COMPUTER MODELING OF OIL RECOVERY BY THE LARGE-BLOCK AVERAGING METHOD

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In numerical experiments to study the processes occurring during the operation of oil fields, as a rule, well operating modes, changes in oil saturation and reservoir pressure distributions, and the density of oil reserves are predicted. The forecast can be carried out on the basis of various descriptions, in particular, using statistical or hydrodynamic models.

Hydrodynamic models are based on strict laws of conservation of mechanics. This is their main advantage and the main difference from statistical models. Calculations based on hydrodynamic models require information about the distribution of reservoir parameters throughout the object (it is three-dimensional, the parameters change over time). It is important that the accuracy of the accepted model of underground hydromechanics is consistent with the inevitable inaccuracy and incompleteness of the initial information about the structure and properties of the reservoir system [1–3].

When creating hydrodynamic models, the concept of "reliable information" about reservoir parameters is usually replaced by the concept of "plausible information". The latter (plausible) is obtained at the stage of model adaptation, which is a way to distribute well measurement data and other available a priori information to the entire facility. As a rule, it is impossible to unambiguously determine the structure and properties of a reservoir system in the inter-well space; the obtained "plausible" parameters in general may not coincide with the real characteristics [3].

In the report, on the example of using the tools of the created computer constantly operating model of oil field development, it will be noted and discussed:

- features of the geometric description of the modeling object;
- accepted approximations in the description of filtration processes;
- algorithmic and computational methods for approximating the corresponding system of equations of underground hydrodynamics;
- the results obtained in the GeoBazaDannych software complex.

Theoretical, methodological issues and fundamentals; technical and algorithmic solutions; techniques and rules for data preparation; tools and instruments for conducting, visualizing, interpreting the results of computational experiments are described in [4]. At the same time, in particular, the difficult

issues of setting up models and techniques for achieving the required accuracy are noted – extremely time-consuming and lengthy calculations that require analysis by specialists of a large number of options when selecting "plausible" data to describe the reservoir system. The novelty of this work is the use of software tools for intellectual analysis, an illustration of effective solutions to model adaptation issues.

Key positions. Within the framework of the concept of the GeoBazaDannych system, when solving problems of mathematical modeling of objects of geology, underground hydrodynamics, a technique is being developed, following which the core and basis for building computer geological models is a digital description of the volume-limiting surfaces. In this case, the main stage is the construction of generalized surfaces describing the topology of the object, the sequence of occurrence of geological bodies, layers, that is, a kind of structural "bookcase" ([5]). For a three-dimensional geological object structured by layers, the approach of building a model in the "constructor" mode is used, when the model is assembled and edited in parts, which are individual geological elements. For layers, distributions of the studied parameters are included in the description. Such parameters are: reservoir type, capacity, porosity, permeability, oil saturation of the reservoir. The initial data for these descriptions, as a rule, are the values of the observed parameter at points with known geometric coordinates, at points that are placed irregularly on the area, for example [1], measurement data on seismic profiles, exploration wells.

When analyzing and predicting the operation of a concrete field (deposit), it is considered that the simulated object is composed of several layers (or only one); the layers can be separated, hydrodynamically interconnected, may have an impenetrable boundary along the perimeter, or a flowing one; wells can open all or only some layers [5, 6]. Filtration it is modeled separately in each oil stratum.

The distributions of the parameters of each layer take into account heterogeneities (variable in area "in plan"), namely: capacity, porosity, absolute permeability, oil saturation. It is accepted that defined flows/exchanges are possible along the perimeter and/or on sections of the roof, sole. At the initial moment of time, the distributions of oil saturation and reservoir pressure are considered to be known. Boundary conditions (described in detail in [4]) – impermeability conditions or the intensity of inflow or pressure of structured reservoir water are set along the perimeter; bottom-hole pressures are set at producing wells; conditions for the absence of oil and pressure or flow rate are set at injection wells. Separately, we note that in the GeoBazaDannych model,

processes in the wellbore are not considered – wells are set by sources, drains. It is believed that the processes in the layers are isothermal and thermodynamically equilibrium, two immiscible phases participate in filtration – water and oil.

In the GeoBazaDannych, for the purposes of designing and forecasting scenarios for the development of oil fields, a methodology has been created and implemented in the software package that allows, with a relatively rough division of the filtration area into separate block elements (may contain several wells), to calculate the main technological indicators. The technique makes it possible to assess the depletion of layers in blocks on average, and when divided into small elements (as in ordinary grid models) to describe filtration in detail. Combined options are possible when reservoir flooding is described in detail in the area of increased interest, and outside – in large blocks.

