ГЕОЛОГІЧНА ІНФОРМАТИКА

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MODELING OF DISPLACEMENT PROCESSES IN HETEROGENEOUS ANISOTROPIC GAS RESERVOIRS

(Представлено членом редакційної колегії д-ром фіз.-мат. наук, проф. Б.П. Масловим)

Nowadays there are important problems of increasing efficiency of development and exploitation of gas deposits. There are problems associated with the growth of gas production in heterogeneous anisotropic reservoirs, increasing gas recovery, achieving economic efficiency and so on. In this situation, there are popular methods of computer modeling of gas productive reservoirs, because they allow getting information of the structure and characteristics of the gas reservoir, the distribution parameters of permeability and other important factors in it. They also allow evaluating and calculating uncertainty arising from the lack of information about the gas reservoir properties outside the well. Currently there are many methods of computer modeling, allowing solving various practical problems. From another hand there are some problems related to the accuracy and adequacy of simulation of heterogeneous anisotropic permeable collector systems in real conditions of gas deposits exploitation.

On the base of combined finite-element-difference method for solving the nonstationary anisotropic piezoconductivity Lebenson problem, with calculating of heterogeneous distribution of permeable characteristics of the gas reservoir, we carried out modeling of filtration processes between production and injection wells.

The results of computer modeling show that intensity of the filtration process between production and injection wells depends essentially on their location both in a shifting-isotropic and anisotropic gas reservoir. Therefore, for the effective using of poorly permeable shifting-isotropic gas-bearing reservoirs, it is necessary to place production and injection wells along the main anisotropy axes of the gas-bearing layers. At the placing production and injection well systems in low-permeable anisotropic reservoirs of a gas field, the most effective exchange between them will take place when the direction of increased permeability of the reservoirs coincides with the direction of the location of the wells. Obviously, the best conditions for gas production processes in any practical case can be achieved due to optimal selection of all anisotropic filtration parameters of the gas reservoir.

One can use obtained results for practical geophysical works with a purpose optimizing of gas production activity in low-permeable heterogeneous anisotropic reservoirs. Presented method for more detailed investigation of low-permeable heterogeneous anisotropic gas-bearing deposits can be used.

Keywords: computer modeling, anisotropic filtration processes, gas reservoirs.

Introduction and statement of the problem. Nowadays, there are actual problems of increasing and effective supporting of the stable gas production. For that purposes in practice, different modern technologies for intensity of the gas filtration process between producing and injection wells have been used (*Кошляк, 2002; Тер-Саркисов, 1999; Яскин и др., 2018*). There are different technologies, which can influence the main filtration parameters of the gas reservoir such as permeability, porosity, viscosity and any other additional factors. From the other hand, an important factor in gas production in poorly permeable depleted reservoirs is the calculation of anisotropy in the processes of gas phase displacement.

However, for effective using of the gas technologies in practice it is necessary to realize the complete anisotropic filtration processes between production and injection wells in reservoirs. In this situation, computer methods of the anisotropic heterogeneous gas reservoirs modeling are very effective, because they help to obtain information about anisotropic filtration processes between acting wells in many practical cases.

Furthermore, they allow evaluating and taking into account uncertainties due to poor information about the structure and filtration properties of the reservoir outside the wells. Moreover, we can obtain all this information by comparatively cheap way and use for effective analysis, control and management of the gas production processes.

Analysis of latest investigations. At that moment, there are many methods of the gas reservoirs modeling, which allow resolving of various practical problems in gas production (*Азиз и Сеттари, 2004; Каневская, 2003; Chen, et al., 2006; Ertekin, et al., 2001*): a) determination of gas filtration processes under different actions on the reservoir in vicinity of acting wells; b) the general choice of the system of development of depleted gas reservoirs; c) supporting of optimal volumes of gas production in low-permeability depleted gas reservoirs; d) determination of final reserves and stagnant zones in gas reservoirs; e) gradual analysis and reduction of risks of development and provision of strategy and tactics of operation of the system of acting wells in difficult mining conditions.

Pinpointing unresolved issues. Now there remain the number of problems connected with accuracy and adequacy of modeling of specific anisotropic heterogeneous poor permeable gas reservoir systems in realistic conditions.

