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FORECASTING THE HYDRODYNAMIC MODE FOR MECHANICAL FIELD DISCOVERY AND COVERAGE

The method of calculating the parameters of the hydrodynamic regime of the mine field is developed takes into account different periods of its operation. The structure of the array is schematized by using layers that match the workout horizons. Estimated water intake for lies in the dynamics of expansion and flooding of the produced space. As a result of simulation the possibility of application of the technique in real mountain-hydrogeological conditions is shown.

Introduction. The problem of managing the hydrodynamic regime of coal mines is currently one of the relevant for the mining industry of Ukraine. She acquired a special significance in the period restructuring and closure of mines, when their flooding leads to flooding of large areas, the exit of mine gases on the surface of the earth, other negative phenomena.

Ecologically and technically optimal solutions for the organization of the operation of mine drainage, as with ex-operation, and during conservation of mines, can be accepted only on the basis of reliable forecasts of change hydrodynamic regime of mine fields. As a tool for such prediction is usually used Numerous filtration models are in place. Their probability and effectiveness largely depends on the adequately-The consideration of mining technical and hydrogeological characteristics of the developed fields. To the top More important factors requiring careful consideration when performing forecasts include: The filtration properties of the collapse zones, the anisotropy of cracked arrays, the unevenness of the the laying of layers on different horizons, the branching of underground workings of various types, the variability of the angles of pas-life layers, etc.

Known methods of numerical filtration simulation, including mining enterprises [1, 2] do not completely take into account the above factors, and the calculated parameters of the models on the magnitude These grids are often not related to the structure of the mine field and the processes that occur there, which need There is a large scale. Spatial models of filtration [3] are useful for calculations at a specific time-mine field or in the theoretical study of the peculiarities of hydrodynamic processes in blunt array Their application requires a large amount of detail, which is not always ensured output-them data. In addition, excessive complication of models often does not meet the requirements and requirements of engineer-non-technical solutions, as well as the accuracy of the parameters. As a certain alternative to the aforementioned approaches Analytical methods of filtration simulation can be considered [4, 5]. However, their application is limited not a condition for the relative homogeneity of the mine field.

The optimum is the use of quasi-spatial models constructed on the flow chart. new failsafe filtering. It is necessary, on the one hand, to adequately take into account the schedule of holding mining and heterogeneity of the array. On the other hand, the model parameters should be consistent with physics processes inside the grid blocks, avoiding simulation calibration of the results during the company tasks. The purpose of this work is to develop and approbate such a model, as well as to substantiate its para-Tables on the example of the prediction of the hydrodynamic regime of the mine field.

Schematic of the mine field. The volume of cavities within the mine field V consists of a volume of three-shins and pores V_f, as well as the volume of the produced space V_w. Volume V_f takes into account both natural and technogenic cracksmanship Changing the parameter V_w in space is determined on the basis of actual mining plans from taking into account the filling factor [6].

In order to adequately reflect the filtration heterogeneity and spatial distribution of zones from The operation of the mine field is performed by dividing it into blocks in the form of rectangles. On everyone the horizon thickness Δz, where the working is carried out, the total volume of the produced space $V_{w,l}$ (l = 1, ... N_z, N_z - number of layers), as well as several zones with different values of the filtering para-meters and volume of produced space. Then, according to the horizontal distribution of the volume V_w by and, taking into account the sequence of workout for each block, you can specify the volume of output, the time their appearance and repayment. Based on the volume $V_{w,l}$ is the area of the horizontal section of the workings S_h at a given depth z as the ratio of the volume of cavities in the layer to its thickness $S_h(z) = V_w(z)/\Delta z$ [5].

An example of such a filtration schematization is shown in Fig. 1 and 2. The presence of zones of enhanced infiltration-(tanks of mine water, relief relief) is modeled by the task of uneven area intensity of infiltration supply ε.

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4
3
2
1
0
V_w, m³/m
0.02
0.01
K_f, m / good in
-700 -600 -500 -400 -300 -200 -100 0 100 200
z, m

Fig. 1. Distribution of the produced space V_w and average coefficient Filtration K_f through depth at different working horizons

Calculation of the hydrodynamic regime of the mine field. In the conditions of violation of natural geological their structures in the development of layers, the presence of areas of collapse with increased vertical permeability the calculation of groundwater level change is advisable based on the equation of planned non-sustained filtration [7].

$$\frac{\partial}{\partial x}\left(T_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_y \frac{\partial H}{\partial y}\right) + Q_w - \varepsilon = n_f \frac{\partial H}{\partial t}. \qquad (1)$$

Here H - groundwater level, T_x and T_y - water distribution along *Ox* and *Oy* axes, respectively, n_f - fissure porosity of rock masses, Q_w - intensity of effluents, ε - intensity of infiltration.

