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MODELING THE FILTRATION FLOW OF A BINARY GAS MIXTURE IN A POROUS LAYER TAKING INTO ACCOUNT ADSORPTION AND DESORPTION PROCESSES

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Abstract. The development of modern technologies in the field of mining operations related to oil and natural gas production, greenhouse gas storage, and mining safety leads to the need to solve a wide range of problems related to filtration and gas exchange in rock formations that are porous media. In many of these problems, it is essential to consider the dynamics of individual components of gas mixtures. This paper considers a number of model problems on the filtration flow of a mixture of two gases. For simplicity, it was assumed that the gases are practically no different, except for their adsorption-desorption properties, expressed in the adsorption rate and the adsorbent capacity with respect to these gases. All other physical and chemical parameters of the gases are the same. Such physical simplification is important for emphasizing and highlighting the manifestation of adsorption effects in gas mixtures. The research presented herein is founded on the equations that describe the conservation of a designated component, factoring in diffusion movement, the Darcy relationship, and the extended Langmuir adsorption equation, which considers the competitive interactions of gas components during adsorption.The stage of dynamic adsorption is considered, i.e. such a characteristic part of the process, when the filtration flow and adsorption phenomena are mutually dependent and, accordingly, have a significant effect on each other. Some examples of filtration flows that may be of interest in the practical aspect, and where each component of the mixture is important, are considered. Through a one-dimensional approach, equations for molar concentrations are derived, and the boundary conditions for the three model scenarios are discussed. The solution is computed numerically via an explicit scheme. The study includes graphs depicting the changes in molar concentrations of the components along the reservoir's length for different moments of time. The results demonstrate that both the adsorption rate and the adsorbent's capacity for specific gas mixture components have a substantial impact on the dynamic characteristics of the process. An assessment of the calculation's accuracy is included. The findings reveal not only the kinetic behavior of the gas mixture but also that of each component individually, which is important for understanding gas exchange processes.

Keywords: porous medium, gas, filtration, adsorption, desorption.

1. Introduction

The principles governing the flow of gases and liquids during filtration have been extensively advanced through hydrogeological research and innovations in oil and gas extraction technologies [1]. The laws of motion are based on the equations of conservation of mass and an expression that takes into account the resistance of the medium to the moving mass. Typically, due to the low filtration velocities, the Darcy equation is used. In numerous cases, a gas mixture can be considered as a homogeneous mass with averaged physical parameters. However, in conditions where phase transitions or chemical transformations occur, as well as the impact of microorganisms on gas exchange, there is a need for a more detailed examination of the flow and consideration of the characteristics of each component constituting the gas mixture.

One of such areas that has received great impetus at present is the study of filtration flows taking into account adsorption-desorption phenomena. The relevance of such problems arises during gas exchange processes in soils, but the greatest interest is presented by problems related to the extraction of natural gases from coal seams and the storage of greenhouse gases. Significant focus in the academic literature is directed towards gases such as CO_2, CH_4, N_2, and H_2O, which play roles in various technological processes or are found in natural seams. A characteristic of these gases is their ability to be adsorbed within coal seams, with H_2O also undergoing condensa-

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tion. Due to the interaction of these gases with each other and with the surfaces of the adsorbent, a complex flow pattern arises, which must take into account the dynamics of adsorption or desorption of each component.

The theory governing the adsorption-desorption processes in a multicomponent gas environment relies on the extended Langmuir equation, which is based on the dynamic local equilibrium of the adsorption process [6]:

$$a_J = \frac{A_J \gamma_J p_J / p_A}{\left[1 + \sum_{I=1}^{N} \gamma_I p_I / p_A\right]}, \tag{1}$$

where α_J is adsorption, kg/m^3; p_J is the partial pressure of the J-th component, Pa; p_A is the atmospheric pressure, Pa; γ_J are the coefficients characterizing the rate of the process; A_J is the value characterizing the capacity of the adsorbent for a given component, kg/m^3.

Equation (1) describes adsorption on the surface, but, as noted in [7], can effectively describe both surface adsorption and the filling of micropores despite their distinct physical characteristics, given that the coefficients are selected correctly.

A similar adsorption law for the specified gases is corroborated by various research works, including [8, 9], and the experimental results from [10, 11] enable the application of the determined coefficients as approximations. It is clear from equation (1) that the process of adsorption is primarily influenced by the partial pressures of the gases present in a specific location. Consequently, changes in the gas mixture's composition and its delivery to the porous medium can significantly impact the outcome of the process. As a result, a range of challenges emerges related to the substitution or exchange of one gas for another, which is presently a focus of considerable research.

