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Satbayev University

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ИЗВЕСТИЯ

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РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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ANALYSIS OF FLUID FILTRATION MECHANISMS IN FRACTURED RESERVOIRS

Abstract. Carbonate reservoirs play a vital role in the world's gas and oil resources. With the expanding exploration, many deep fractured offshore reservoirs have been found. It has strong anisotropy. Therefore, fractured carbonate reservoir and its flow mechanism have been a challenging research topic in reservoir engineering. However, the existing theories cannot properly describe the fluid flow mechanisms in fractured porous media. The matrix and fracture system have different flow properties and depend on several parameters, such as interporosity flow, storage coefficient. According to the different combination of natural fracture, cave and matrix in carbonate reservoir it is not easy task to build analytical model for this kind of reservoirs. Based on the comprehensive study on the existing theories and methods, the flow features of fractures and the fluid exchange between different porous media as well as the analytical models have been thoroughly reviewed. In this paper this type of reservoir is divided into two model: dual-medium model and triple-medium model. The flow mechanics of naturally fractured reservoir is discussed. Different kinds of physical and mathematical models are established. This paper can be used for the future development and studies of fluid flow model in fractured reservoirs, because there are numerous carbonate fields in Kazakhstan.

Key words: mathematical model; fractured reservoirs; matrix characterization; filtration mechanisms; carbonate reservoirs.

Introduction. Fractured carbonate reservoirs are composed of limestone or dolomite, and their structure and rock physical properties are very different from conventional sedimentary reservoirs. Currently, the reserves of carbonate reservoirs in the world account for more than 65% of the total reserves of crude oil, the production of carbonate oil and gas reservoirs accounts for more than 65% of the total world production of oil and gas. Typically, the fracture system of carbonate oil and gas reservoirs is prevalent, and it is important filtration channels and fluid storage spaces in carbonate oil and gas reservoirs. The degree of fracture propagation mainly affects the productivity of an individual well and the efficiency of oil displacement.

Due to the complex process of accumulation of fractured carbonate reservoirs, development characteristics, physical properties, heterogeneity, fluid distribution rules, reservoir types, development models and dynamic characteristics of fractures, caverns, matrix and other reservoirs are very different from traditional oil and gas reservoirs. Although the filtration mechanism of fractured carbonate reservoirs originated from the theory of filtration of conventional sandstone formations, its research in complexity far surpassed that of traditional oil and gas sandstone formations, and has become an important scientific branch of fluid mechanics. The study of the filtration mechanism of fractured carbonate reservoirs is very important for the effective development of this type of oil and gas reservoirs and the development of the importance of filtration mechanics.

The development of natural fracture systems is an important feature of fractured carbonate reservoirs. The fracture system is not only a reservoir for oil and gas reservoirs, but also the main channel for fluid filtration. Therefore, determining the filtration capacity of fluids in natural fracture systems is important for determining the characteristics of the formation. In [1], based on the development of the relative roughness of cracks, the author investigated the problem of fluid filtration in cracks as a laminar flow regime. Filtration between smooth and rough surfaces was investigated. A classical formula was derived to describe the filtration capacity of a fracture (1), the cubic law has been the basis for characterizing the filtration capacity of a fracture since its proposal. Subsequently, this law was further investigated by scientists to describe the filtration of a network of natural fractures [2, 3]

$$q = \frac{a^3}{12\mu} \frac{\Delta p}{L} \quad (1)$$

Where: q flow rate, $м^3 / s$; μ -fluid viscosity, $Pa \cdot s$; a - crack opening, m ; Δp - the pressure difference between the two ends of the crack, Pa ; L - crack length, m.

Under the influence of rock stress, the opening of natural fractures will change at a local point, this assumption suggests that the cubic law is too simplified. To solve this problem, there used methods for correcting the height of the cracks, changing the function of the crack width, modifying the density distribution functions of the crack width and changing the roughness of the crack. The degree of disclosure follows the cubic law (2), which looks like this [4]:

$$q = \frac{1}{12\mu} \frac{\Delta p}{L} \int_0^{\infty} a^3 f(a)\, da \quad (2)$$

Where $f(a)$ - is the density function of the probability distribution of the crack opening.

Having applied the theory of fractals in the field of petroleum engineering, many scientists have proposed the theory of fractals to characterize fractures and their shape. Thus, the cubic law is used to study the filtration capacity of fracture systems [5]. The following formula (3) is a fractal expression of the cubic law [6]:

$$q = \frac{(a - 2h)^3}{12\mu} \frac{\Delta p}{L} \quad (3)$$

Where h - the average height of particles on a representative unit, *m*.

