GEOMECHANICAL STATE OF A ROCK MASS NEAR A CRACK OF HYDRORUPTURE FORMED FROM A DEGASATION BOREHOLE

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RESUME

The movement of methane and the stress state of a rock mass near a vertical crack of a hydrorupture formed from a wall of a hole, drilled from the earth’s surface is investigated. The mass is modelled by the elastic porous medium with the initial stresses caused by the weight of rocks and their lateral compression. The regularities of redistribution of initial stresses near a crack are established. Influence of elastic deformability of a medium on the permeability of a mass is investigated. On the basis of the solution of problems of the theory of a filtration the field of speeds and the distribution of pressure of gas in a mass are studied. The estimation of the geometrical sizes of a domain of degasation is given. The formula for calculation of quantity of the methane excreting in a crack of hydrorupture is received.

INTRODUCTION

The known reserves of a petroleum and a gas are not enough to ensure own needs of the Ukraine. It is possible to cover only 14% of a petroleum and 30% of a gas from a general need of Ukraine at the expense of the internal resources. So the coal is a main power resources of Ukraine. But coal mining becomes more labour-consuming and dangerous with each year. In this connection an important place is given to alternate kinds of energy, at the expence of which it is planned to make up to 10% of all energy in Ukraine after 2010 year. The methane of Donbass coal deposit is believed to the alternate source of energy. Its reserves are evaluated from 12 up to 25 trillions $m.^3$. They exceed the own resources of a natural gas in some times.There was a prompt rise in prices on all power resources, including on natural gas during the last years. Now the costs on a realization of the projects of a degasation of coal deposits and of an extraction of a methane in industrial volumes are comparable with the costs on natural gas exported to Ukraine. Just this circumstance enables closely to approach to a practical realization of a production of methane from coal deposits [1].

The methane gas of coal deposits of Ukraine is valuable power and chemical raw material. Its structure and an useful properties are equivalent ones to “dry” natural gas which outputs from the best deposits in Russia [2].

For an extraction of methane it is necessary to use the modern technologies, approbated by a world practice. Here it should be noted that there are the American technologics connected with a hydrorupture of a rock mass for the purpose to increase a quantity of an excerted gas. However, the automatic transposition of the American technologics is impossible due to the varieties of the geological conditions and the mechanical properties of a rocks of a coal deposits of Donbass and of USA. Therefore it is necessary to justify theoretically and to check up experimentally an applicability of new technologies in the real conditions of Donbass. One from such attempts of the theoretical investigation of a geomechanical state of a rock mass in a neighbourhood of a crack of hydrorupture, derivated from a degasation hole, made in the present report.

THE MOTION OF A GAS NEAR A CRACK

For an estimation of efficiency of a way of increase of a debit of a gas borehole by hydrorupture of a rock mass it is necessary to investigate distribution of stresses and movement of metane near the created crack. The case when the vertical crack, formed from a wall of a hole on depth *?* from the earth's surface , dissects not only a coal seam, but also rocks containing it is considered below. In other words, the case when a thickness of a coal seam *2h1* is less than a height of a crack *2h2* is investigated. The geometrical sizes of a crack are those, that its length *L* on two orders is more than a width *2b* and on the order more than a height. Therefore a movement of gas and stressed state of a mass near a crack with the big degree of accuracy can be investigated on the basis of the solution of the plane problems of the theory of an elasticity and the theory of a filtration of gas.

In vertical plane *S*, which perpendicular to longitudinal axis of a crack, we shall enter the Cartesian rectangular system of coordinates *?? y*. We shall locate an axis *?* in a middle plane of a coal seam.