Considering in this work combined finite element − difference method resolving nonstationary piezoconductivity Lebenson problem (*Басниев и др., 2003; Lubkov, 2019*) allows calculation of the different filtration parameters in the anisotropic heterogeneous gas reservoirs and gas penetration conditions on the border of investigating area in any time. Therefore, we can adequately define the distribution of the gas reservoir pressure between producing and injection wells in anisotropic heterogeneous poor permeable gas reservoir systems in realistic exploitation conditions.

Setting objectives. The aim of the article is modeling of pushing processes in the anisotropic low permeable gas reservoirs based on the elaborated combined finite element – differences method.

Research part and findings validated. Mathematical formulation and solving problem. We consider the gas reservoir in which the presence of gas is very small. We suggest that the average reservoir thickness is considerably smaller than its horizontal sizes of the considered area, so it's sufficient to use a two-dimensional nonstationary anisotropic model of piezoconductivity Lebenson problem (*Басниев и др., 2003; Lubkov, 2019*). In that case, the general formulation of the nonstationary anisotropic piezoconductivity Lebenson problem, taking into account the conditions of penetration of the gas phase on the borders of considering region, in rectangular axes (X, Y) can be presented as:

$$\frac{\partial P^2}{\partial t}=\frac{1}{c}\left(k_{xx}\frac{\partial^2 P^2}{\partial x^2}+k_{yy}\frac{\partial^2 P^2}{\partial y^2}+2k_{xy}\frac{\partial P^2}{\partial x}\frac{\partial P^2}{\partial y}\right)+\gamma; \quad (1)$$

$$P(t=0)=P_0; \quad (2)$$

$$k_b \, grad P^2=\alpha(P^2-P_b^2). \quad (3)$$

Here (1) – nonstationary piezoconductivity Lebenson equation; (2) – initial condition; (3) – condition of the gas penetration in the reservoir borders; $P(x,y,t)$ – pressure, as function of coordinates and time; $c=\eta m/P_0$ – coefficient of Lebenson piezoresistivity; k_{xx}, k_{yy}, k_{xy} – anisotropic gas coefficients permeability; η – gas dynamic viscosity; *m* – porosity coefficient; γ – gas production parameter; P_0 – initial pressure of the porous layer; α – coefficient of the gas penetration in the border of reservoir; P_b – pressure in the border of investigating area; k_b – gas coefficients permeability in the border of investigating area

For resolving nonstationary piezoconductivity Lebenson problem (1) – (3), we use variation finite element method, which leads to the solving of variation piezoconductivity Lebenson equation (*Lubkov, 2019*):

$$\delta \mathrm{I}(P)=0. \quad (4)$$

Here I(*P*) – functional of piezoconductivity Lebenson problem (1) – (3), which after substitution $\tilde{P}=P^2$ can be presented as:

$$\mathrm{I}(\tilde{P})=\frac{1}{2}\iint_S\{k_{xx}(\frac{\partial\tilde{P}}{\partial x})^2+k_{yy}(\frac{\partial\tilde{P}}{\partial y})^2+2k_{xy}\frac{\partial\tilde{P}}{\partial x}\frac{\partial\tilde{P}}{\partial y}+ +2\int_{P_0}^{P}c\frac{\partial\tilde{P}}{\partial t}d\tilde{P}-2\gamma\tilde{P}\}dxdy-\frac{1}{2}\int_L\alpha(\tilde{P}-2\tilde{P}_м)\tilde{P}dl; \quad (5)$$

here, *S* – the square of investigating area; *L* – contour, which surrounds the square *S*, *dl* – element of the contour.

For resolving variation equation (4), we use eight-nodal isoparametric quadrangular finite element (*Лубков, 2017; Lubkov, 2019*). As global coordinate system, where we unit all finite elements of investigating area S, rectangular system (*x, y*) is using. As local coordinate system, where in limits of every finite element we define approximation functions φ_i and make numerical integration, normalizing coordinate system (ξ, η) is used (*Лубков, 2017; Lubkov, 2019*).

