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Consideration of Reservoir Geomechanical Properties in the Development of Multilayer Oil Fields

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Abstract: In the context of the increasing relevance of the development of oil fields with complex mining and geological conditions and low-efficiency reservoirs, a number of problems arise in the process of developing complex reservoirs related to the influence of reservoir fracturing on filtration processes, significant structure heterogeneity, variability of the stress-strain state of rocks, etc. Therefore, an important task in the design of the development of such fields is a comprehensive account of the complex geological structure. To solve such problems, the authors proposed a methodological approach that allows more reliable prediction of changes in reservoir pressure when building a geological and hydrodynamic model of a multilayer field. Relevant in predicting the technological parameters of the development is to take into account the compressibility of the rock and its influence on the absolute permeability, which is the main parameter that determines the law of fluid filtration in the reservoir. The paper analyzes the structure of a complex multi-layer deposit of the Alpha field, processes the results of compression studies of 178 standard core samples, and obtains the dependences of the compressibility factor on porosity for each of the layers. By the method of multiple regression, the dependence of permeability on a number of parameters (porosity, density, calcite and dolomite content, compressibility), which made it possible to take into account the influence of secondary processes on the formation of absolute permeability.
At the final stage, the effectiveness of the proposed methodological approach was assessed in the construction of a geological and hydrodynamic model of the field. An increase in the quality of the life adaptation of the main technological indicators of development and increase in predictive ability improved model.

Keywords: Geomechanical Properties; Compressibility Of The Pore Space; Geological And Hydrodynamic Model; Complex Manifold; Absolute Permeability; Effective Pressure; Oil Field; Multilayer Field

INTRODUCTION

To date, most of the large hydrocarbon fields are in the late stages of development. In this regard, the development of deposits with hard-to-recover reserves, which include multilayer deposits with complex reservoirs, is becoming increasingly important. Such reservoirs are characterized by significant heterogeneity, fracturing, and disjunctive disturbances, which together have a significant impact on fluid filtration processes in the reservoir system [5]. When designing a development, an integrated approach to accounting for data from geological and field studies is required [3].

In accordance with regulatory documents [7], when developing oil production facilities, a prerequisite for making design decisions is the construction of permanent geological and technological models (PGTM). One of the main tasks of the PGTM is to predict the levels of oil and gas production in the short and long term. However, for the process of constructing PDGTM of complex reservoirs, the presence of uncertainties associated with the underestimation of the following geological features is typical: secondary processes (karst, dolomitization, development of fracturing), the effect of changes in effective pressure on the void space of the reservoir rock during development, abnormally high reservoir pressures and stress stresses in zones of tectonic faults. The papers [15, 16] present the results of experiments on the core, showing the different nature of the change in porosity and permeability during the creation of a stressed state of rocks as a result of stress loads.

Known research aimed at creating models that take into account the geological structure, fluid filtration processes and geomechanics of the reservoir. As part of the study [1], a geomechanical model was built to optimize well construction under conditions of abnormally high reservoir pressures by using high-precision seismic monitoring.

METHODOLOGY

The Alfa deposit, located on the territory of the Ustyurt desert in the seber region, was chosen as the object of research. The field is multilayer, characterized by a complex geological structure, the development of secondary processes in carbonate reservoirs. The reservoir was formed during four cycles of reef building: the first Zadonsk (D3fm1(zd)) and three Yelets (D3fm1(el)). The rocks of the first cycle are separated from the later ones by a dense but relatively fragile barrier 3-55 m thick. The deposit of the Yelets deposits is reservoir-massive, lithologically shielded with horizontal oil-water contact of different levels, complicated by zones of different facies. The capacitive space of the Zadonsk and Yelets deposits is represented mainly by leaching pores and vugs, dolomitization and recrystallization pores.

In this paper, in order to refine the geological and hydrodynamic models of oil and gas reservoirs, an approach is considered that allows, using the analysis of core studies, to discretize the compressibility parameter of the pore space over the entire volume of the model, thereby taking into account the heterogeneity of rock properties, which significantly affects the development of oil and gas fields. deposits. At the first stage, an analysis of the overall dynamics of reservoir pressure for the reservoirs under consideration was carried out.