The purpose of this article is to develop a mathematical model that describes the filtration dynamics of a bicomponent gas mixture, considering the adsorption and desorption characteristics of each component, and to analyze how key parameters affect the behavior of these components.

2. Methods

We will assume that the temperature and pressure in the formation are such that the gas components of the mixture have only adsorption properties (the presence of water vapor, due to additional physical effects associated with phase transitions, requires separate consideration). Then the mass conservation equation for the J-th gas component will have the form

$$\frac{\partial(\varepsilon\rho c_J)}{\partial t} + \frac{\partial(\varepsilon\rho u c_J)}{\partial x} + \frac{\partial(\varepsilon\rho v c_J)}{\partial y} = \frac{\partial}{\partial x}\left(\rho D_{EF\,J}\frac{\partial c_J}{\partial x}\right) + \frac{\partial}{\partial y}\left(\rho D_{EF\,J}\frac{\partial c_J}{\partial y}\right) + g_J, \tag{2}$$

where t is time, s; x, y are coordinate axes, m; u, v are filtration velocity, m/s; ε is porosity; ρ is gas density, kg/m^3; c is mass concentration of the J-th component; D_{EFJ} is effective diffusion coefficient of the J-th component, m^2/s; g is mass influx or outflow of the component under consideration associated with the adsorption process, kg/(m^{3}s).

The filtration velocity of the mixture will be determined from the Darcy equation [1]

$$u = -\frac{K}{\mu} gradp, \tag{3}$$

where K is the permeability, m^2; p is the pressure, Pa; $\mu = \sum_{1}^{N} c_I \mu_I$, Pa·s; μ_I – coefficient of dynamic viscosity of the I-th component, Pa·s. For a homogeneous gas or mixture with a constant composition and at a constant temperature T, equations (2), when added together over J, become the well-known equation for pressure

$$\frac{\partial p}{\partial t} + \frac{K}{2\mu}\left(\frac{\partial^2 p^2}{\partial x^2} + \frac{\partial^2 p^2}{\partial y^2}\right) + g\frac{RT}{\varepsilon}, \tag{4}$$

where R is the universal gas constant, J/(mol K); T is the temperature, K.

In our case, for simplicity, we will consider a binary mixture, then from equations (2) we can move on to a system for molar concentrations, taking into account that

$$p_J = n_J RT, \tag{5}$$

where n_J is the molar concentration of the J-th component, mol/m^3.

As a first approximation, we consider the one-dimensional case. After transformations for a binary gas mixture, we can write

$$\begin{aligned} Scb\frac{\partial n_1}{\partial t} &= \varepsilon m_1 K \cdot Scb_2 \frac{\partial}{\partial x}\left(\frac{n_1}{\mu}\frac{\partial p}{\partial x}\right) + \varepsilon m_2 K \cdot Zn^{-1} A_1 \gamma_1 \gamma_2 (RT/p_A)^2 n_1 \frac{\partial}{\partial x}\left(\frac{n_2}{\mu}\frac{\partial p}{\partial x}\right) + \\ &+ \varepsilon D_{EF} m_1 \cdot Scb_2 \left[\frac{\partial^2 n_1}{\partial x^2} - \frac{\partial}{\partial x}\left(n_1 \frac{\partial \ln(\rho/\rho_0)}{\partial x}\right)\right] + \\ &+ \varepsilon D_{EF} m_2 \cdot Zn^{-1} A_1 \gamma_1 \gamma_2 (RT/p_A)^2 n_1 \left[\frac{\partial^2 n_2}{\partial x^2} - \frac{\partial}{\partial x}\left(n_2 \frac{\partial \ln(\rho/\rho_0)}{\partial x}\right)\right], \end{aligned} \tag{6}$$

$$\begin{aligned} Scb\frac{\partial n_2}{\partial t} = {} & \varepsilon m_2 K\cdot Scb_1\frac{\partial}{\partial x}\left(\frac{n_2}{\mu}\frac{\partial p}{\partial x}\right)+\varepsilon m_1 K\cdot Zn^{-1}A_2\gamma_1\gamma_2\left(RT/p_A\right)^2 n_2\frac{\partial}{\partial x}\left(\frac{n_1}{\mu}\frac{\partial p}{\partial x}\right)+ \\ & +\varepsilon D_{EF}m_2\cdot Scb_1\left[\frac{\partial^2 n_2}{\partial x^2}-\frac{\partial}{\partial x}\left(n_2\frac{\partial\ln(\rho/\rho_0)}{\partial x}\right)\right]+ \\ & +\varepsilon D_{EF}m_1\cdot Zn^{-1}A_2\gamma_1\gamma_2\left(RT/p_A\right)^2 n_2\left[\frac{\partial^2 n_1}{\partial x^2}-\frac{\partial}{\partial x}\left(n_1\frac{\partial\ln(\rho/\rho_0)}{\partial x}\right)\right], \end{aligned} \tag{7}$$

where $Zn=\left[1+RT/p_A\sum_{N=1}^{2}\gamma_M n_M\right]^2$, $Scb_1=\varepsilon m_1+Zn^{-1}A_1\gamma_1\frac{RT}{p_A}\left[1+RT/p_A\gamma_2 n_2\right]$,