$$\varphi_1=\frac{1}{4}(1-\zeta)(1-\eta)(-\zeta-\eta-1);$$
$$\varphi_2=\frac{1}{4}(1+\zeta)(1-\eta)(\zeta-\eta-1);\varphi_3=\frac{1}{4}(1+\zeta)(1+\eta)(\zeta+\eta-1);$$
$$\varphi_4=\frac{1}{4}(1-\zeta)(1+\eta)(-\zeta+\eta-1);$$
$$\varphi_5=\frac{1}{2}(1-\zeta^2)(1-\eta);$$
$$\varphi_6=\frac{1}{2}(1-\eta^2)(1+\zeta);$$
$$\varphi_7=\frac{1}{2}(1-\zeta^2)(1+\eta);\varphi_8=\frac{1}{2}(1-\eta^2)(1-\zeta). \quad (6)$$

In this system coordinates, pressure, initial pressure, pressure in the border of investigating area, coefficient of the gas penetration in the border and derivatives of pressure on coordinates approximated in such way:

$$x=\sum_{i=1}^{8}x_i\varphi_i;\ y=\sum_{i=1}^{8}y_i\varphi_i;\ \tilde{P}=\sum_{i=1}^{8}P_i\varphi_i;$$
$$\tilde{P}_0=\sum_{i=1}^{8}P_{0i}\varphi_i;\ \tilde{P}_b=\sum_{i=1}^{8}P_{bi}\varphi_i;\ \alpha=\sum_{i=1}^{8}\alpha_i\varphi_i;$$
$$\frac{\partial\tilde{P}}{\partial x}=\sum_{i=1}^{8}P_i\Psi_i;\ \frac{\partial\tilde{P}}{\partial y}=\sum_{i=1}^{8}P_i\Phi_i;$$
$$\Psi_i=\frac{1}{|\mathrm{J}|}(\frac{\partial\varphi_i}{\partial\eta}\frac{\partial y}{\partial\xi}-\frac{\partial\varphi_i}{\partial\xi}\frac{\partial y}{\partial\eta}); \quad (7)$$
$$\Phi_i=\frac{1}{|\mathrm{J}|}(\frac{\partial\varphi_i}{\partial\xi}\frac{\partial x}{\partial\eta}-\frac{\partial\varphi_i}{\partial\eta}\frac{\partial x}{\partial\xi});$$

where $\mathrm{J}=\frac{\partial y}{\partial\xi}\frac{\partial x}{\partial\eta}-\frac{\partial y}{\partial\eta}\frac{\partial x}{\partial\xi}$ – Jacobian matrix between systems (*x, y*) and (ξ, η).

Following variation equation (4) and suggesting, that nodal meanings from derivatives of pressure on time $\frac{dP_i}{dt}$ are known values and can't be variated we get system of differential equations for *k*–nodal of *p*–finite element in such view:

$$\frac{\partial\mathrm{I}_p}{\partial P_n}=\sum_{i=1}^{8}\{\mathrm{H}_{ni}^p\frac{dP_i}{dt}+(\mathrm{A}_{ni}^p+\mathrm{Q}_{ni}^p)P_i-\mathrm{Q}_{ni}^pP_0^i\}-\gamma_n^p=0; \quad (8)$$
$$\mathrm{H}_{ij}^p=\int_{-1}^{1}\int_{-1}^{1}c^p\varphi_i\varphi_j|\mathrm{J}|d\xi d\eta;$$
$$\mathrm{A}_{ij}^p=\int_{-1}^{1}\int_{-1}^{1}(k_{xx}^p\Psi_i\Psi_j+k_{yy}^p\Phi_i\Phi_j+k_{xy}^p\Psi_i\Phi_j)|\mathrm{J}|d\xi d\eta;$$
$$\mathrm{Q}_{ij}^p=\int_L\alpha\varphi_i\varphi_j dl;\ \gamma_i^p=\int_{-1}^{1}\int_{-1}^{1}\gamma^p\varphi_i|\mathrm{J}|d\xi d\eta.$$

For resolving the system of linear differential equations of the first order (8) at initial conditions (7) we use method of finite differences. At that, approximation of derivative in time can be realized on the base of implicit differential scheme:

$$\frac{dP}{dt}=\frac{P(t+\Delta t)-P(t)}{\Delta t}. \quad (9)$$

Putting expression (9) into the system (8), we obtain the next system of linear algebraic equations:

$$\sum_{i=1}^{8}\{(\frac{1}{\Delta t}\mathrm{H}_{ni}^p+\mathrm{A}_{ni}^p+\mathrm{Q}_{ni}^p)P_i(t+\Delta t)-\frac{1}{\Delta t}\mathrm{H}_{ni}^pP_i(t)-\mathrm{Q}_{ni}^pP_0^i\}-\gamma_n^p=0,$$
$$(n=1-8). \quad (10)$$