It was established that the formation pressure in the deposit over the entire period of well operation decreased to an average of 26.3 MPa (34%) relative to the initial one (40.3 at a saturation pressure of 22.5 MPa). According to the rules of rational development, it is not allowed to reduce the reservoir pressure below saturation pressure, therefore, the calculation of the range of effective effective pressures on the reservoirs is carried out at the initial reservoir pressure and at saturation pressure according to the formula

$P_{eff}=P_{rp}-P_{rpl}$

where Prp. – rock pressure, MPa; Prpl – reservoir pressure, MPa

For each reservoir, the parameters that affect the formation of permeability are taken into account. For the genus D3fm1(el1) porosity, calcite content and density turned out to be significant parameters rocks, which is explained by the presence of paleokarst and a large number of caverns. Contents mites did not have a statistically significant effect on the permeability, which indicates the importance the influence of leaching on the filtration characteristics of the reservoir. On the formation of proreservoir permeability D3fm1(el3) and D3fm1(zd) are influenced by porosity and density parameters.These rocks are less susceptible to secondary processes, so the content of calcite in them and lomita did not have a statistically significant effect on absolute permeability.

The obtained dependences (2) - (4) allow you to distribute the absolute permeability over all mu volume of the studied layers. To do this, at the first stage, using the curves of the properties of porous density, calcite content in the rock, calibrated according to the data of core studies properties, cubes of properties are created by interpolating parameters over the entire scope of the model. Then, Based on the obtained dependencies, the absolute permeability is recalculated for all layers.

RESULTS

At the final stage of the work, the effectiveness of the proposed method was tested. The convergence with the actual data of the PDGTM created by the standard method and the model created in the framework of this study was assessed (Table 2). The task was performed once, additional adjustment of the PDGTM was not carried out.

According to the results of the calculations, the convergence of the MPGTM with the actual one for cumulative oil production increased by 24.9%, for cumulative fluid production by 9.9%. There is also a significant increase in the convergence of reservoir pressure dynamics with actual values (Fig. 8).

In the course of the work, an analysis of the geological structure of the Alfa multilayer field was carried out, the need to take into account the geomechanical properties and heterogeneity of the structure when building a geological and hydrodynamic model was identified. To take into account the compressibility parameter, an allowable range of effective pressures has been identified. The results of compression tests of 178 core samples were analyzed, and dependences of compressibility on porosity were plotted in the allowable range. Using the methods of mathematical statistics, the necessity of taking into account the compressibility separately for each productive formation has been proved. For a more physical distribution formation pressure in conditions of highly dissected reservoirs, by adding a sub-reservoir to the model, the elastic properties of tight rocks are taken into account. To clarify the filtration characteristics of the formations, the properties of core samples were analyzed in detail: permeability, porosity, density, calcite and dolomite content. It has been established that the reservoirs of the D3fm1(el1) formation have the best reservoir properties, and the worst reservoirs of the D3fm1(zd) formation.

To create a permeability cube for complex reservoirs, multidimensional dependences of permeability on a set of parameters (porosity, density, calcite and dolomite content) were used separately for each reservoir, which made it possible to take into account heterogeneity of the structure and the influence of secondary processes on the permeability parameter. The results of tuning the modified model to the actual data were compared with the model without modifications. As a result, the model was able to successfully tune the change in reservoir pressure over time, as well as significantly improve the quality of tuning fluid and oil production indicators.

CONCLUSION

The application of the proposed approach made it possible to significantly simplify the procedure for adapting geological and hydrodynamic models to actual development indicators.

The discretization of the pore space compressibility factor depending on porosity, as well as the addition of a subreservoir to the model, made it possible to increase the level of physicality of the formation pressure distribution in the volume of the PGTM and to reproduce the actual data of the development history of the studied production objects with greater convergence. The distribution of absolute permeability depending on the set of parameters made it possible to reproduce with high accuracy the filtration processes characteristic of complex reservoirs, which significantly improved the quality of the PDGTM of the considered field and, accordingly, the quality of short-term and long-term forecasts.

When taking into account geomechanical properties in the model according to the method described in this paper, the calculation speed did not change, which became a significant advantage over full-fledged geomechanical models, the calculations of which last up to six days.

In further studies, the authors of the article plan to use machine learning algorithms to improve the accuracy of the geological base and reduce the degree of model subjectivity in the distribution of parameters in the interwell space.

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