With the development of the theory of filtration, it was found that uneven filtration of fluids is observed in fractures [7]. The cubic law cannot describe the flow of fluid in such cracks. Filtration modeling in channels is carried out using a physical and digital model.

The mechanical properties and permeability of natural fractures are closely related to the morphology of their surface. The use of a rock surface scanner with a mechanical probe made it possible to study the development of a system of channels of natural cracks, the morphology of the surface of cracks in sedimentary rocks using a photoelectric system for automatic measurement of the three-dimensional shape of the surface. The relationship between the characteristic scale parameters of the fracture and the flow capacity is analyzed. In [8, 9], a three-dimensional numerical model of a crack system was studied using a laser scanner. A digital picture of the fracture morphology was realized using a three-dimensional laser scanning device. A predicted model of the ability of a crack to close under the vertical stress was created, a systematic study of the morphological characteristics of the surface of reservoir cracks, the law of closure of a crack under the action of various forces and characteristics of fluid filtration in cracks was carried out.

*Development of research on the effect of stress on cracks***.** The filtration capacity of fractured oil and gas reservoirs is more susceptible to stress. Due to the constant development of experimental methods and equipment improvements, many scientists have conducted experiments and studies of the stress-sensitive effects of fractured oil and gas reservoirs. In [10], a stress dependence test method for fractured reservoirs was proposed. During the experiments, it was found that the permeability of the oil phase and hydraulic fracture opening change with increasing effective stress, depending on the nonlinear function. The internal relationship between the crack width, the dependence of ω to stress and permeability has been studied. Also, the regularity of the change in permeability and the restoration of reverse permeability under stressful conditions were investigated. The mechanism of stress dependence and factors of influence of fractured reservoirs are analyzed. The intrinsic relationship between crack initiation, stress dependence and physical properties has been studied. In [11], tests were carried out for the stress dependence on the core of microcracks under tension, prepared as part of the test, and at the same time, proceeding from the mechanism of deformation of the fractured medium, the characteristics of the stress dependence of fractured formations with low permeability were quantitatively analyzed, as well as quantitatively the characteristics of stress dependence of a fractured medium and their relationship with microcracks and surface roughness are explained. According to the studies, the fracture channel system played a decisive role in characterizing the filtration capacity of the fracture, but there is no complete theory of the characteristics of the filtration capacity of a complex system of channels under the influence of three-dimensional stress. Consequently, further research should focus on the description of a complex system of channels and multiphase flows.

At present, fluid exchange in fractured carbonate reservoirs is mainly based on statistical methods that allow to equate fracture filtration with a macroscopic continuous filtration field and introduce the concept of a block to describe the macroscopic filtration characteristics of various porous media. A fractured binary medium usually consists of matrix pores and a network of fractures. Modern methods of description are mainly divided into two main types of fluid exchange methods: continuous and discrete.

Experiment on physical modeling of the mechanism of fluid exchange. Physical modeling is an important method for studying fluid flow in porous media. It can more accurately model the law of fluid exchange between media. Due to the successful development of high-precision flow and pressure measurement devices in recent years, the results of physical simulations are reliable. Experiments on the influence of such factors as crack surface roughness, gravity and capillary force on the law of fluid exchange between media, as well as one-dimensional and two-dimensional physical experimental models of cracks and karst cavern systems have been widely used [10]. Then, with the development of etching and engraving technologies for plexiglass and marble, more and more complex physical models were created to study the various laws of wettability of formation fluids and the laws of exchange with complex structures, such as various forms of cracks and various combinations of media. In [12], a visual physical model of filtration was used to study the laws of waterflooding of fractured-cavernous reservoirs and the mechanism of enhanced oil recovery. A quantitative analysis of the interrelated distribution and penetration parameters of matrix fractures reveals a microscopic penetration mechanism between matrix and fracture. Based on the current state of the art of physics simulation experiments, the focus of in-depth studies should be on the research and development of an experimental platform for microscopic visualization of filtration in multi-fractured systems and a large-scale 3D model experiment on fluid filtration.

Single-phase mechanism of fluid exchange. Multiple fluid models are important for describing fluid exchange in fractured carbonate reservoirs. Assuming that the movement of fluid into the matrix and fractures satisfies Darcy's law, and taking into account the mechanism of fluid exchange in the pores of the matrix and the network of fractures, a mathematical model of filtration in a double medium was proposed [13]. Subsequently, various scientists have proposed orthogonal fracture models by simplifying the fracture system and matrix system with different ratios of the orthogonal distribution of fracture blocks and different properties [14] such as the dual medium model [15], the spherical dual medium model [16] and the fractured dual medium model [17]. Consistent with the reservoir matrix, the system development further refines the traditional dual media model to a fracture propagation structure model.

