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DEVELOPMENT OF A METHODOLOGY FOR ASSESSING THE EXPEDIENCY OF MINE WORKINGS DECOMMISSIONING BASED ON THE GEOMECHANICAL FACTOR

Purpose. Substantiation of the methodology for predicting the state of mine workings based on the study on geomechanical processes when assessing the consequences of mine closure taking into account the entire period of their existence, during which the development of displacement with various intensity occurs in the surrounding coal-bearing mass.

Methodology. The study is based on methods of analysis and synthesis, methods of comparison, abstraction, analogy, calculation and construction. The methods of mine tool observations of the manifestations of rock pressure and their processing by methods of correlation and dispersion analysis for establishing the relationship of displacements of the mine working contour with geomechanical factors were used.

Findings. A possibility of stage-by-stage decommissioning of mine workings when grouping mining-and-geological conditions is substantiated. An example of calculating the displacements in a mine working during its decommissioning is presented. The given calculation expressions make it possible to assess the mine working state, taking into consideration the patterns of the geomechanical factor influence on making a technical decision on the expediency of its further operation.

Originality. The patterns of the rock pressure manifestation development in sequentially abandoned mine workings have been determined. Based on the methods of correlation-dispersion analysis, the dependence of the mine working contour displacements on geomechanical factors have been revealed throughout the entire period of its existence.

Practical value. A methodology for assessing the state of mine workings at the time of their decommissioning has been developed, which is an integral part of the recommendations to limit the negative influence of mine closure. The peculiarity of the methodology is in taking into account the entire period of mine workings existence, which leads to a well-grounded technical decision on the possibility of dismantling the metal structures with the complete exclusion of emergency situations.

Keywords: *rock mass, displacements, life time, decommissioning of mine workings, geomechanical factor*

Introduction. According to the World Coal Association (WCA), about 30 % of the world's primary energy demand is provided through the use of coal [1]. In general, about 41 % of all electrical energy in the world is generated from coal. Coal is also used to smelt 70 % of the world's steel [2].

Annually, about 7.8 billion tons of coal is mined in the world and the tendencies of this production are relatively contradictory: on the one hand, there is a tendency for a stable increase in coal production, on the other, there is the same steady process of closing the mines, especially in European countries [3].

According to a directive of the European Union, unprofitable enterprises are deprived of government funding, and, as a result, each unprofitable mine in Europe must cease mining from January 1, 2019. For example, in Spain, this has led to the closure of 26 coal mines. This deadline was set back in 2010, when the European Union began to take the initiative in an effort to get rid of dependence on coal.

It should be noted that among the European coal countries, Germany is not at all a pioneer in cessation of this traditional industry. For example, in Belgium, the last mine was closed back in 1992, in France – in 2004, and in the UK – in 2015. In all these countries, the hard coal mining has been discontinued for economic reasons, and it is only very recently that there has been a tendency to abandon it for environmental reasons.

At the same time, the experience of Germany shows that with the help of government subsidies, the process of closing the industry can be extended over many decades. The advantage of the German approach is that it is socially responsible.

In Poland, the last coal mine should be closed in 2049. The Polish government has decided to abandon coal in the energy sector, as well as to completely close 4 mines and place on hold 14 mines more for 3 years.

The global closure of mines in Ukraine began in 1996. Over these years, a systematic approach to making a decision on mine liquidation has not been developed yet.

It should be noted that there are several ways to mine closure. Dry closure is a method involving a special reformation of the relief, when hydrogeologists connect underground passages in such a way that water, flooding the mine, still remains at a great depth and does not mix with groundwater. Semidry closure involves the constant pumping of water from the mine, as in the operating mode. One more way is to pump liquid glass, concrete or sand into the mine to avoid subsidence of the bottom, but it is quite expensive and is only justified if there is a city above the mine. There is also the so-called wet closure – this is a simple flooding of a mine with water that is constantly pumped out during its operation [4, 5].