$Scb_2=\varepsilon m_2+Zn^{-1}A_2\gamma_2\frac{RT}{p_A}\left[1+RT/p_A\gamma_1 n_1\right]$, $p=\left(n_1+n_2\right)RT$, $\rho=m_1n_1+m_2n_2$,

$Scb=Scb_1\cdot Scb_2-Zn^{-2}\left(RT/p_A\right)^4\left(\gamma_1\gamma_2\right)^2A_1A_2n_1n_2$, m – molar mass, kg/mol.

From equations (6), (7) it is evident that the formal replacement of one index by another does not change the equations. The effective diffusion coefficient D_{EF} in equations (6), (7), according to [12] is defined as $D_{EF}=\varepsilon D/\beta$, where β is the tortuosity coefficient. The tortuosity coefficient is an adjustable coefficient associated with the internal structure of the pore space. In [12] a number of formulas are given, which can differ significantly from each other. In [13] this coefficient is given in the form

$$\beta=\varepsilon+1.5(1-\varepsilon). \tag{8}$$

As for the diffusion coefficient D, formulas for its calculation in binary gas systems are given in [14]. In our case, we will represent this value in the form

$$D=D_0\frac{\left(T/T_0\right)^{3/2}}{\left(p/p_A\right)}, \tag{9}$$

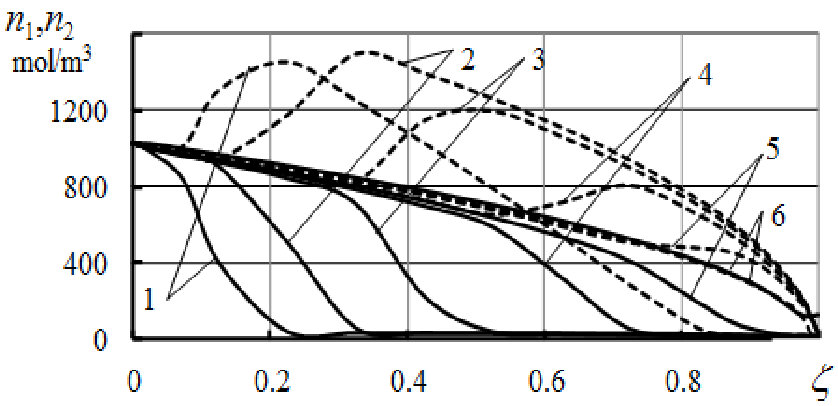
where D_0 is taken to be equal to 10^{-5} m^2/s; T_0 is the initial temperature, K. It is important to emphasize the dependence of this coefficient on temperature and pressure. In order to more clearly show the influence of adsorption or desorption, we will assume that the two components of the mixture are no different from each other except for the adsorption-desorption characteristics, i.e. we will consider gases with different values of A_J and γ_J, and all other physical and chemical parameters are the same. The presence of two gas components leads to an interesting variety of physical problems.

In this paper, we will consider three problems that have important practical applications. The first problem is related to the injection of a binary mixture into a seam. Due to different adsorption-desorption parameters, the constituent components will move differently in a porous body. The second practically important problem arises when one gas is displaced by another. For example, CO_2 gas is currently used for its burial and for displacing CH_4 from oil-bearing strata [9, 15]. Here, adsorption parameters can also play a significant role in the process. The third problem is of interest when the blown-through layer is almost instantly sealed on both sides, then some mass of gas remains in it, the components of which are somehow distributed over the volume of the pore space. Let us now show the results of calculations of the indicated problems for a one-dimensional case. We will carry out a numerical solution of the problem using dimensionless parameters $\tau = t/T_M$ ($T_M = \mu \cdot L^2/(K \cdot p_A)$ is the time scale, s) and $\zeta = x/L$ (L is the length of the formation, which we will take as 1 m).

Gas injection into the seam. We will assume that when gas is injected into the seam, we know the values of pressure at the gas inlet and outlet. In addition, we know the composition of the injected gas, so the values of $n_J = N_J$ at the inlet are known. At the outlet, these values are unknown, only their sum is known, since the outlet pressure is known. Thus, when $\zeta = 0$ $RT(N_1 + N_2) = p_0$ (p_0 – inlet pressure).