The fracture structure model consists of a network of vertical lattice fractures. The cracks represent both the matrix space and the filtration channel. The model does not take into account the permeability of the rocks. In [13], a classical model of double porosity, single permeability and a model of double porosity are proposed. The dual permeability model assumes that the matrix is the primary fluid storage space and the fracture is the primary fluid filtration channel. Pseudo-stationary fluid movement in rock blocks and fracture systems can be expressed by the following formula:

$$\varphi_m c_m \frac{\partial p_m}{\partial t} = \frac{\alpha_{m-1} k_m}{\mu}\left(p_f - p_m\right) \tag{4}$$

Where, φ_m- porosity of the matrix system,%; c_m- complex compressibility of the matrix system, Pa^{-1}; p_m - pressure of the matrix system, *Pa*; k_m- permeability of the matrix system, m^2; p_f- pressure in the fracture system, *Pa*; α_{m-1} is the shape factor of the channel filtration between the matrix and the crack, $1/m^2$; *t*- production time, *sec*.

Kazemi's model simplifies the fracture network to a layered shape. Swan's model is similar to the Warren-Root model, but the shape of the matrix element changes from a block to a sphere (Figure 1). In work [17], striving for the difference in scale, method of connection and conductivity of the network of fractures in the formation, the Warren-Root model was refined to a model of double porosity and fracture. The spatial distribution of real fractures is complex, and fracture opening and closing phenomena are observed during filtration. At the same time, under the influence of the mathematical apparatus and the computing power of the computer, the complexity of the assumptions of the physical model should be appropriately limited. Thus, a new type of fluid exchange is established. This is the next line of research that can accurately describe the spatial difference in fracture distribution and reduce the complexity of solving the math problem.

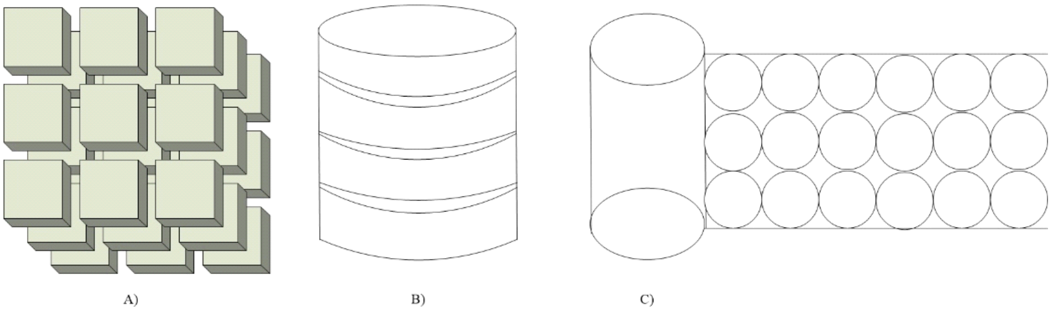


Figure 1 - Comparison of the Warren-Root model (a), the Kazemi model (b) and the Suan model (c)

Materials and methods. Many scientists have carried out experiments to physically simulate the law of two-phase filtration in fractures and have determined the functional relationship between capillary pressure and saturation, as well as relative permeability and saturation (or capillary pressure). Through experiments on displacement on physical models of natural rocks, the relationship between capillary force, relative permeability and saturation in the fracture, as well as the mechanism of oil displacement and the law of fluid exchange were deeply studied in [18-20]. In recent years, many experimental methods have been performed to determine the permeability of the oil-water phase of a fractured-porous reservoir. Fractures were built on the basis of experimental models of various filtration modes in the fracture network and a computational model of the phase permeability of natural oil reservoirs. An experimental method was proposed for analyzing the phase permeability of oil-water of a complex system of a network of fractures. In addition, the theory of finite elements was used to study various scales based on a mathematical model of two-phase filtration taking into account the capillary force [19, 20].

Results. There is a big difference in filtration law between fractures and matrix, the structure of fluid filtration in fracture and matrix is different, and the scale of real fractures is different. Consequently, the mechanism of multiphase fluid exchange in fractures of different scales needs to be investigated.

Similar to the mechanism of fluid exchange, the creation of a mathematical model of filtration also took place in two main stages: the creation of a mathematical model of filtration through a continuous crack and a mathematical model of filtration through a discrete crack.