In complicated hydrogeological conditions, filtration calculation is performed with the help of a number-their models. For the solution of equation (1), alternating-triangular scheme of the finite difference method is used. which combines the advantages of an explicit scheme with significant computational stability [8, 9].

In the case of layer heterogeneity of the mine field, the value of H *is* considered as the average probability Hundred groundwater level over some comparison plane H_{gl} . As the last one, it's advisable to take the level the occurrence of permeable rocks below the sole of the deepest working horizon. More precise determining the level of groundwater within the grid block requires either the involvement of three-dimensional models of filter- or detailed numerical analysis based on data on the vertical distribution of permeability and made space.

Parameters of water supply are determined by the formulas:

$$T_x(x, y) = \int_{H_{Gl}}^{H} K_x(x, y, z)dz, \quad T_y(x, y) = \int_{H_{Gl}}^{H} K_y(x, y, z)dz, \qquad (2)$$

where K_x and K_y are the values of the filtration coefficient along the axes *Ox* and *Oy*, respectively. For layered approximation the parameter of the permeability of integration in terms (2) is replaced by the corresponding sum.

The peculiarity of the developed methodology is the method of calculating the inflow to workings in accordance with the adopted schematization of a fake array. The water inflow to the workings within the block (i, j) is determined by the sum using water intakes for all drained horizons of working out, the number of which is equal to N_{ij} :

$$Q_{w,ij} = \sum_{k=1}^{N_{ij}} Q_{w,ijk} \qquad (3)$$

The value of N_{ij} varies with the development and drainage of deeper horizons and, depending on the position of water level in the shaft trunk, hydraulically connected with the workings.

4

2 5
S
3

1

ε, mm / day
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12

1 2 3 4 5

Fig. 2. Location of work horizons and sources of infiltration within mine field 1, ..., 5 - contours of the horizons working on the marks: 1) from 75 to 210 m; 2) from -100 to 75 m; 3) from -300 to -100 m; 4) from -500 to -300 m; 5) from -600 to -500 m; S - mine shaft

The influx of water from surrounding rocks into the debris in the block on the *k*- th development horizon can be traced fuse according to the linear law:

$$Q_{w,ijk} = K_{ijk} S_{w,ijk} \frac{\Delta H_{w,ijk}}{L_{a,ijk}}, \qquad (4)$$

where K_{ijk} is the coefficient of filtration on the *k*- th horizon in the block (*i, j*), $S_{w,ijk}$ - the surface area of the "working-environment" array ", $\Delta H_{w,ijk}$ is the pressure drop in water-saturated rocks around the output and the runoff surface, $L_{a,ijk}$ - the average length of the filtration path from an arbitrary point of the array to the surface of the output. Parameters that in- in expression (4), can be estimated on the basis of statistical characteristics of the disturbed rock massif.

Thus, the filtration area S_w (further indices *i, j, k* for simplicity omitted) is determined as follows. You- going from the approach to the cylindrical shape of the workings, can be written for the volume of cavities V_w within block of parallelepiped:

$$V_w = \pi \int_{r_{min}}^{r_{max}} r^2 l_w(r) p_w(r)\, dr \approx \pi l_{w,a} \int_{r_{min}}^{r_{max}} r^2 p_w(r)\, dr, \qquad (5)$$

where $l_w(r)$ - length of elaboration of radius r, $l_{w,a}$ - its average value for workings of all sizes; $p_w(r)$ is the density distribution of workings by volume, [r_{min}, r_{max}] - range of change of output radiuses.

With similar assumptions:

$$S_w = 2\pi \int_{r_{min}}^{r_{max}} r l_w(r) p_s(r)\, dr \approx 2\pi l_{w,a} \int_{r_{min}}^{r_{max}} r p_s(r)\, dr, \quad (6)$$

where $p_s(r)$ is the density of the distribution of workings in the area of their lateral surface, depending on the radius. Collapsed Taking (5) and (6), we obtain:

$$S_w = 2V_w \int_{r_{min}}^{r_{max}} r l_w(r) p_s(r)\, dr \Big/ \int_{r_{min}}^{r_{max}} r^2 l_w(r) p_w(r)\, dr. \quad (7)$$