After summing equations (10) by all finite elements, we obtain the global system of linear algebraic equations, which allows defining unknown meanings of pressure in the moment of time $t+\Delta t$ via their meanings at previous moment *t*. We resolve the global system equations on the base of Gauss numerical method without choosing the main element (*Лубков, 2017; Lubkov, 2019*). After solving, we can define the pressure at all nods of the finite element net. According to the found nodal values, the pressure can be determined at any point of the gas reservoir area in any time. The use of quadratic approximation and implicit difference scheme leads to increasing of the accuracy and also convergence and stability of the numerical solution of the problem (*Азиз и Сеттари, 2004; Лубков, 2017; Chen et al., 2006*).

Modeling of anisotropic gas displacement processes. Let us consider filtration processes of an anisotropic gas reservoir in the vicinity of a production well with the power of 24840 m^3 over day at the initial reservoir pressure of 20 MPa. Taking into account the expansion of the gas, at the surface the well power will be $2{,}484\cdot10^6$ m^3 over day. We suggest anisotropic gas reservoir area with the size of 9×9 km^2.

We choose some average characteristic parameters of the gas reservoir (*Басниев и др., 2003*): η = $0{,}18\cdot10^{-4}$ Pa·s; m = 0,15. In that case coefficient of Lebenson piezoresistivity is $c=0{,}27\cdot10^{-12}$ s. In modeling, we will consider that borders of investigating area are impenetrable, thus the gas penetration coefficients on the borders of considering area equal zero.

From the figures we can see the pressure distributions between gas production and injection wells at the given well power and various anisotropic parameters of the gas permeability after 30 days of continuous acting.

In fig. 1 − we can see distribution of pressure between producing and injection wells in the shifting-isotropic case of gas permeability distribution ($k_{xy} \neq 0$). In fig. 2 − distribution of pressure between producing and injection wells at their horizontal installation relatively of the main anisotropy axes. In fig. 3 − distribution of pressure between producing and injection wells at their vertical installation relatively of the main anisotropy axes. In fig. 4 − distribution of pressure between producing and injection wells at their diagonal (shifting) installation relatively of the main anisotropy axes.