At the outlet from the seam we will take the pressure to be atmospheric, and for the components n_1 and n_2 we will use "soft" conditions, which are often used in the literature when there are no specific values. In the book [16] this problem of computational fluid mechanics is well covered. We will assume that if the concentration, for example n_1 is ten times greater than n_2, then at the outlet at $\zeta = 1$ $\left.\frac{\partial n_2}{\partial \zeta}\right|_{\zeta=1} = 0$, and n_1 is taken to maintain atmospheric pressure, i.e. $(n_1)_{\zeta=1} = {p_1}/{RT} - (n_2)_{\zeta=1}$ ($p_1 = p_A$ – atmospheric pressure). In the case where n_1 and 12 are quantities of the same order, we will assume that at some time step τ_M we have $\left.\frac{\partial n_2}{\partial \zeta}\right|_{\zeta=1} = 0$ and $(n_1)_{\zeta=1} = {p_1}/{RT} - (n_2)_{\zeta=1}$, and on the next τ_{M+1} we swap the components, i.e. $\left.\frac{\partial n_1}{\partial \zeta}\right|_{\zeta=1} = 0$, and $(n_2)_{\zeta=1} = {p_1}/{RT} - (n_1)_{\zeta=1}$. Thus, due to such a combination, we maintain the outlet pressure in the solution.

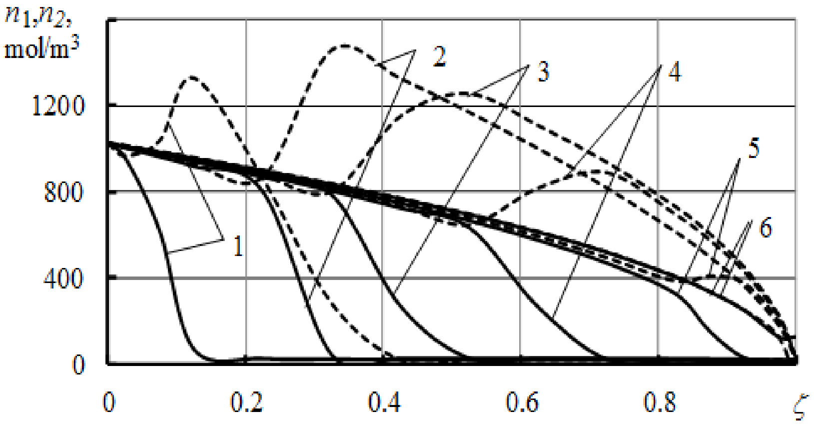
Fig. 1 shows the curves n_1 and n_2 along the reservoir for the case when $A_1 = 100$, $A_2 = 0$, $\gamma_1 = \gamma_2 = 0.02$, $N_1 = N_2$. Here, a mixture of gases with such adsorption characteristics is pumped at a pressure of 5.0 MPa into a layer with the same mixture of gases located at one atmosphere. As depicted in Fig. 1, the molar concentrations of the primary component effectively establish a front at the initial moment, which subsequently expands and disperses during its movement. The second component does not undergo adsorption; rather, it travels in the form of a soliton, whose apex initially rises and then gradually declines. Since N_1 is equal to N_2 at the beginning, the values of n_1 and n_2 within the formation's depth tend to converge over time. This phenomenon is clearly illustrated by curves 5 and 6. In the first half of the formation, curves 5 begin to overlap, although they still exhibit significant differences in the second half at the exit. In contrast, curves 6 have nearly merged entirely.



Curves: 1 – τ = 0.004; 2 – 0.016; 3 – 0.036; 4 – 0.064; 5 – 0.084; 6 – 0.32
Solid line - n_1, dotted line - n_2.

Figure 1 – Distribution curves of molar concentrations along the length of the formation ζ at different dimensionless times during injection of a gas mixture

We see approximately the same picture in Fig. 2, where the curves of components n_1 and n_2 are shown with $A_1 = A_2 = 100$, $\gamma_2 = 0.01$ and $\gamma_1 = 0.1$. The tenfold difference in γ_J produces a clear distinction in the adsorption of these components. Thus, the first curves closely resemble those in the first figure, whereas the second curves are more compressed towards the horizontal axis. This is clearly illustrated by the first curve. The resulting soliton is much narrower than the one presented in Fig. 1. At this stage, the fifth curves nearly coincide, diverging only at the exit, while the sixth curves are entirely identical.