The mathematical model of fracture filtration in a continuous medium of fractured reservoirs is mainly divided into six categories: homogeneous fracture type, pore fracture type, pore-karst-cavern type, pore-karst-cavern-fracture type, pore-fracture-karst-cavern type, and multi-porous filtration type [21,22]. Mathematical model of homogeneous filtration of fractured type (model of ordinary porosity). This mathematical model is consistent with the homogeneous reservoir filtration model. The fracture is considered as the only storage and filtration space for the fluid, the influence of the matrix is ignored, and it is suitable for carbonate reservoirs with advanced fractures (Figure 2), the filtration equation is as follows:

$$\frac{k_f}{\mu}\nabla^2 p_f = \beta_f \frac{\partial p_f}{\partial t} \quad (5)$$

Where k_f is the permeability of the fracture system, m^2; p_f- pressure of the crack system, *Pa*; β_f- coefficient of accumulation of cracks, Pa^{-1}.

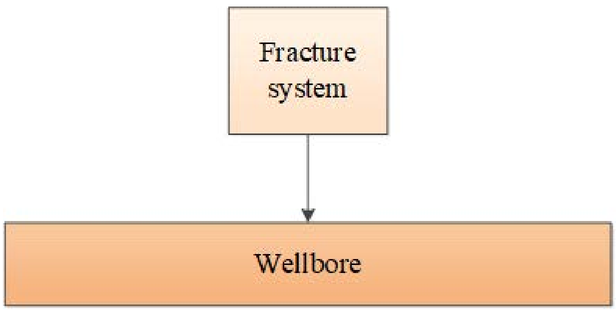
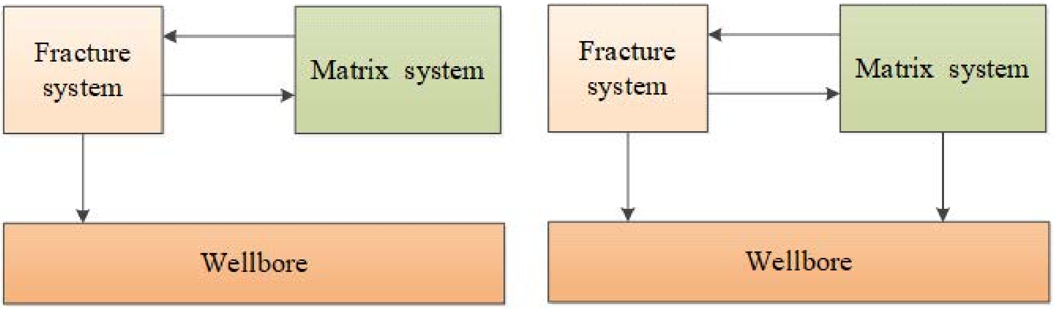


Figure 2 - Physical model of a fractured reservoir



a) б)

Figure 3 - Physical model of a fractured porous reservoir.

Mathematical model of filtration by the type of pore fractures (model with dual porosity and single permeability and model with dual porosity and dual permeability). For this type, the model is divided into a dual porosity and single permeability model and a dual porosity and dual permeability model depending on whether the matrix system is filtered into the wellbore. For the dual porosity and single permeability model, fluid flows from the matrix system to the fracture system, and then flows from the fracture system to the wellbore (Figure 3a); for the dual porosity and dual permeability model, except for fluid exchange between the matrix system and the fracture system, each matrix and fracture system will be filtered into the wellbore (Figure 3b). Expression of the mathematical model of liquid filtration in each medium:

$$\begin{cases} \frac{k_f}{\mu}\nabla^2 p_f + \frac{\alpha_{m-f}k_m}{\mu}\left(p_m - p_f\right) = \beta_f \frac{\partial p_f}{\partial t} \\ \frac{k_m}{\mu}\nabla^2 p_m - \frac{\alpha_{m-f}k_m}{\mu}\left(p_m - p_f\right) = \beta_m \frac{\partial p_m}{\partial t} \end{cases} \quad (6)$$

Where, k_f is the permeability of the crack system, m^2; p_c- pressure of the crack system, *Pa*; α_{m-c}- coefficient of accumulation of the system of cracks, $1/m^2$; β_m is the storage coefficient of the matrix system, Pa^{-1}.

Mathematical model of porous medium filtration. This model assumes that the fractures of the system are not developed, the wells are mostly drilled in the karst and vug zone, and there is fluid in the matrix system that flows into the cavity. The fluid in the cavity is mainly dependent on the elastic expansion of the rock. Filtration process (Figure 4), a mathematical model of reservoir filtration corresponding to this physical model:

$$\begin{cases} \frac{k_c}{\mu}\nabla^2 p_c + \frac{k_m\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_c \frac{\partial p_c}{\partial t} \\ -\frac{k_m\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_m \frac{\partial p_m}{\partial t} \end{cases} \quad (7)$$

Where k_c is the permeability of the cavern system, m^2; - pressure in the cavernous system, *Pa*; α_{m-c} - coefficient taking into account the forms of filtration between the matrix and cavern, $1/m^2$; β_c is the accumulation coefficient of the cavern coefficient, Pa^{-1}.