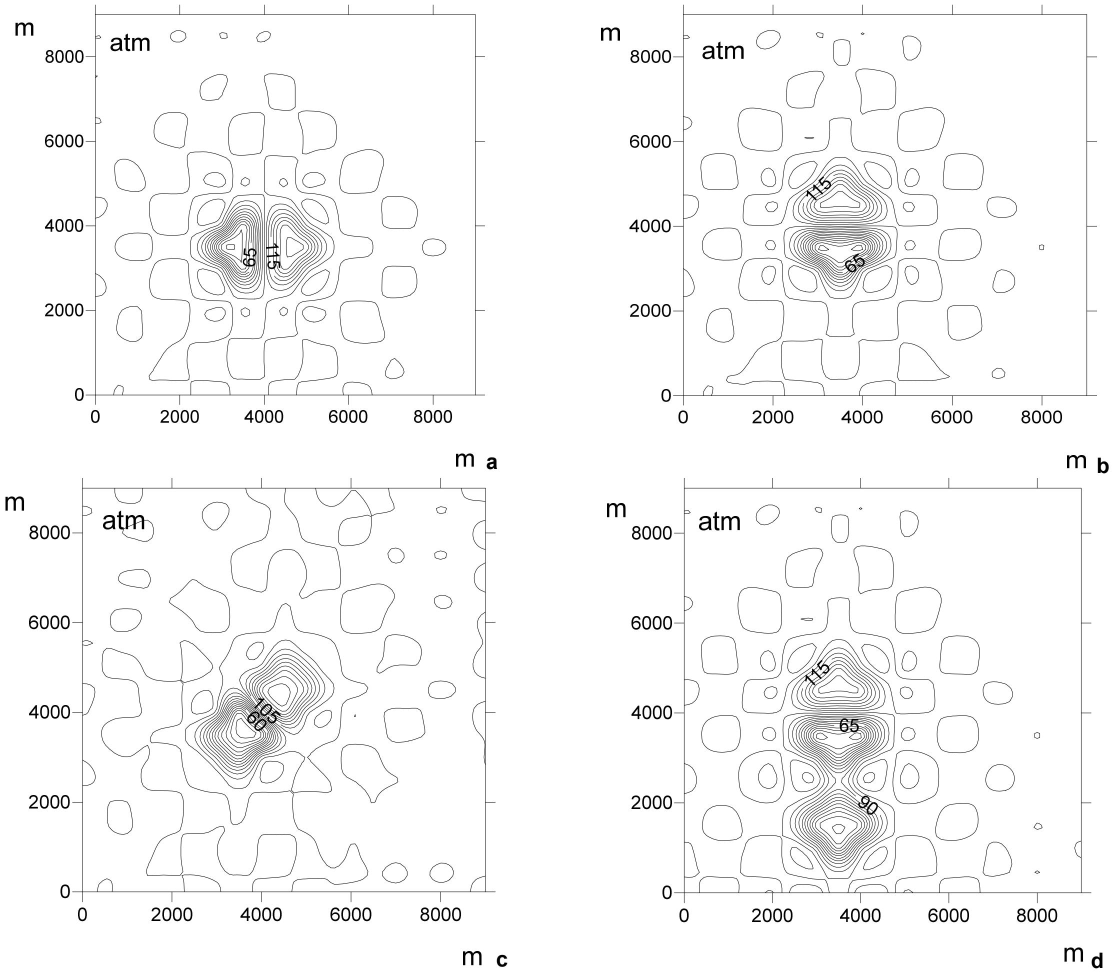
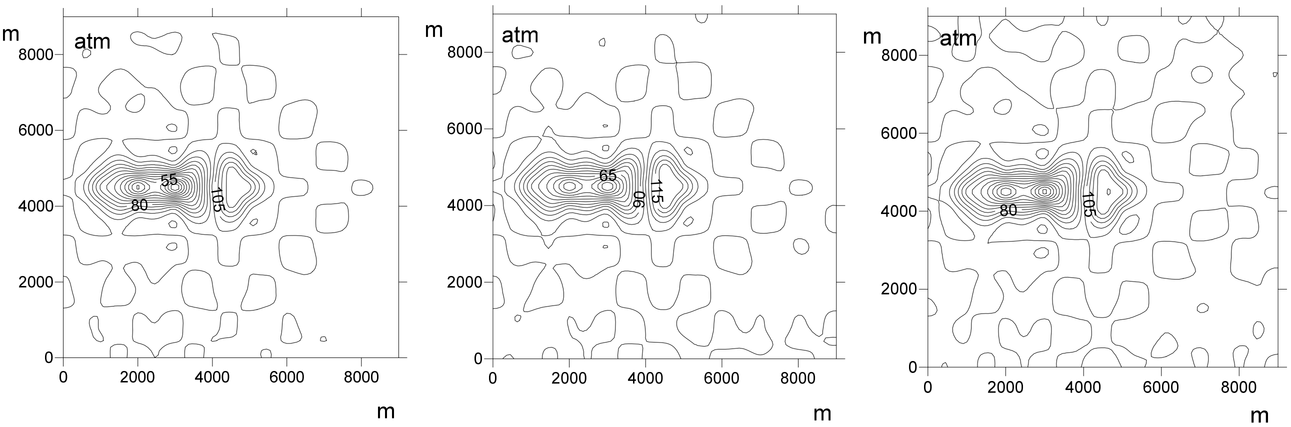


Fig. 1. Distribution of pressure between production and injection wells over month from beginning in shifting-isotropic case of permeability gas distribution:
a – k_{xx} = 0,0012 D, k_{yy} = 0, 0012 D, k_{xy} = 0,0012 D; b – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,0012 D; c – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,0012 D; d – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,0012 D. (1D (Darsi) = 10^{-12} m^2)