Parameter distribution $p_w(r)$ and $p_s(r)$ can be estimated if there is information about the size of workings in unit block or part of the mine field. With a uniform distribution ($p_w(r) = p_s(r) = 1/(r_{max} - r_{min})$):

$$S_w = \frac{4}{3}\frac{r_{max}^2 - r_{min}^2}{r_{max}^3 - r_{min}^3} V_w. \quad (8)$$

Then, with a normal range of radii of workings (r_{min} = 0.5 m, r_{max} = 2.2 m) $S_w \approx 1.32\, V_w$. With increase particles of small designs, the numerical coefficient before V_w increases, although usually does not exceed 2-2.5. Increase Squeezing the area of contact "work-surrounding array" is similar to an increase in the specific surface of the skeleton porous medium with decreasing particle size [10].

When the pressure is centered along the vertical in the accepted calculation scheme, the pressure drop $\Delta H_{w,ijk}$ calculated as the difference between the level of groundwater and the average position drained (or flood-them) production on the horizon of working out:

$$\Delta H_{w,ijk} = H_{ij} - H_{w,k},$$

where $H_{w,k}$ - the average high position of drained (or flooded) excavations in the *k*- th layer. Size $H_{w,k}$ depends on the level position in the shaft trunk H_s, which determines the drainage area. When drained no array $\Delta H_{w,ijk} > 0$, so the drain comes from a cracked array to the output. When flooding in the under-The mine field appears zones where $\Delta H_{w,ijk} < 0$, while water from the system of workings goes to cracks

Within the framework of the created model it is possible to take into account different levels of drainage in different parts of the mine fields, as well as uneven appearance of workings.

The parameter L_a in the formula (4) can be estimated as follows. Assume that the hollow (particle the volume of workings in the total volume) in the horizontal or vertical section of the block is equal to it volume hollow space $\eta_a = V_w / V_b$, where V_b is the volume of the block. Then the total area of intersection of workings through the unit which facet S' is $S_{w,\Sigma} = \eta S'$. The average cross-sectional area of a single block development unit:

$$S'_w = \pi \int_{r_{min}}^{r_{max}} \frac{r p_s(r)}{\cos\alpha}\, dr, \quad (9)$$

where α is the angle between the work and the block face. With uniform distribution $p_s(r)$ and the same values r_{max} and r_{min} value of S'_w will be about 9 m^2. Assume further that the ratio of the area of the impenetrable phase to the area the workings in the intersection remains the same on the scale of the block and for a smaller block around the my workings out:

$$\frac{S_1}{S'_w} = \frac{S'}{S_{w,\Sigma}}, \quad S_1 = \frac{S'_w}{\eta_a}, \quad (10)$$

where S_1 is the area of the impermeable phase in the intersection, which is one development.

Within the intersection of the area S_1, the filtration goes to the boundary of the "mining array". The average distance from The point of such an intersection to the boundary can be determined by replacing it with one of the simplest figures (circle, square) of the same area (Fig. 3). In the case of a circle we select the outer boundary - circle radius $R_m = \sqrt{S'_w/\pi}$ and the inner circle is a radius $r_w = \sqrt{S_{w,s}/\pi}$. Average distance from arbitrary inward The point of such a figure to a small circle will be:

$$r_a = \pi \int_{r_w}^{R_m} r\, r dr \Big/ \pi \int_{r_w}^{R_m} r dr = \frac{2}{3}\frac{R_m^3 - r_w^3}{R_m^2 - r_w^2}. \quad (11)$$

For typical values of hollow and size of workings, the value of r_a is several meters, decreasing shouting in strongly disturbed areas and growing in parts of the mine field with a small volume of production-space. Taking into account the vibrations of the cavities, we must take $L_a = \chi r_a$, where χ is the coefficient of convolution those adopted by analogy with the porous medium [10].

Changing the level of water in the trunk in the period of drainage and extraction is determined by the schedule worked out-Coal layers. After disabling the drain on each time step, the value of H_s is calculated by By the formula [5]:

$$H_s(t + \Delta t) = H_s(t) + Q_{w,\Sigma}(t)\,\Delta t \; S_h(H_s(t)), \quad (12)$$

where $Q_{w,\Sigma}(t)$ is the total flow to workings at time t, $S_h(H_s)$ - the area of their horizontal surface at the level H_s.

