MATHEMATICAL MODELING OF THE GAS FILTRATION PROCESS IN DIRECTLY CONNECTED THREE-LAYER POROUS MEDIUM LAYERS

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ANNOTATION

Currently, due to the complexity of the gas filtration process in multilayer porous medium layers directly connected to each other, it is more difficult to obtain adequate results. Because a good result can be achieved only by solving such problems in three dimensions. This leads to its own complications. Therefore, it is necessary to develop various efficient numerical methods, calculation algorithms and create their software tools for calculating oil and gas field exploitation rates. By using modern computer technology and applying effective numerical methods, it is possible to obtain accurate numerical results and present them in a visual form in 3D graphics. Numerical methods are used to solve the boundary value problem set to the parabolic type differential equation representing the process of unstable gas filtration in a porous medium with a complex field [1, 2].

The main and important indicators of development of gas fields are: change of pressure in formations and wells over time; changes in the number of wells and their discharges over time; optimal placement of wells and their changes over time. Based on these parameters, conducting full-scale real-time experiments to investigate the gas filtration process in porous media gas layers is time-consuming and expensive. . Sometimes it is impossible to conduct real experiments. In such cases, it is necessary to apply numerical methods using modern computer technologies to study the object and implement computational algorithms developed for problem solving [5].

Taking into account the above factors, the mathematical model of the non-stationary gas filtration process in a three-dimensional inhomogeneous porous medium is described by the following differential equation

$$\begin{cases} 2a_1mh_1\mu\dfrac{\partial P_1}{\partial t}=\dfrac{\partial P_1^2}{\partial x^2}+\dfrac{\partial P_1^2}{\partial y^2}+\dfrac{\partial}{\partial z}\left(k_1(z)\dfrac{\partial P_1^2}{\partial z}\right) \\ 2a_2mh_2\mu\dfrac{\partial P_2}{\partial t}=\dfrac{\partial P_2^2}{\partial x^2}+\dfrac{\partial P_2^2}{\partial y^2}+\dfrac{\partial}{\partial z}\left(k_2(z)\dfrac{\partial P_2^2}{\partial z}\right)-Q \\ 2a_3mh_3\mu\dfrac{\partial P_3}{\partial t}=\dfrac{\partial P_3^2}{\partial x^2}+\dfrac{\partial P_3^2}{\partial y^2}+\dfrac{\partial}{\partial z}\left(k_3(z)\dfrac{\partial P_3^2}{\partial z}\right) \end{cases} \quad (1)$$

When determining the main indicators of the development of gas fields, we solve (1) a system of differential equations based on the following initial, boundary and internal conditions:

$$P_i(x,y,z,t)=P_H(x,y,z), \quad t=0, \quad (2)$$

$$-\frac{k\,h}{\mu}\frac{\partial P_i^2}{\partial n}=\alpha\left(P_A-P_i\right), \;\; i=1,2.3$$

(3)

$$\oint_{s_{i_q}}\frac{k\,h}{\mu}\frac{\partial P_2}{\partial n_s}ds=-q_{i_q}(t), \quad i_q=\overline{1,N}_q. \quad (4)$$

$$Q=\sum_{i_q=1}^{N_q}\delta_{i,j,r}q_{i_q} \qquad i_q=\overline{1,N}_q.$$

(5)

Obviously, the conditions of equality and continuity of pressure functions must be fulfilled at each boundary between the layers:

$$P_1\big|_{z=L_1} = P_2\big|_{z=L_1};\ P_2\big|_{z=L_2} = P_3\big|_{z=L_2};$$
$$k_1 \frac{\partial P_1}{\partial z}\bigg|_{z=L_1} = k_2 \frac{\partial P_2}{\partial z}\bigg|_{z=L_1};\ k_2 \frac{\partial P_2}{\partial z}\bigg|_{z=L_2} = k_3 \frac{\partial P_3}{\partial z}\bigg|_{z=L_2}$$

…..(6)

To solve the given boundary value problem by numerical method (1)-(6), we make it dimensionless. To discretize the problem, the algorithmic idea of the variable directions (cross-sectional scheme) opaque scheme is used. The transition from the *l*-time layer to the *l+1* layer is performed in three stages with $0.3\Delta\tau$ steps.