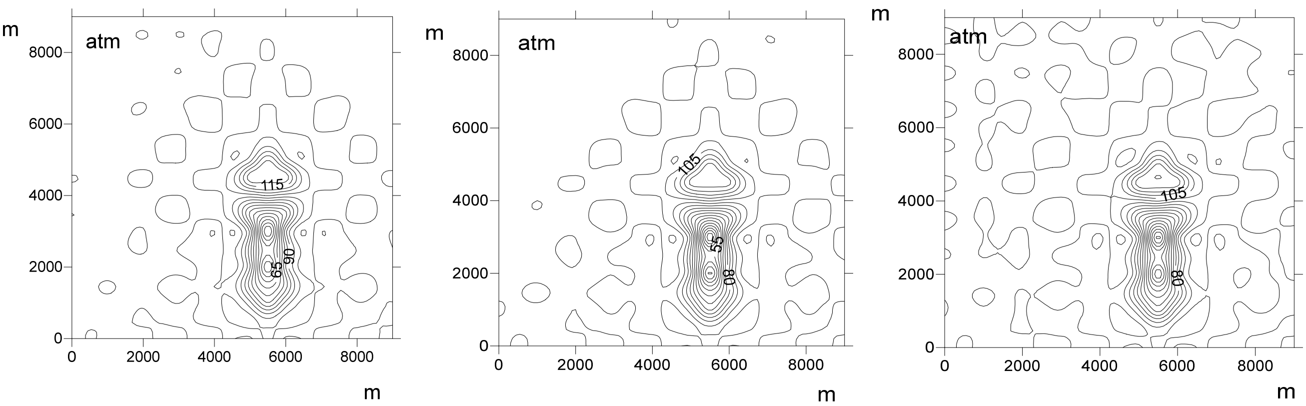
Discussion of the results. The modeling results show a significant effect of the anisotropy of the gas reservoir permeability on the nature of the filtration processes around the production and injection wells, and therefore on the gas production process. In fig. 1 it is possible to detect the degree of intensity of the filtration process between production and injection wells depending on their installation in shifting-isotropic gas reservoir. The most intensive filtration process between production and injection wells occurs when they are placed along the main anisotropy axes (fig. 1, a, b, d). In that case, the gas production process is the most efficient. In the case of diagonal (shifting) installation relatively of the main anisotropy axes, the mutual exchange between production and injection wells decreases and gas production is reduced accordingly (fig. 1,c). In fig. 2 we can see that the most intensive exchange between production and injection wells is observed in case 2, a, when the direction of increased permeability coincides with the direction of well location. Accordingly, the least intense exchange is observed in case 2, b, when the direction of increased permeability is perpendicular to the direction of the wells. Case 2, c, when the direction of increased permeability is shifted, corresponds to the average exchange rate. In fig. 3 we can see that the most intensive exchange between production and injection wells is observed in case 3, b when the direction of increased permeability coincides with the direction of wells distribution, the least intense in case 3 a when the direction of increased permeability is perpendicular to the direction of wells. That is, the pattern of exchange intensity between production and injection wells is repeated. In fig. 4 − the most intensive exchange between production and injection wells is observed, respectively, in the case of 4, c, also when the direction of increased permeability coincides with the direction of the wells. Moreover, cases 4, a and 4, b have an equally intensive exchange between production and injection wells. Based on the obtained information, for the effective use of weakly permeable shifting-isotropic gas reservoir, it is necessary to install production and injection wells along the main anisotropy axes. At installing systems of production and injection wells in anisotropic low permeable gas reservoirs, the most effective exchange between them will take place when the direction of increased permeability of the reservoir coincides with the direction of the wells. Obviously, for achievement of the best conditions of gas production in any practical case we need in systematic analysis and optimal selection of all influential factors of the anisotropic gas filtration processes. From the other hand, we can evaluate these factors by using presented method.



a b c

Fig. 2. Distribution of pressure between production and injection wells at their horizontal installation relatively of the main anisotropy axes over month from the action beginning:

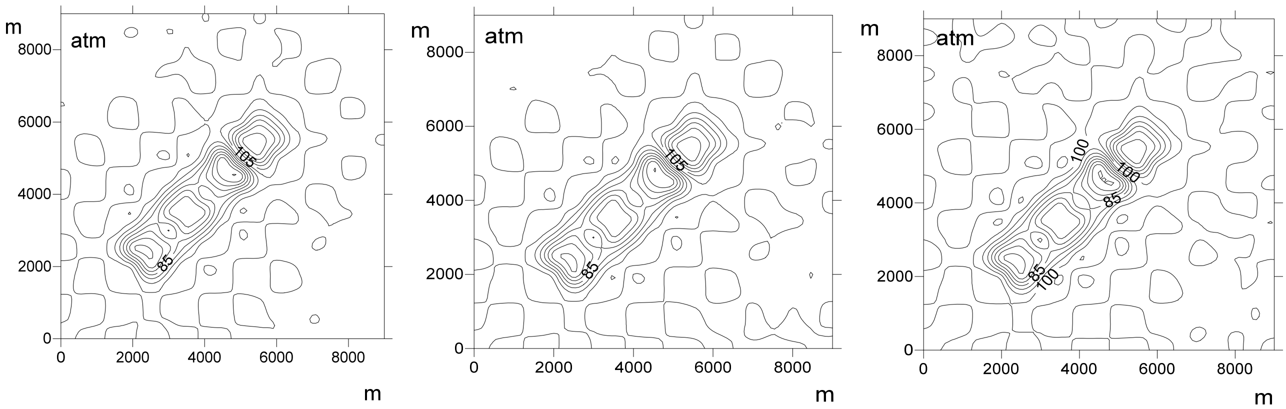
a – k_{xx} = 0,012 D, k_{yy} = 0, 0012 D, k_{xy} = 0,0012 D; b – k_{xx} = 0,0012 D, k_{yy} = 0,012 D, k_{xy} = 0,0012 D;
c – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,012 D



a b c

Fig. 3. Distribution of pressure between production and injection wells at their vertical installation relatively of the main anisotropy axes over month from the action beginning:

a – k_{xx} = 0,012 D, k_{yy} = 0, 0012 D, k_{xy} = 0,0012 D; b – k_{xx} = 0,0012 D, k_{yy} = 0,012 D, k_{xy} = 0,0012 D;
c – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,012 D



a b c

Fig. 4. Distribution of pressure between production and injection wells at their diagonal (shifting) installation relatively of the main anisotropy axes over month from the action beginning:

a – k_{xx} = 0,012 D, k_{yy} = 0, 0012 D, k_{xy} = 0,0012 D; b – k_{xx} = 0,0012 D, k_{yy} = 0,012 D, k_{xy} = 0,0012 D;
c – k_{xx} = 0,0012 D, k_{yy} = 0,0012 D, k_{xy} = 0,012 D

Conclusions. The elaborated combined finite element – differences method of resolving anisotropic nonstationary anisotropic Leibenson piezoconductivity problem in deforming gas reservoirs allows adequately in the quantity level describing of low permeable gas filtration process between producing and pushing wells in realistic conditions. The obtained results show that the intensity of the filtration process between production and injection wells and, accordingly, the productivity of gas production depends essentially on their location, both in the shear-isotropic and in the anisotropic gas reservoirs.

The obtained information shows that it is necessary to place production and injection wells along the main anisotropy axes of reservoir for effective exploitation of anisotropic low permeable gas reservoirs.

At installing systems of production and injection wells in anisotropic low permeable gas reservoirs, the most effective exchange between them will take place when the direction of increased permeability of the reservoir coincides with the direction of the wells. Obviously, for achievement of the best conditions of gas production in any practical case we need to realize systematic analysis and optimal selection of all influential factors of the anisotropic gas filtration processes. From the other hand, we can define and evaluate these factors by using the presented method. In the future, it is interesting to create on the basis of the elaborated finite-element-difference method a practically significant method of optimizing gas production in real exploitation conditions of production and injection wells in low-permeability anisotropic gas reservoirs.

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МОДЕЛЮВАННЯ ПРОЦЕСІВ ВИТІСНЕННЯ В НЕОДНОРІДНИХ АНІЗОТРОПНИХ ГАЗОНОСНИХ ПЛАСТАХ

У наш час важливими є проблеми підвищення ефективності розробки та експлуатації газових родовищ. Зокрема, це проблеми, пов'язані зі зростанням видобутку газу в неоднорідних анізотропних пластах, досягненням економічної ефективності тощо. У цій ситуації затребуваними є методи комп'ютерного моделювання газопродуктивних пластів, оскільки вони дозволяють отримувати інформацію про структуру та характеристики газового пласта, параметри розподілу проникності та інші важливі фактори. Вони також дозволяють оцінювати та обчислювати невизначеності, що виникають внаслідок недостатньої інформації про властивості газового пласта поза межами свердловин. Існує багато методів комп'ютерного моделювання, що дозволяють вирішувати різні практичні задачі. З іншого боку, залишаються деякі питання, пов'язані з точністю та адекватністю моделювання неоднорідних анізотропних колекторських систем у реальних умовах експлуатації газових родовищ.