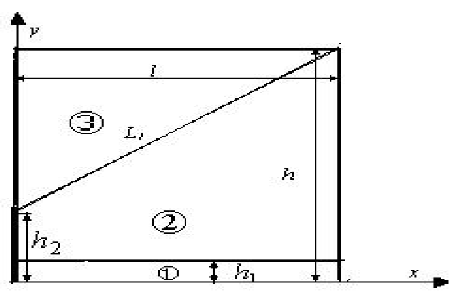

Fig. 1. Domain of movement of gas near a crack

The system of relations, describing a filtration of gas in a mass, contains the equation of indissolubility, Darcy's law (the equations of movement) and the equation of a state of gas. As is known [3], in case of the steadied movement of gas this system will be transformed to the equation

$$\Delta ?^2=0 , \qquad (1)$$

where $\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ -Laplace operator, *P* – gas pressure

It is assumed, that the axis *?* divides height of a crack half-and-half. Then by virtue of symmetry it is enough to consider a movement of gas in the first quadrant of plane *?? y* (fig. 1). We believe, that domain of a filtration of gas is the rectangle with the sides *2l, 2h* on which border pressure is equal natural

Pn. Pressure upon walls of a crack equal *P0*. By virtue of the symmetry at *y =0* and*?=0, y> h2* speeds are directed along axes *?* and *y*.

Therefore on a segment *y=0, 0 <? <l* a derivative $\frac{\partial P}{\partial y}=0$

and at $x = 0$, *h2 <y <h* $-\frac{\partial P}{\partial x}=0$.

Let's divide a domain of a filtration of gas into zones 1,2,3 (fig. 1). A zone 1- coal seam, zones of 2,3-rocks close and above a crack. Solving the equation (1) with the mentioned above conditions, we shall find distribution of pressure *P1, P2, P3* in zones 1-3

$$P1 = P_2 = \sqrt{P_0^2 + \frac{P_n^2 - P_0^2}{l}x} \qquad (2)$$

$$P_3 = \sqrt{P_0^2 + \frac{P_n^2 - P_0^2}{h-h_2}(y-h_2)} = \sqrt{P_n^2 - \frac{P_n^2 - P_0^2}{h-h_2}(h - y)}$$

From the first formula (2) it is visible, that on the general boundary of zones 1-2 the pressures *P1* and *P2* coincide. From a condition of equality of pressures *P2* and *P3* on a line dividing zones 2 and 3, we shall find the equation of the direct *L1* (fig. 1)

$$\frac{x}{l} = \frac{y-h_2}{h-h_2} \qquad (3)$$

Speeds of a filtration of gas are written thus in a coal layer

$$\vec{v}_1 = -\frac{k_y}{2ml}\frac{P_n^2 - P_0^2}{\sqrt{P_0^2 + \frac{P_n^2 - P_0^2}{l}x}}\vec{i}\ , \qquad (4)$$

in zone 2:

$$\vec{v}_2 = -\frac{k_n}{2ml}\frac{P_n^2 - P_0^2}{\sqrt{P_0^2 + \frac{P_n^2 - P_0^2}{l}x}}\vec{i} \qquad (5)$$

in zone 3:

$$\vec{v}_3 = -\frac{k_n}{2m(h-h_2)}\frac{P_n^2 - P_0^2}{\sqrt{P_0^2 + \frac{P_n^2 - P_0^2}{h-h_2}(y-h_2)}}\vec{j} \qquad (6)$$

where ky*, kn* - permeabilities of coal and rocks, , $\vec{i}, \vec{j}$ - unity vectors.

From a condition of a continuity of normal speeds on the boundary *L1*

$$|v_2|_{L_1}\sin a = |v_3|_{L_1}\cos a\ , \qquad (7)$$

where

$$\sin a = \frac{h - h_2}{\sqrt{l^2 + (h - h_2)^2}}, \quad \cos a = \frac{l}{\sqrt{l^2 + (h - h_2)^2}}, \tag{8}$$

we find connection between parameters *l* and *h*, describing the sizes of domain of movement of gas

$$l = h - h2 \tag{9}$$

The speed v_2 in a section *?=l* equal to zero at $l \to \infty$. We shall determine a length of a zone of movement of gas *l*,* outside which the speed v_2 will be practically equal to zero, from a condition