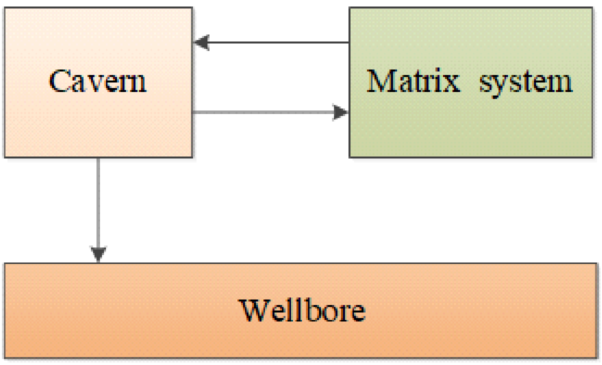


Figure 5 - Physical model of a cavernous-porous reservoir.

Mathematical model of porous-cavernous-fracture filtration. For a situation where there are three reservoir pore systems, caverns and fractures exist simultaneously, in accordance with the law of fluid exchange between the systems and depending on whether fluid moves into the wellbore, this type of ternary medium model is a single permeability model and a double permeability model. permeability for three media. Among them, the model with three pores and one permeability can be divided into two models according to the different environments encountered in the wellbore. This is a three-fracture model with one karst permeability.

When the fracture system serves as the only filtration channel for fluid flow into the wellbore, and the karst caverns and matrix system complement the filtration into the fracture system (Figure 6a), the mathematical model looks like this:

$$\begin{cases} \frac{k_f}{\mu}\nabla^2 p_f + \frac{\alpha_{m-f}}{\mu}\left(p_m - p_f\right) + \frac{\alpha_{c-f}}{\mu}\left(p_c - p_f\right) = \beta_f \frac{\partial p_f}{\partial t} \\ \frac{k_m}{\mu}\nabla^2 p_m - \frac{\alpha_{m-f}}{\mu}\left(p_m - p_f\right) = \beta_m \frac{\partial p_m}{\partial t} \\ \frac{k_c}{\mu}\nabla^2 p_c - \frac{\alpha_{c-f}}{\mu}\left(p_c - p_f\right) = \beta_c \frac{\partial p_c}{\partial t} \end{cases} \quad (8)$$

Where, α_{c-f} is the shape factor of the channel between caverns and fractures, $1/m^2$.

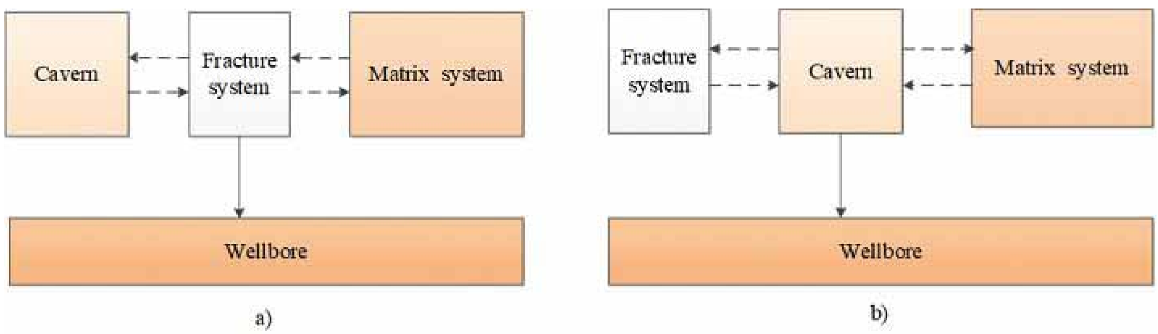
When the system of karst caverns serves as the only filtering channel for fluid flow into the wellbore, and the system of fractures and matrices, respectively, supplements the fluid in the system of karst caverns (Figure 6b), the mathematical model looks as follows:

$$\begin{cases} \frac{k_c}{\mu}\nabla^2 p_c + \frac{\alpha_{m-c}}{\mu}\left(p_m - p_c\right) + \frac{\alpha_{f-c}}{\mu}\left(p_f - p_c\right) = \beta_c \frac{\partial p_c}{\partial t} \\ \frac{k_m}{\mu}\nabla^2 p_m - \frac{\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_m \frac{\partial p_m}{\partial t} \\ \frac{k_f}{\mu}\nabla^2 p_f - \frac{\alpha_{f-c}}{\mu}\left(p_f - p_c\right) = \beta_f \frac{\partial p_f}{\partial t} \end{cases} \quad (9)$$

Where α_{c-f} - is the shape factor of the channel between caverns and fractures, $1/\text{м}^2$.