R_m

r_m

S_1 S'_w

Fig. 3. Scheme for calculating the water intake from the array

Approbation of the technique. The developed method is used to calculate the change in groundwater level in the mine field during its development and after disabling drainage. Output data were taken the bottom with mining and hydrogeological conditions, typical for the Central region of the Donbas. On the border of the mines-a field with a size of 5 × 6 km, the stationary level of underground water of 200 m was established. Fractal hollow-the density of the rocks of the array is 0.015. When flooding, to take into account the moisture content in the cracks, instead of this values in equation (1) were given a lower water efficiency parameter. Parameters characterizing the distribution the actions of the coefficient of filtration and the volume of the produced space in depth, are shown in Fig. 1 and 2. Calculated Ki was carried out on a rectangular grid with the size of blocks of 50 × 50 m, with a maximum step in the time of 10 days. The simulation results are presented in Fig. 4-6.

600
500
400
300
200
100
0

Q, m³/h

200
100
0
-100
-200
-300
-400
-500

H, m

0 5 10 15 20 25 30 35 40 45 50 55 60 65

t, years old

Fig. 4. Change of water supply (fat curve), water level in the mine trunk (thin black curve) and groundwater level near shaft barrel (thin gray curve)

An analysis of the change in the total water supply to the mine (Fig. 4) shows that the largest inflow of observation When working on the upper layers, which are characterized by greater permeability. This will explain In particular, local maxima of the value Q_w in the first 10-20 years after the start of development. In this The level of groundwater is predominantly within the upper two horizons of working with relatively high filtration coefficient. With the deepening of workings and drainage of the lower horizons water intake is stabilized.

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5000
x, m
4000
B
3000
A
2000
1000
0
0 1000 2000 3000 4000 5000 *x, m* 6000

N m
200
100
B
0
-100
A
-200
-300
-400
-500
-600

Fig. 5. Groundwater level in the mine field before disablement of drainage

The period of a slight decrease in water supply (28-55 years after the start of treatment) characterizes
It is almost constant water level in the shaft barrel and the distribution of groundwater (Figure 5), which repeats
contours of working zones. The greatest decrease is observed in those zones where according to
those output data the volume of space produced more. As the level of groundwater under flooded
nor the specified unevenness is smoothed out (Fig. 6).

N, *m*

x, m

and)

N, *m*

x, m

b)

Fig. 6. Levels of groundwater: a) along profile A-A, b) along profile B (Figure 5)
for different periods after disabling drainage

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The level of groundwater under flood falls behind the water level in the shaft barrel. This is due to the fact that that filling of workings out by water occurs basically at the expense of lateral inflow. Full saturation the water of drained cracks does not occur simultaneously with the flooding of productions at the same height, and from the late-caused by the restoration of elastic stocks.

Conclusions The developed method allows predicting the dynamics of drainage and flooding of the mine fields taking into account the specifics of mining and geological and hydrogeological conditions. With the help of the accepted It is possible, within the framework of a two-dimensional model, to calculate water intakes at each riston The applied method of approximation on layers-horizons of working out allows to create regional models that, with the increase of territory coverage, would maintain the adequacy of the mapping of the structure. Tours of fake massifs in coal mining regions. In addition, the developed method makes it possible It is more reasonably to predict the dynamics of methane emission and squeezing out mine mines from the mine as the flooding zones of gas evacuation.

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Rudakov D.V., Sadovenko I.O. Forecasting of the hydrodynamic regime during the working out and the flood the mine field

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Rudakov DV, Sadovenko IO Forecasting the hydrodynamic regime during work out and flooding a minefield

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Forecasting of hydrodynamic regime during minefield flooding and flooding / D.V. Rudakov, IA Sadovenko
The method of calculating the parameters of the hydrodynamic regime of the mine field is developed, taking into account having different periods of its operation. The structure of the array under development is schematized with the power of the layers corresponding to the development horizons. Calculated water intake depends on dynamically The expansion and flooding of the developed space. Simulation shows the possibility the application of the technique in real mountain-hydrogeological conditions.

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Forecasting of the hydrodynamic regime during work out and flooding a minefield / DV Rudakov, IO Sadovenko.
The principles for calculating the hydrodynamic regime are developed for different stages of the minefield exploitation. The structure of a massif is simplified using the layers corresponding to working the horizons The calculated water influx depends on underground space enlargement and flooding. The numerical Modeling has shown how the developed principles can be applied to real mining and hydrogeological conditions.

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The method of calculating parameters of the hydrodynamic regime of the mine field, which takes into account, is developed different periods of its exploitation. The structure of the development array is schematized with the help of datas corresponding to the working horizons. Estimated water intake depends on the dynamics expansion and flooding of the produced space. The simulation shows the possibility of using Sowing techniques in real mining and hydrogeological conditions.