$$\frac{\partial n_2(l)}{\partial l} \Big|_{l=l*} = e \tag{10}$$

At numerical researches the parameter e is believed equal to 0,5 $\cdot 10^{-6}$. From calculations it follows, that with growth of depth a domain of movement of the gas, characterized by the parameter *l*,* increases.
Character of change of speed of a filtration of gas in rocks (fig. 2) depending on coordinate *?* for the depth, equal 600?, is shown on the diagram. Calculations are executed at the following values *of* parameters:
P0 =0,1? P?, *Pn* =6? P?, ky=0,1·10^{-16} m^2, kn=0,2·$10^{-15}$$m^2$, μ=0,6·10^{-10} ? P?.
Numerical researches have shown, that at the chosen values of parameters a speed of the filtration of gas on the order more in rocks, than in a coal seam .

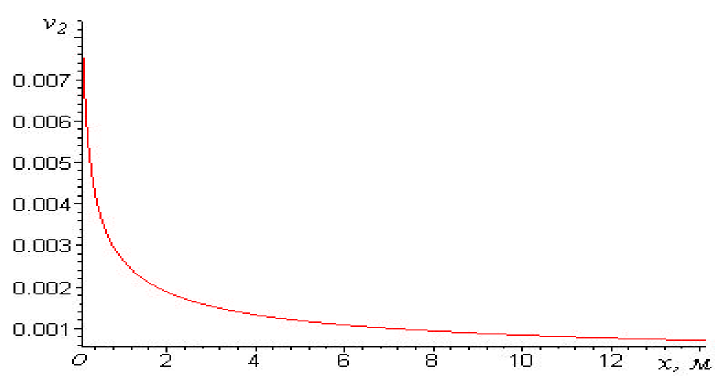

Fig. 2. Change of speed of a filtration of gas in rocks by increasing a distance from a crack.

In case of a non-stationary filtration of gas the distribution of the pressure in a neighborhood of a crack was investigated on the basis of the equation

$$\frac{\partial^2 P^2}{\partial x^2} + \frac{\partial^2 P^2}{\partial y^2} = \Phi(P)\frac{\partial P^2}{\partial t} \tag{11}$$

where

? (?) = ? ? in zone 1, *? (?) = ? ?* in zones 2,3,

$$\Phi_y = \frac{m}{k_y}\left(m_y + \frac{abRT}{(1+aP)^2}\right)\frac{1}{P}\ , \qquad (12)$$

$$\Phi_n = \frac{m}{k_n}\frac{m_n}{P}\,. \qquad (13)$$

Here *my, mn* – the porosities of coal and rocks, *R*-a gas constant, *?*-temperature, *a*, *b*- the sorbtion constants of coal.

At the solution of the equation (11) in the domain of movement of gas to the boundary conditions are added initial. For definition of unknown border of domain of movement of the methane, we use a kinematic condition for speed of a filtration in section *?=l (t)*. For function *l (t)* the approached formula is received

$$l(t) = \sqrt{\frac{k_n}{m}\frac{P_n^2 - P_0^2}{P_n}t} \qquad (14)$$

In it a permeability of medium is necessary to equal *ky* at of movement of methane in a coal layer.

On fig.3 the curves showing an increase of a domain of degasation in a coal layer and rocks are constructed at the following values of parameters: *P0* =0,1 ? ??, *Pn* =12 ? ??, *ky*=$0{,}1\cdot10^{-16}$ m^2, *kn*=$0{,}2\cdot10^{-15}m^2$, $\mu=0{,}6\cdot10^{-10}$? ??