When the system of karst caverns serves as the only filtering channel for fluid flow into the wellbore, and the system of fractures and matrices, respectively, supplements the fluid in the system of karst caverns (Figure 6b), the mathematical model looks as follows:

$$\begin{cases} \frac{k_c}{\mu}\nabla^2 p_c + \frac{\alpha_{f-c}}{\mu}\left(p_f - p_c\right) = \beta_c \frac{\partial p_c}{\partial t} \\ \frac{k_f}{\mu}\nabla^2 p_f - \frac{\alpha_{f-c}}{\mu}\left(p_f - p_c\right) + \frac{\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_f \frac{\partial p_f}{\partial t} \\ \frac{k_m}{\mu}\nabla^2 p_m - \frac{\alpha_{m-c}}{\mu}\left(p_m - p_f\right) = \beta_m \frac{\partial p_m}{\partial t} \end{cases} \quad (10)$$



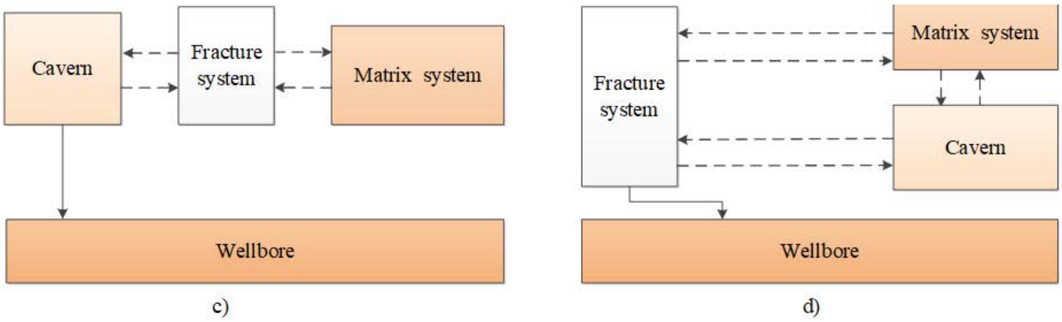


Figure 6 - Physical model of porosity-vuggy-fracture reservoir.

When a fracture and a system of karst caverns serve as filtering channels for the simultaneous flow of fluid into the wellbore, and the matrix system complements the filtration of a system of fractures and a system of karst caverns (Figure 6d), then the mathematical model looks as follows:

$$\begin{cases} \frac{k_f}{\mu}\nabla^2 p_f + \frac{\alpha_{m-f}}{\mu}\left(p_m - p_f\right) + \frac{\alpha_{c-f}}{\mu}\left(p_c - p_f\right) = \beta_f \frac{\partial p_f}{\partial t} \\ \frac{k_m}{\mu}\nabla^2 p_m - \frac{\alpha_{m-f}}{\mu}\left(p_m - p_f\right) - \frac{\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_m \frac{\partial p_m}{\partial t} \\ \frac{k_c}{\mu}\nabla^2 p_c - \frac{\alpha_{c-f}}{\mu}\left(p_c - p_f\right) + \frac{\alpha_{m-c}}{\mu}\left(p_m - p_c\right) = \beta_c \frac{\partial p_c}{\partial t} \end{cases} \quad (11)$$

Filtration of multimedia model. In some complex carbonate reservoirs, fractures, caverns and matrix are very heterogeneous and several types of filtration media can exist. Therefore, it can be described by a mathematical model of filtering the n-matrix of media:

$$\begin{cases} \frac{k_1}{\mu}\nabla^2 p_1 + \frac{\alpha_1}{\mu}\left(p_2 - p_1\right) = \beta_1 \frac{\partial p_1}{\partial t} \\ \frac{k_2}{\mu}\nabla^2 p_2 + \frac{\alpha_1}{\mu}\left(p_1 - p_2\right) + \frac{\alpha_2}{\mu}\left(p_3 - p_2\right) = \beta_2 \frac{\partial p_2}{\partial t} \\ \frac{k_3}{\mu}\nabla^2 p_3 + \frac{\alpha_2}{\mu}\left(p_2 - p_3\right) + \frac{\alpha_3}{\mu}\left(p_4 - p_3\right) = \beta_3 \frac{\partial p_3}{\partial t} \\ \cdots \\ \frac{k_{n-1}}{\mu}\nabla^2 p_{n-1} + \frac{\alpha_{n-2}}{\mu}\left(p_{n-2} - p_{n-1}\right) + \frac{\alpha_{n-1}}{\mu}\left(p_n - p_{n-1}\right) = \beta_{n-1} \frac{\partial p_{n-1}}{\partial t} \\ \frac{k_n}{\mu}\nabla^2 p_n + \frac{\alpha_{n-1}}{\mu}\left(p_{n-1} - p_n\right) = \beta_n \frac{\partial p_n}{\partial t} \end{cases} \quad (12)$$