The resulting systems of finite difference equations are nonlinear with respect to the pressure function. Therefore, to solve the equation, we make the terms of the nonlinear equation quasi-linear based on the quasi-linear method and use the iterative method [3, 4]. According to this method, the nonlinear terms of the system of finite difference equations (1) are expressed as follows:

$$\psi(P) \cong \psi(\tilde{P}) + (P - \tilde{P}) \frac{\partial \psi(\tilde{P})}{\partial P}$$

(7)

Here $\tilde{P}$ is the approximate value of the pressure function P, which is determined during $\tilde{P} = P_{i,j,r}^{(s)}$ iterations, $P_{i,j,r}^{(0)} = \hat{P}_{i,j,r}$.

An iteration process is applied to the pressure function at each time layer. The iteration process continues until the following conditions are met.

$$\max_{i,j,r} |P_{1\,i,j,r}^{(s)} - P_{1\,i,j,r}^{(s-1)}| \le \varepsilon;\ \max_{i,j,r} |P_{2\,i,j,r}^{(s)} - P_{2\,i,j,r}^{(s-1)}| \le \varepsilon;\ \max_{i,j,r} |P_{3\,i,j,r}^{(s)} - P_{3\,i,j,r}^{(s-1)}| \le \varepsilon.$$

(8)

In order to study and determine the main indicators of three-layer gas deposits and perform computer calculation experiments, the following

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preliminary data are needed: the length of the layer is $L = 10000m$; layer power $h = 10m$; initial formation pressure $P_H = 300atm$; layer permeability $k = 0.1Darsi$; the viscosity of the gas is $\mu = 0.01sPz$.

Numerical results of computational experiments are presented in 3D graphical form. In the center of the discrete filtration field there are five wells with the same discharge q=500000 m^3/day.

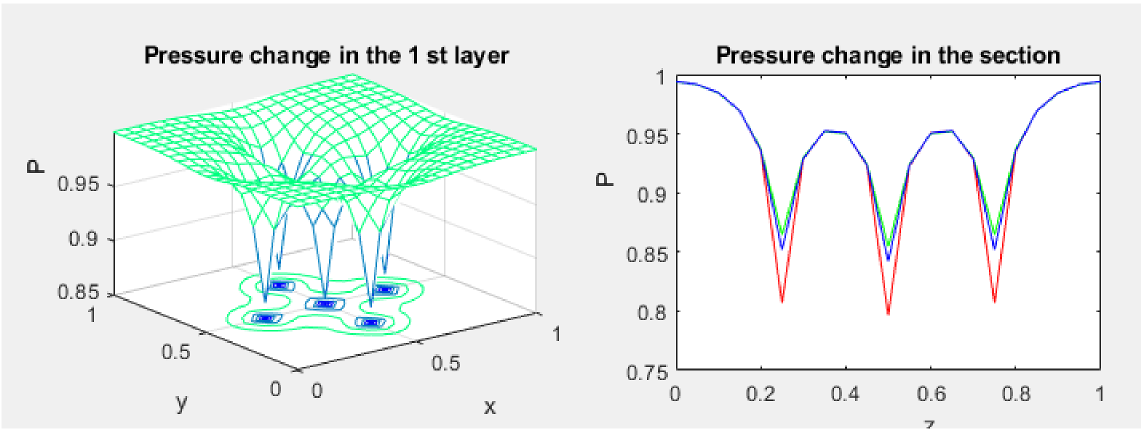

Figure 1. Graph of the results of the numerical solution of the three-dimensional problem ($k_1 = 0.1;\ k_2 = 0.2;\ k_3 = 0.3;\ \mu = 0.02.$)