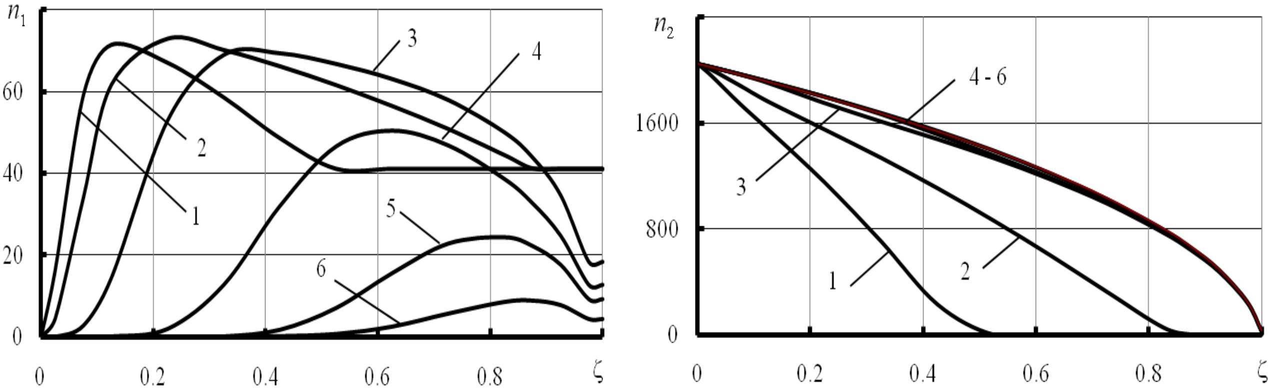


Curves: 1 – τ = 0.004; 2 – 0.04; 3 – 0.088; 4 – 0.156; 5 – 0.232; 6 – 0.46
Solid line - n_1, dotted line - n_2.

Figure 2 – Distribution curves of molar concentrations along the length of the formation at different dimensionless times during injection of a gas mixture.

Displacement of one gas by another. In this series we will show the following variants associated with different values of A_1 and A_2. The displacing gas is supplied at 5.0 MPa, and the displaced gas is at atmospheric pressure. The boundary condition at $\zeta = 0$ for the displaced component is determined by the equality of the input flow rate to zero, i.e. $q_2 = U_0 \cdot (n_2)_{\zeta=0} - D_{EF} \left. \frac{\partial n_2}{\partial \zeta} \right|_{\zeta=0} = 0$, ($U_0$ – the velocity of the filtration flow in the initial section of the formation), then for the displacing component $(n_1)_{\zeta=0} = N_1 = {p_0}/{RT} - (n_2)_{\zeta=0}$. Here the input pressure is $p_0 = 5.0$ MPa, and the output pressure is atmospheric p_A. At the right end, the conditions are the same as in the first case.

In Fig. 3 A) the curves n_1 are shown for the displaced component with $A_1 = 100$ and $\gamma_1 = 0.02$, and in Fig. 3 B) - for the displacing component n_2 with $A_2 = 0$. From Fig. 3 A) it is clearly seen how the resulting soliton of the displaced gas shifts towards the outlet, gradually decreasing. The displacing gas is not adsorbed here, therefore it fills the pore space rather quickly and already at $\tau = 0.06$ curve 4 practically characterizes the steady flow in the formation. The following curves 5 and 6 slightly clarify this state. The outgoing gas (curve 6 in Fig. 3 A)) at this time makes up a small proportion of the mixture at the outlet.



A)

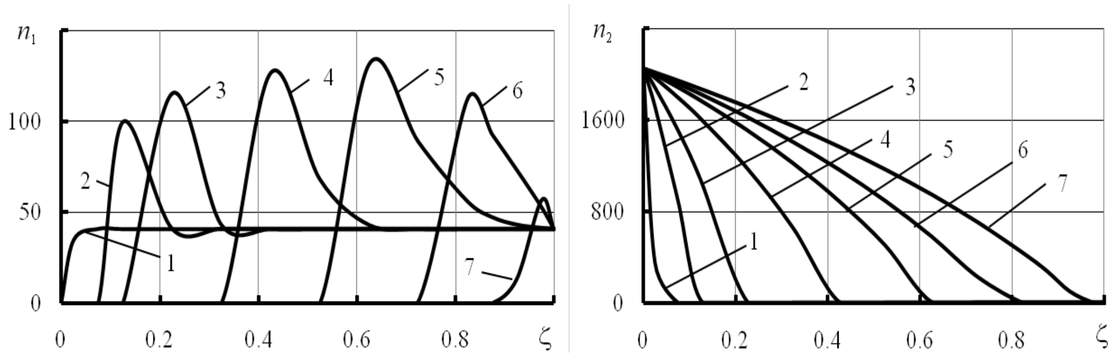
B)

Curves: 1 – $\tau = 0.0012$; 2 – 0.004; 3 – 0.02; 4 – 0.06; 5 – 0.1; 6 - 0.188

Figure 3 – Distribution curves of molar concentrations along the length of the reservoir at different dimensionless times during the displacement process.