На основі комбінованого скінченно-елементно-різницевого методу для нестаціонарної анізотропної задачі п'єзопровідності Лейбензона, з урахуванням неоднорідного розподілу різних фільтраційних параметрів всередині анізотропного газоносного пласта і на його межах, проведено моделювання процесів фільтрації між видобувними та нагнітальними свердловинами.

Результати комп'ютерного моделювання показують, що інтенсивність процесів фільтрації між видобувними та нагнітальними свердловинами і, відповідно, продуктивність видобутку газу суттєво залежить від їх розташування, як у зсувно-ізотропних, так і анізотропних газоносних пластах. Виходячи з отриманої інформації, для ефективного використання слабопроникних зсувно-ізотропних газоносних пластів необхідно розміщувати видобувні та нагнітальні свердловини уздовж головних осей анізотропії пласта. При розміщенні систем видобувних та нагнітальних свердловин у слабопроникних анізотропних пластах газового родовища найбільш ефективний обмін між ними буде проходити, коли напрямок збільшеної проникності пласта збігається з напрямком розташування свердловин. Очевидно найкращі умови видобутку газу можуть бути досягнуті тільки після системного аналізу та оптимального підбору усіх впливових факторів анізотропії газоносного пласта у кожному практичному випадку.

Отримані результати можна використовувати для практичних геофізичних робіт з метою оптимізації газовидобувної діяльності в слабопроникних неоднорідних анізотропних родовищах. У подальшому викликає інтерес використання представленого методу для більш детального дослідження останніх.

Ключові слова: комп'ютерне моделювання, анізотропні фільтраційні процеси, газоносні пласти.

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МОДЕЛИРОВАНИЕ ПРОЦЕССОВ ВЫТЕСНЕНИЯ В НЕОДНОРОДНЫХ АНИЗОТРОПНЫХ ГАЗОНОСНЫХ ПЛАСТАХ

В настоящее время существуют проблемы повышения эффективности разработки и эксплуатации газовых месторождений. В частности, это проблемы, связанные с ростом добычи газа в неоднородных анизотропных пластах, достижением экономической эффективности и т.д. В этой ситуации востребованными являются методы компьютерного моделирования газовых пластов, поскольку они позволяют получать информацию о структуре и характеристиках газового пласта, параметрах распределения проницаемости и других важных факторах. Они также позволяют оценивать и вычислять неопределенности, возникающие вследствие недостаточной информации о свойствах газоносного пласта вне досягаемости скважин. В настоящее время существует много методов компьютерного моделирования, позволяющих решать различные практические задачи. С другой стороны, остаются некоторые вопросы, связанные с точностью и адекватностью моделирования неоднородных анизотропных коллекторских систем в реальных условиях эксплуатации газовых месторождений.

На основе комбинированного конечно-элементно-разностного метода для нестационарной анизотропной задачи пьезопроводимости Лейбензона, с учетом неоднородного распределения различных фильтрационных параметров внутри анизотропного газоносного пласта и на его границах, было проведено моделирование процессов фильтрации между добывающими и нагнетательными скважинами.

Результаты компьютерного моделирования показывают, что интенсивность процессов фильтрации между добывающими и нагнетательными скважинами и, соответственно, производительность добычи газа существенно зависит от их расположения, как в сдвигово-изотропных, так и анизотропных газоносных пластах. Исходя из полученной информации, для эффективной эксплуатации слабопроницаемых сдвиго-изотропных газоносных пластов, необходимо размещать добывающие и нагнетательные скважины вдоль главных осей анизотропии пласта. При размещении систем добывающих и нагнетательных скважин в слабопроницаемых анизотропных пластах газового месторождения наиболее эффективный обмен между ними будет происходить, когда направление повышенной проницаемости пласта будет совпадать с направлением размещения скважин. Очевидно, наилучшие условия добычи газа могут быть достигнуты только в результате системного анализа и оптимального учёта всех важных факторов анизотропного газоносного пласта в каждом практическом случае.

Полученные результаты могут быть использованы на практике геофизических работ с целью оптимизации газодобывающей деятельности в слабопроницаемых неоднородных анизотропных пластах. В дальнейшем вызывает интерес использование представленного метода для более детального исследования последних.

Ключевые слова: компьютерное моделирование, анизотропные фильтрационные процессы, газоносные пласты.