The use of the GeoBazaDannych model for reproducing and predicting oil recovery processes is possible at the stages of primary and secondary production, as well as when using advanced flooding methods.

The basic rules for separating simulated objects into blocks. The corresponding vertical partitioning and schematization are determined by the availability of the source data and the requirements for the model. According to the stratification, the oil deposit is represented as a set of *N* layers. Layers can coincide with real layers, represent individual layers as a set of layers (interlayers), or combine layers of similar structure into one layer. The flow area in the plan is divided into *M* subdomains (block elements), bounded by polylines/boundaries (depending on the geological conditions of the reservoir and its properties, on the well placement scheme). Each subdomain can contain an arbitrary number of wells (there may not be any wells in the subdomain). Wells can be located at the tops, on the sides, or inside subdomains.

The division into blocks, uniform for all layers, is carried out taking into account the geological conditions of the reservoir and its properties, and depends on the well placement system. When dividing an object (fields, deposits) into blocks, the following factors are taken into account:

• the lithological structure of the object;

• the variability of reservoir properties in the selected subdomains should be minimal, i.e. reservoir properties in them are characterized by minimal heterogeneity;

• the layout of wells and the expected pattern of flooding, following the allocation rules to ensure minimal flows of liquid phases between blocks (for example, you need to split along the cutting rows of injection wells).

The architecture and composition of the GeoBazaDannych software complex are described in [4]. We note the subsystems for the implementation of splitting the filtration area into subdomains (block elements), calculating the dynamics of flooding:

• Gen_MAPw generator and editor of thematic maps and digital fields is a multifunctional software package; in particular, it provides the following capabilities: creation and editing of vector images; supports calculation using several methods and algorithms of digital fields approximating volume distributions of geometric, geophysical and other characteristics of objects of ecology and geology, underground reservoirs, active layers of soils;

• Geo_MDL software package – mathematical, algorithmic and software tools for building geological models of soil layers, multilayer stratums; the complex can work in interactive and batch modes, its modules provide the user with means of analysis, visual representation, modeling of bounding surfaces and distributions of geophysical and other parameters in layers, territories;

• software and algorithmic support for the formation and maintenance of constantly operating hydrodynamic models of multiphase filtration in porous, fractured media with tools for adapting mathematical models on the history of oil recovery processes, calculating reservoir capacitance characteristics, forecasting and expertise of oil recovery measures.

The tools of intellectual adaptation are described in [7, 8]. The report will provide several representative examples of automatic block formation using clustering tools in cases where it is performed taking into account the distributions of effective capacity or the specific density of recoverable reserves.

References

1. Aziz, H. Matematicheskoe modelirovanie plastovyh sistem / H. Aziz, E. Settari – M.: Nedra, 1982. — 407 p.

2. Bulygin, V.Ya. Pravdopodobnoe modelirovanie / V.Ya. Bulygin. – Kazan: KGU, 1985. – 170 p.

3. Halimov, E.M. Detal'nye geologicheskie modeli i trehmernoe modelirovanie / E.M. Halimov // Neftegazovaya geologiya. Teoriya i praktika.– 2012. – № 3(7). – P. 1–10.

4. Taranchuk, V.B. Komp'yuternye modeli podzemnoi gidrodinamiki / V.B. Taranchuk. – Minsk : BGU, 2020. – 235 p.

5. Bulygin, D.V. Geologiya i imitaciya razrabotki zalejei nefti / D.V. Bulygin, V.Ya. Bulygin. – M.: Nedra, 1996. – 382 p.

6. Barvenov, S.A. Metodika, instrumentarii adaptacii matematicheskih modelei processov podzemnoi gidrodinamiki / S.A. Barvenov, M.F Kibash, V.B. Taranchuk // Vybranyya navukovyya pracy BDU, t. “Matematika”. – Minsk, 2001. – P. 34–65.

7. Taranchuk, V.B. Features and examples of clustering in the system GeoBazaDannych / V.B. Taranchuk // AIP Conference Proceedings 2497, 030025 (2023): Volume 2497, Issue 1, 2023, – P. 1-9. doi: https://doi.org/10.1063/5.0103603.

8. Taranchuk, V.B. Examples of Integration of Intelligent Computing Modules and the System GeoBazaDannych / V.B. Taranchuk // Open Semantic Technologies for Intelligent Systems (OSTIS-2024) : Research Papers Collection / BSUIR. – Minsk, 2024. – Issue 8. – P. 189–194.