The next pair in Fig. 4 shows the curves of displacement of gas with $A_1 = 0$ by gas with $A_2 = 100$ and $\gamma_2 = 0.02$. Here the displaced gas is not adsorbed, therefore solitons are more clearly expressed. The curves for the displacing gas are similar to the curves of the same gas in Fig. 1, since frontal displacement occurs.

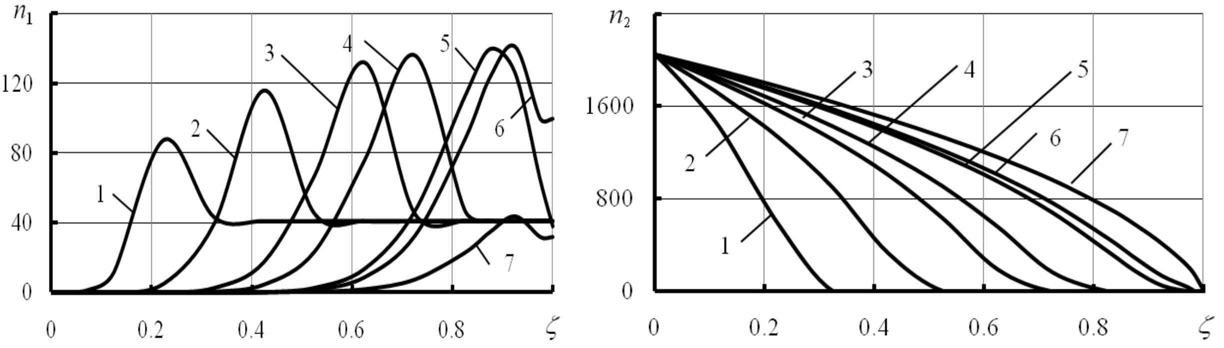
Fig. 5 shows the displacement curves of the same gas, i.e. this is a problem of gas injection into a geological formation. If we add n_1 and n_2 and multiply by RT, we obtain the change in pressure in the formation when injecting adsorbing gas with $A = 100$ and $\gamma = 0.02$.



A) B)

Curves: 1 – τ = 0.00004; 2 – 0.00054; 3 – 0.00208; 4 – 0.00848; 5 – 0.0194; 6 – 0.03; 7 – 0.0461

Figure 4 – Distribution curves of molar concentrations along the length of the reservoir at different dimensionless times during the displacement process.

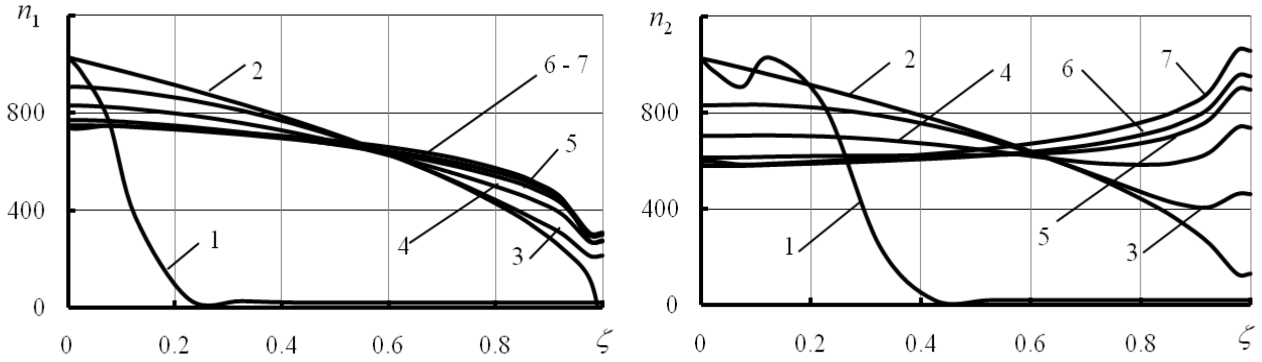


A) B)

Curves: 1 – τ = 0.004; 2 – 0.012; 3 – 0.024; 4 – 0.032; 5 – 0.048; 6 – 0.052; 7 – 0.068

Figure 5 – Distribution curves of molar concentrations along the length of the reservoir at different dimensionless times during the displacement process.