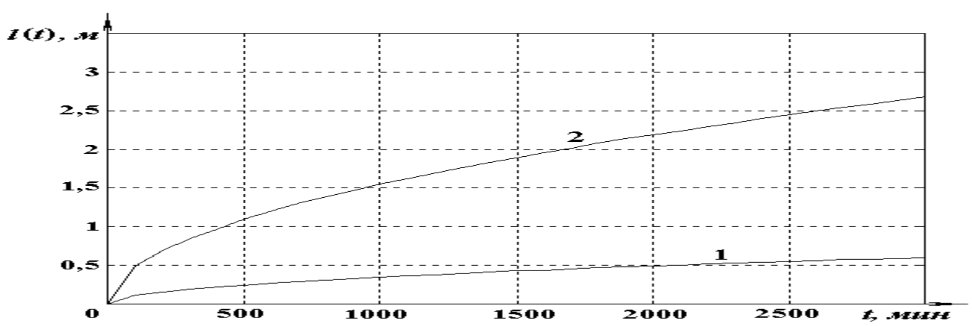

Fig. 3 Change of a zone of degasation in dependence on time
1-coal seam; 2-rocks

The schedules show, that the border of a domain of degasation removes faster in rocks, than in a coal seam. As a result of delay of degasation front in a coal the part is formed on the contact of a seam with rocks, through which gas goes from coal to rocks.

The quantity of the gas excreted in a crack, according to the decision of a filtrational problem is defined by the formula

$$Q = \frac{2\,r\,L}{lm}\frac{P_n^2 - P_o^2}{P_o^2}\left[k_y h_1 + k_n\left(h_2 - h_1 + b\right)\right] \qquad (15)$$

A STRESSED STATE 0F ROCK MASS NEAR A CRACK OF HYDRORUPTURE

Presence of a crack in a massif drives to a change of its initial a stressed state caused by weight of rocks and their lateral compression. Additional components of stresses, which appear due to formation of a crack in a mass, calculate by formulas of G.N.Kolosova – N.I. Mushelishvili [4]

$$s_y + s_x = 4\,\mathrm{Re}\,\Phi(z)$$

$$s_y - i t_{xy} = \Phi(z) + \Omega(\bar{z}) - (z - \bar{z})\overline{\Phi'}(z) \qquad (16)$$

At absence of the external efforts, acting to walls of a crack, the functions of complex variable $\Phi(z), \Omega(z)$ have a form

$$\Phi(z) = \Omega(z) = \frac{bgH}{2}\left[\left(1 - \frac{z}{H}\right)\left(1 - \frac{z}{\sqrt{z^2 - h^2}}\right) - \frac{h^2}{2H\sqrt{z^2 - h^2}}\right], \qquad (17)$$

where g - average specific weight of rocks, b - factor of lateral thrust, h=h1.

Calculations have shown, that in the regions of a mass, adjoining to walls of a crack, zones of unloading of normal stresses are observed. Above and under a crack the domains of concentration of stresses are located. In these domains compressing stresses increase as approaching to a crack.

Redistribution of stresses changes natural permeability of a mass in domain, adjoining to a crack. An inverse quantity of permeability R is linear function of components of elastic deformation:

$$R=R0 + be +2a\ ex \qquad (18)$$

Here *a*, *b* - constants, *R0* =1/*ko*, *ko* - natural permeability, *ex, ey* - the components of deformation connected with the stresses *sx, sy,* **t***xy* by relations of generalized Hooke's law , *?=ex+ey*.

Calculations have shown, that as in rocks, as in a coal a permeability changes in a neighborhood of a crack, comparable with its double height.

THE CONCLUSIONS

A distribution of pressure and a field of speeds of methane in a coal seam and rocks have been investigated on the basis of the solution of problems about a stationary and non-stationary filtration of gas in a neighborhood of a vertical crack of hydrorupture. It has been shown, that at the chosen values of the parameters describing a permeability of a mass near to a crack, speed of a filtration on the order is more in rocks, than in a coal seam. The estimation of change of an extent of domain of a gas filtration in a dependence on time has been given. It has been found, that the boundary of a degasation zone moves with the greater speed in rocks, than in a coal seam. It has been established, that a domain of a degasating influence of a crack increases with a growth of depth. The formula for calculation of quantity of the gas excreted in a crack of hydrorupture has been received.

The distribution of stresses and elastic deformations in a neighborhood of a crack has been investigated. It has been revealed, that in domains, adjoining to walls of the crack, the zones of unloading of normal stresses are formed.

Near the ends of a crack the domains of concentration of compressing stresses are located. The influence of redistribution of stresses on filtrational properties of a mass near a crack has been established.

THE LITERATURE

Not available. (In Russian)