rock physical parameters. Therefore, the steps of stochastic modeling should include two stages of simulation of two models:

In the first stage, the full multi-dimensional dynamic comprehensive optimization stochastic simulation method is used to optimize stochastic simulation of large-scale heterogeneity related to geology and sedimentary based on omni-directional seismic data and logging data [3].

In the second stage, on the basis of the simulation results in the first stage, the full multi-dimensional dynamic comprehensive optimization continuous simulation method is used to simulate all kinds of physical parameters of different sedimentary belts [4-5]. At this stage, the parameters of different sedimentary zones are different, so we should determine the variation of variables and the relationship between variables and spatial structure based on core data. Thus we obtain the relevant dynamic simulation parameters. In summary, the first stage of simulation provides important geological morphology and spatial structure, while the second stage of simulation provides the dynamic change law of rock physical parameters in a small range.
2.3. Methods of the full multi-dimensional dynamic comprehensive optimization stochastic simulation

Stochastic simulation of the full multi-dimensional dynamic comprehensive optimization provides many important means and methods with great development prospects for reservoir description in the future. These methods include Boolean dynamic random simulation, sequential Gauss random simulation, sequential indicator random simulation, truncated Gauss random simulation, probability field dynamic random simulation, dynamic random annealing simulation, fractal dynamic random domain simulation, Markov dynamic random field simulation, and mosaic process dynamic random simulation, etc. All the above methods have their own applicable conditions and suitable types. In practical application, we should choose according to the specific conditions.

2.4. Problems to be considered in the full multi-dimensional dynamic comprehensive optimization stochastic simulation

2.4.1. The problem of the main heterogeneity of reservoirs in the full multi-dimensional dynamic synthesis optimization stochastic simulation.

In the full multi-dimensional dynamic comprehensive optimization stochastic simulation, the most influential heterogeneous feature must be considered first. If the phenomenon studied is a mixture of different objects and statistical population, the geometry should be simulated first. Then the distribution of reservoir attributes parameters is simulated in geometric form.

2.4.2. The problem of Joint Simulation of Multiple Variables

In many cases, it is important to reproduce the spatial interdependence of several variables. In stochastic reservoir simulation, the relationship between porosity, permeability and oil saturation is often considered. Most simulation methods based on stochastic functions can be used to simulate several variables jointly. However, due to the complexity of practical problems, it is difficult to deduce and simulate cross-covariance on computer. Usually, in practical applications, it is necessary to simulate the important or the most relevant variables (principal variables) first, and then sample them with conditional distribution.

2.4.3. Ergodicity problem in the fully multi-dimensional dynamic synthesis optimization stochastic modeling

The purpose of stochastic modeling for the full multi-dimensional dynamic comprehensive optimization is to generate statistics that reflect and fit the original data. The key to this problem is to simulate the degree to which the statistical loyalty entity realizes the original data statistics. The given model statistics are obtained from the sample statistics. The limited sample size often makes these statistics rough. Therefore, it is not necessary and impossible to reproduce each statistic accurately through each implementation. The difference between the simulated statistics and the statistic of a given model is called "ergodic bias". A random function is said to be ergodic if its corresponding statistics tend to a certain value when the study area becomes larger. Therefore, as long as the random function is stationary and ergodic, and the simulation field is large enough, then any realized statistics of the random function can accurately reflect the parameters of the model.

2.4.4. Selection of the full multi-dimensional dynamic synthesis optimization stochastic model

When we build the selection criteria of the full multi-dimensional dynamic synthesis optimization stochastic model, we should pay attention to the following factors. First, the realized statistics should be as close as the model statistics. Second, how is the subjective aesthetic evaluation of the entire model? Third, can we optimize an implementation that reflects the data and features of the model that was not imported before the simulation? Fourth, Can we dig all kinds of complex information that can truly reflect the objective reality of underground oil and gas reservoirs? Whether it is from a subjective aesthetic or based on actual data, the choices made must be based on actual data. In this way, the research phenomenon can be better reflected.

3. New progress in application of the full Multi-dimensional dynamic comprehensive optimization stochastic simulation

The full-dimensional dynamic comprehensive optimization stochastic simulation has become a new and important means of petroleum reservoir description. Compared with the traditional interpolation method, it has great advantages and has been widely used in petroleum reservoir description [6].

In recent years, the introduction of some new theory and methods (such as fractal theory, genetic coefficient method, neural network technology, etc.) not only enriches the stochastic simulation theory, but also broadens the application range of stochastic simulation and improves the application effect of stochastic simulation. With the
development of reservoir description technology, the continuous improvement of geostatistics and the development of computer technology, the full-dimensional dynamic comprehensive optimization stochastic simulation method has played an increasingly important role in petroleum reservoir description.

In fact, the full Multi-dimensional dynamic comprehensive optimization stochastic simulation in petroleum reservoir description has become a new frontier cross-cutting subject in information optimization decision-making in oil and gas field development. So the author has made a thorough study of this topic. In his study, for the first time, a series of modern information quantification methods and stochastic information optimization methods have been fully used [7]. He creatively proposed a complete information optimization decision-making idea. According to the characteristics of many types of oil reservoirs and complex structures in China's onshore oilfields, he studied how to extend the information flow in the general information space of oil and gas reservoirs in onshore high water cut oilfields to the non-homomorphism information flow in the generalized measure and functional information space [8-9]. The author made full use of modern information processing and quantification methods such as omnidirectional multi-information stochastic dynamic optimization analysis theory and method, stochastic control theory and method, stochastic signal optimal filtering theory and method, optimal information entropy method and multi-factor Fuzzy information search method [10-12]. He conducted in-depth search, mining, dynamic filtering and optimization research on many complex information flows in the objective reality of deep stratigraphic oil and gas reservoirs. He provides a batch of omni-directional and multi-information optimization decision models and intelligent application optimization software for further improving the multi-factor and multi-information optimization method in petroleum reservoir description and continuously enhancing the comprehensive information decision-making level and benefit in oil and gas field development.

This research provides stochastic simulation and application optimization software for distribution description of underground petroleum reservoirs, theoretical description and method of remaining oil distribution, and scientific evaluation method of oil and gas reservoirs, etc. After being adopted by Changqing Petroleum Exploration Bureau, Liaohe Petroleum Exploration Bureau, Central Plains Petroleum Exploration Bureau, Yanchang Oil Mine Administration Bureau, Jilin Oilfield Branch, Xinjiang Oilfield Branch, Yumen Oilfield Branch and Northwest Sinopec Company, remarkable economic benefits have been achieved. According to incomplete statistics, the annual cumulative production of crude oil will be increased 191170 tons and natural gas will be increased $7009 \times 10^4$ for our country. It can be predicted that the in-depth study of the full Multi-dimensional dynamic comprehensive optimization stochastic simulation will provide a series of new theories, new means, new methods and new models with far-reaching significance and broad application prospects for the sustainable development of reservoir description in the future.

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