Where α_n is the form factor between the second matrix medium and the matrix medium, $1/m^2$; β_n is the accumulation factor of the n-th matrix medium, Pa^{-1}; p_n is the pressure of the n-th system of the matrix medium, Pa; k_n - permeability of the n-th matrix medium, m^2.

After nearly half a century of theoretical research, the fracture filtration mathematical model is largely complete, and the media matrix filtration mathematical model can basically summarize the filtration characteristics of various types of fractured oil and gas reservoirs. Hence, future research should focus on n-matrix environments.

Discussion. Since the process of accumulation of hydrocarbons is the migration of fluids from the source formation to the target formation under the influence of various driving forces, during the accumulation of oil and gas, light fluids move into the pore space of the reservoir. initial water is displaced into oil and gas reservoirs. Consequently, all oil and gas formations contain a certain amount of formation water, but some formations have a low water saturation, which is lower than the mobile water saturation of the formation. For this type of oil and gas reservoirs, the movement is considered to be single-phase filtration. For oil and gas reservoirs with a high formation water content, the filtration process includes at least two-phase fluids. Almost most of the reservoir filtration is related to multiphase filtration. The general mathematical model of three-phase filtration is presented in equation (13) and equation (14) [23-29]:

$$\nabla \bullet \left[\alpha_c \frac{kk_{rl}}{\mu_l B_l} \left(\nabla p_l - \gamma_l \nabla Z \right) \right] + \frac{q_{lsc}}{V_b} = \beta_c \frac{\partial}{\partial t} \left(\frac{\varphi S_l}{B_l} \right), \left(l = o, w \right) \quad (13)$$

$$\nabla \bullet \left[\alpha_c \frac{kk_{rg}}{\mu_g B_g} \left(\nabla p_g - \gamma_g \nabla Z \right) \right] + \nabla \bullet \left[\alpha_c \frac{kk_{ro}}{\mu_o B_o} \left(\nabla p_o - \gamma_o \nabla Z \right) \right] + \frac{q_{gsc}}{V_b} = \beta_c \frac{\partial}{\partial t} \left(\frac{\varphi S_g}{B_g} + \frac{\varphi R_s S_o}{B_g} \right). \quad (14)$$

Where β_c is the conductivity conversion factor; α_c volume conversion coefficient, k - absolute formation permeability m^2, μ_i - phase viscosity, $Pa \cdot s$; p_i - phase pressure Pa, k_{ri}- phase relative permeability, fraction; S_i is the phase saturation, %; B_i is the volumetric coefficient of the phase, m^3 / m^3; γ_i - the specific gravity of the fluid, R_s is the ratio of dissolved gas and oil, V_b is the volume of the block, m^3, Z is the height, m.

Conclusion. Based on the results of the literature review, filtration mechanisms in fractured carbonate reservoirs were determined, and the filtration capacity of natural fractures was shown, the mechanism of fluid exchange between the cavity-fracture medium and the matrix was shown. Mathematical models of multilayer and multiphase filtration in cracks have been established.

When modeling a multiphase and multilayer connection of a complex system of channels, as well as a multiphase mechanism of fluid exchange in fractures of different scales, a discrete mathematical model of filtration in fractures is mainly used. In subsequent studies, attention should be paid to the combination of experimental and numerical modeling, the combination of fluid mechanics and solid mechanics, taking into account the heterogeneous characteristics of the reservoir and the filtration mechanisms of fractured reservoirs. Thus, there is still research to be done on the theory of filtration of fractured carbonate reservoirs. Based on this literature review, further studies of the filtration mechanism of fractured carbonate reservoirs should take into account the following aspects:

• A combination of fluid mechanics and solid mechanics, since fractured carbonate reservoirs contain fluids such as oil, gas and water. The filtration of each fluid is very different. During filtration, the pressure field changes, which causes changes in the local stress field, which leads to different laws of opening and closing cracks of different scales. Therefore, it is necessary to take into account this process. It is also necessary to take into account the laminar and turbulent filtration modes.