Setting pressure within the geological formation. We will now present the results of the calculations regarding the distribution of components during the formation blockage process. The initial segment of this issue mirrors the first problem discussed earlier. A gas mixture is introduced into the formation, and after a duration of τ_*, the supply ceases, resulting in the blockage of the formation. In this initial segment, the boundary conditions remain consistent with those previously outlined. In the subsequent segment of the problem, impermeability conditions are established on both the left and right sides $\left.\frac{\partial n_1}{\partial \zeta}\right|_{\zeta=0}=\left.\frac{\partial n_2}{\partial \zeta}\right|_{\zeta=0}=\left.\frac{\partial n_1}{\partial \zeta}\right|_{\zeta=1}=\left.\frac{\partial n_2}{\partial \zeta}\right|_{\zeta=1}=0$, which in this case indicates that the mass flows through the wall are zero. In this case, the pressure gradient inside the pore system of the formation forms internal gas flows, which should lead to the establishment of a certain pressure value. Fig. 6 shows the distribution curves of n_1 and n_2 for the case when p_0 = 5.0 MPa, $p_1 = p_A$, A_1 = 200, A_2 = 50, $\gamma_1 = \gamma_2$ = 0.02.

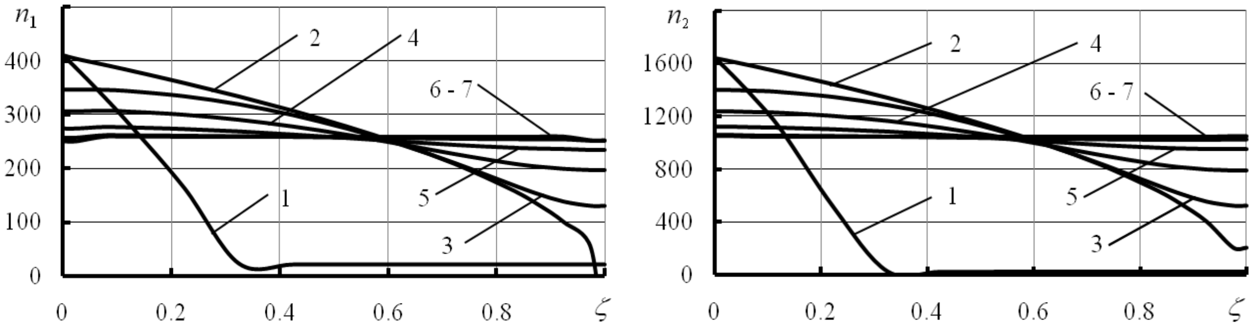


A) B)

Curves: 1 – $\tau = 0.004$; 2 – 0.2; 3 – 0.204; 4 – 0.212; 5 – 0.224; 6 – 0.24; 7 – 0.276

Figure 6 – Distribution curves of molar concentrations along the length of the formation at different dimensionless times during the process of establishing equilibrium

Here in Fig. 6 A) and 6 B), curves 1 correspond to the beginning of the gas injection process. Curves 2 correspond to the time of formation plugging at $\tau = \tau_* = 0.2$. Further, curves 3–7 demonstrate the distributions of the components when a constant pressure is established. If we add the values of n_1 and n_2 corresponding to curves 7, then, in accordance with formula 5, we obtain a pressure value p that exhibits a minor deviation, remaining nearly constant. This indicates that during blockage the equilibrium pressure is established relatively quickly, while the components, as can be seen from this figure, are far from being in an equilibrium state. At this point in time, one can say that the dynamic stage of adsorption of the two-component gas has concluded [17]. The diffusion process will continue but the temporal scale of its occurrence will be distinct and more extended. Here the main role will be played by the effective diffusion coefficient. We will not consider this problem in this article. In order to determine the influence of the γ_J values on the process, the variant with $A_1 = A_2 = 100$ and $\gamma_1 = 0.04$ and $\gamma_2 = 0.01$ was calculated. This variant is not shown here, since the distribution curves of n_1 and n_2 are very close to those shown in Fig. 6. This is due to the fact that the ratio $\gamma_1 A_1 / \gamma_2 A_2$, both in the previous variant and in this one, are the same, so the influence of adsorption is approximately the same. It follows that two different components with different A_J and γ_J during gas injection and plugging can have the most diverse distributions at the end of the dynamic stage of the process depending on both the adsorption-desorption parameters and the value of the supplied pressure. As a result, it is of interest for control to consider the case with identical adsorption-desorption parameters of the components. This is shown in Fig. 7. Here it was assumed that $\gamma_1 = \gamma_2 = 0.02$ and $A_1 = A_2 = 100$. The difference is only in the fractions of the components, i.e. $N_1 = 410$, $N_2 = 1640$. From the figure, it is apparent that the corresponding curves are nearly indistinguishable from one another. There are no oscillations observed, the components are established at the same rate as the pressure. This is to be anticipated, given that the gas is virtually the same.