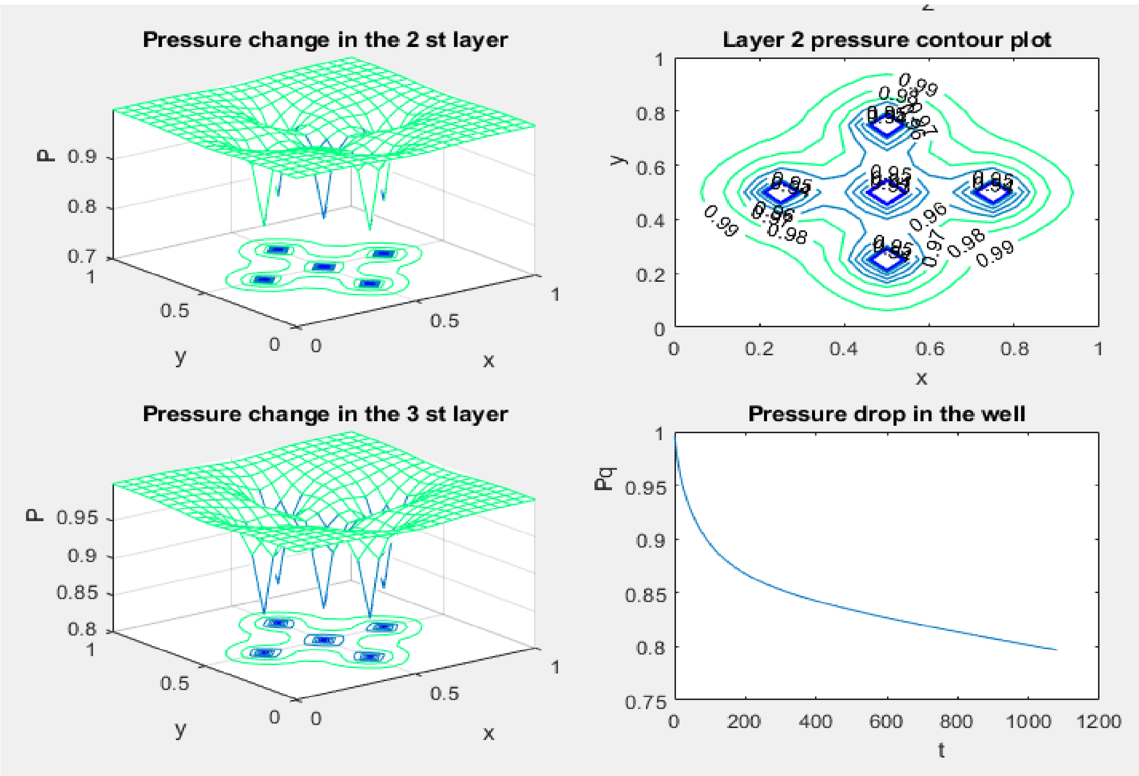

Figure 2. Graph of the results of the numerical solution of the three-dimensional problem ($k_1 = 0.1;\ k_2 = 0.2;\ k_3 = 0.3;\ \mu = 0.02.$)

A number of numerical modeling techniques and software developed to calculate key performance indicators for directly connected three-layer gas fields can be used for analysis and prediction, as well as for the development of multi-layer oil and gas fields. The obtained results show that despite the use of P^2s and their quasi-linearization, the results were symmetrical with respect to the center of the filtration area.

References

1. Абуталиев Ф.Б., Хаджибаев Н.Н., Измайлов И.И., Умаров У. Применение численных методов и ЭВМ в гидрогеологии. – Ташкент: Фан, 1976. – 160 с.

2. Азиз Х., Сеттари Э. Математическое моделирование пластовых систем. Москва-Ижевск:Институт компьютерных исследований, 2004. - 416 с.

3. Бельман Р., Калаба Р. Квазилиниаризация и нелинейные краевые задачи. - М.: Мир, 1968. – 184 с.
4. Закиров С.Н., Лапук Б.Б. Проектирование и разработка газовых месторождений. - М.: Наука, 1974. – 376 с.
5. Гусейн-Заде М.А., Колосовская А.К. Упругий режим в однопластовых и многопластовых системах. - М.: Недра, 1972. – 454 с.
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