• Fractures depend on various factors such as structural heterogeneity, lithology and rock physical properties; in order to characterize fractures of different scales and analyze their influence on the filtration law, it is necessary to take into account the heterogeneity of the reservoir.

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ЖАРЫҚШАҚТЫ КОЛЛЕКТОРЛАРДАҒЫ СҰЙЫҚТЫҚТЫ СҮЗІЛУ МЕХАНИЗМДЕРІН ТАЛДАУ

Аннотация. Жарылған карбонатты коллектор әлемдегі коллекторлардың маңызды түрлерінің бірі, әрі оны сүзу механизмдері мұнай инженериясындағы зерттеулердің өзекті тақырыбы болып есептеледі. Барлау мен игеру тереңдеген сайын көптеген жарықтары бар теңіз резервуарлары табылды. Алайда, қолданыстағы теориялар мұндай ортадағы сұйықтық ағымының механизмдерін дәл сипаттай алмайды. Матрица мен жарықтар жүйесі әртүрлі өткізгіштік қасиеттерге ие және аралық ағын, жинақтау коэффициенті сияқты бірнеше параметрлерге байланысты. Карбонатты коллектордағы табиғи жарықтар, каверналар мен матрицалардың әртүрлі комбинациясына байланысты коллекторлардың осы түріне аналитикалық модель құру оңай емес. Қолданыстағы теориялар мен әдістерді кеңінен зерттеу негізінде жарықтардың өткізу қабілеттілігінің сипаттамалары, әртүрлі кеуекті орта арасындағы сұйықтық алмасу, математикалық модельдер, сондай-ақ коллектордың осы түріндегі сүзу теориясын зерттеудің даму перспективасы жүйелі түрде қарастырылады. Бұл мақалада резервуардың бұл түрі екі модельге бөлінеді: екі орталы модель және үш орталы модель. Табиғи жарықтығы бар коллекторлар ағынының механикасы талқыланды. Әртүрлі физикалық және математикалық модельдер орнатылды. Сондай-ақ, үш фазалы сұйықтықтардың (мұнай, су, газ) екі және үш кеуектілігі бар және жарылған қабаттардағы өткізгіштігі бар орталардағы ағын модельдері талқыланды. Сонымен қатар бірнеше аналитикалық модельдердің қасиеттері мен қолданысы сипатталған нәтижесінде олардың артықшылықтары мен кемшіліктері көрсетіліп, қарастырылмаған бағыттары айқындалды. Қазақстанда карбонатты кен орындары көп болғандықтан, алынған нәтижелер жарықшақ коллекторлардағы флюидтер ағымының моделін әзірлеуді жетілдіру, тереңірек зерттеу үшін колданылуы мүмкін.

Түйінді сөздер: математикалық модель; жарықшақты коллектор; матрицалардың сипаттамасы; сүзілу механизмі; карбонатты коллекторлар.

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АНАЛИЗ МЕХАНИЗМОВ ФИЛЬТРАЦИИ ФЛЮИДОВ В ТРЕЩИНОВАТЫХ КОЛЛЕКТОРАХ

Аннотация. Карбонатный коллектор с трещинами является одним из наиболее важных типов коллекторов в мире, и механизмы его фильтрация были актуальной темой исследований в нефтяной инженерии. По мере углубления разведки и разработки были обнаружены многие морские резервуары с трещинами. Однако существующие теории не могут точно охарактеризовать механизмы течения жидкости в таких средах. Матрица и система трещин имеют разные свойства проводимости и зависят от нескольких параметров, таких как межпоровый поток, коэффициент накопления. В связи с различной комбинацией естественной трещины, каверны и матрицы в карбонатном коллекторе построить аналитическую модель для такого типа коллекторов непросто. На основе обширных исследований существующих теорий и методов систематически рассматриваются характеристики пропускной способности трещин, обмен флюидом между различными пористыми средами, математические модели, а также перспективы развития исследования теории фильтрация в данном типе коллектора. В этой статье этот тип резервуара разделен на две модели: модель с двумя средами и модель с тремя средами. Обсуждается механика потока естественно трещиноватых коллекторов. Устанавливаются различного рода физические и математические модели. Также обсуждаются модели течения трехфазных флюидов (нефть, вода, газ) в средах с двойной и тройной пористостью и проницаемостью в трещиноватых пластах. Эта статья может быть использована для дальнейшей разработки и изучения модели течения флюидов в трещиноватых коллекторах, так как в Казахстане имеется множество карбонатных месторождений.

Ключевые слова: математическая модель; трещиноватый коллектор; характеристика матриц; механизм фильтрации; карбонатные коллекторы.

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