A) B)

Curves: 1 – $\tau = 0.004$; 2 – 0.2; 3 – 0.204; 4 – 0.212; 5 – 0.224; 6 – 0.244; 7 – 0.288

Figure 7 – Distribution curves of molar concentrations along the length of the formation at different dimensionless times during the process of establishing equilibrium

In the context of establishment issues, evaluating the accuracy of the calculations is straightforward. In the final scenario, curves 2 allow for the immediate determination of the mole count in the sample post-layer plugging; this figure, accounting for the adsorbed mass, is 144 mol/m^2. Once pressure equilibrium in the formation is reached (which is $31.8 \cdot p_A$), curves 7 indicate that this value adjusts to 140 mol/m^2. The accuracy of the calculation can also be checked by the results in the first problem, since when the flow is established, adsorption-desorption processes are also established. This indicates that the ratio n_1/n_2, both at the input and at the output in the steady state, should be the same. From Figures 1 and 2 it is clear that curves 6 practically correspond to the established flow. From the calculations it follows that in the initial section $n_1/n_2 = 1$ (this is a specified value), while at the penultimate point this ratio for the first problem at $\tau = 0.32$ is equal to 0.979, for the second at $\tau = 0.46$ it is equal to 0.995. Thus, the accuracy of the calculation is quite satisfactory.

3. Conclusions

A mathematical model of filtration of a two-component gas mixture has been developed taking into account the dynamic stage of adsorption and desorption. The model allows one to trace the complete filtration flow and at the same time determine the behavior of each component in a porous formation in the presence of adsorption-desorption processes. Three problems of practical interest are considered, in which both dynamic and mass-exchange processes associated with the interaction of gases with the surface of a porous body play an important role. The analysis indicates that the adsorption-desorption properties can lead to significant variations in the behavior of different gas components during the filtration process. Furthermore, the results suggest that the adsorption characteristics of the formation, represented by A_J and γ_J, play a crucial role in influencing the flow dynamics of each component. The qualitative insights gained from these flow characteristics enhance our understanding of the underlying physical processes and may prove beneficial in the practical development of relevant technologies.

Conflict of interest

Authors state no conflict of interest.

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МОДЕЛЮВАННЯ ФІЛЬТРАЦІЙНОГО ПОТОКУ БІНАРНОЇ ГАЗОВОЇ СУМІШІ В ПОРИСТОМУ ШАРІ З ВРАХУВАННЯМ ПРОЦЕСІВ АДСОРБЦІЇ ТА ДЕСОРБЦІЇ

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Анотація. У сучасній літературі, присвяченій гірським розробкам і технологіям, велика увага приділяється адсорбційно-десорбційним процесам. Це великою мірою пов'язано з видобутком природного газу, зі зберіганням парникових газів, а також з безпекою гірських робіт. Така спрямованість досліджень представляє широкий клас цікавих завдань, пов'язаний з фільтрацією і газообміном, в якому виникає необхідність розглядати динаміку окремих компонентів газових сумішей. У цій роботі розглядається ряд модельних завдань про фільтраційну течію суміші двох газів. Для простоти було прийнято, що гази практично нічим не відрізняються, окрім адсорбційно-десорбційних властивостей, що виражаються в швидкості адсорбції і місткості адсорбенту по відношенню до цих газів. Таке фізичне спрощення важливе для акцентування і підкреслення прояву адсорбційних ефектів в сумішах газів. У основу завдання покладені рівняння збереження того або іншого компонента з урахуванням дифузійного руху, співвідношення Дарсі і розширене рівняння адсорбції Лэнгмюра, що враховує конкурентні властивості компонентів газу при адсорбції. Розглядається стадія динамічної адсорбції, тобто такій характерній частині процесу, коли фільтраційна течія і адсорбційні явища взаємно залежні і, відповідно, роблять істотний вплив один на одного. Розглянуті деякі приклади фільтраційних течій, які можуть представляти інтерес в практичному аспекті, і де важливий кожен компонент суміші. Виписані рівняння для молярних концентрацій, обговорені граничні умови. Рішення проведене чисельно з використанням явної схеми. Показані криві зміни молярних концентрацій уздовж поперечного зрізу пласта залежно від часу. З результатів видно, що швидкість адсорбції і місткість адсорбенту для того або іншого компонента суміші газу значно впливають на динамічні характеристики процесу. Дана оцінка точності розрахунків. Представлені результати розкривають не лише кінетичну поведінку суміші газів, але і кожного компонента окремо, що може бути важливо в розумінні процесів, пов'язаних з газообміном.

Ключові слова: пористе середовище, газ, фільтрація, адсорбція, десорбція