One of the examples is the experience of DTEK Pavlohradvuhillia PRJSC. The decision to close M. I. Stashkova mine in 2020 was influenced by the technical-and-economic performance of the mine: the load on the stope face decreases, labour productivity decreases, the cost of finished coal products increases, and the financial condition of the mine deteriorates. In addition, there are almost no commercial reserves left on the mine's balance sheet. It has just been mined out. Also, until 2023, Blahodatna, Stepova, Samarska and Yuvileina mines are planned to be closed.

To close mines in this region, it is necessary to develop a hydrogeological and socio-economic prediction for the region, substantiate the phased mine closure, linking it with funding opportunities, as well as to improve the legal/regulatory framework and study environmental problems [6].

A detailed analysis of publication [7] indicates that there are no works which consistently present the theory for substantiating the organizational and technical measures to liquidate the unpromising coal enterprises, taking into account environmental risk.

The published scientific works present the research results of the individual technogenic factors impact. Thus, A. V. Mokhov, A. N. Petrov, Yu. A. Norvatov, D. I. Saveliev and D. Kirner study only hydrogeological aspects, thereby narrowing the range of issues that need to be resolved for obtaining complete objective information. Other scientists assess geomechanical phenomena in the rock mass [8, 9]. In a number of scientific works, the influence of objects of mine surface complex on the natural environment is studied in detail [10, 11].

In the work [12], an attempt is made to assess the probability of various types of damage arising as a result of the coal mine liquidation in the zones of their large-scale closure.

Based on the analysis of the research and monitoring work results [13], it has been found that the cessation of mining does not mean a simultaneous cessation of impacts on the environmental components.

With the purpose of comprehensive assessment of the ecological-and-economic efficiency of options for reducing the negative environmental consequences of the coal mine closure, an economic and mathematical model has been developed [14] with the target function of minimizing the total ecological-and-economic costs.

The work [15] presents an economic substantiation and assessment of expert decisions on the expediency of closing extremely unprofitable mines that do not have prospects for further development, which is essential for the economy of the coal mining industry.

Mine closure is a lengthy process that requires an assessment of all the risks involved [16]. The problem of mining water management also is very actual [17, 18]. All risks are interconnected and, therefore, an integrated approach is needed to minimize them. Firstly, it is necessary to determine what causes the risks. Secondly, it is necessary to develop measures to prevent or minimize their occurrence [19].

Of course, it is impossible to consider all risk groups within the framework of one study and give recommendations on how to minimize the negative consequences of a mine closure. Therefore, this work studies one of three main factors, namely geomechanical, which forms the rock pressure manifestations in underground mine workings and determines the expediency and safety of their phased decommissioning.

Approaches to assessing the expediency of phased decommissioning of mine workings at operating mines. The operation of many mine workings has been stopped for a long period of time, their state (where it is still possible) is examined extremely rarely, which is associated with a considerable risk of such works. Therefore, predicting the state of mine workings on the basis of existing regulatory-technical documentation and the study on geomechanical processes is of particular relevance.

The concept of "comprehensive substantiation" provides for predicting the rock pressure manifestations in the mine working for the period from the beginning of its development to the present moment using various methods of both the industry level [20] and predicting methods developed at Dnipro University of Technology at the Department of Mining Engineering and Education [21, 22]. If to consider the task set from different positions, it is possible to increase the reliability of the predictive assessment of the mine working state at the current time.

As an example of a mine working to be decommissioned, the Pivdennyi passage of slope No. 2 of the K_8^l seam, 310 m horizon, mined-out in 1979 at Belitska mine of Dobropilska Mine Administration and since that moment its period of existence has been 41 years. The depth of the Pivdennyi passage location (in accordance with the extract from the mine working plan of the K_8^l seam, 550 m horizon) varies in the main range of 310–400 m; when performing mining-engineering calculations, the average depth $H = 360$ m was taken.

When surveying the state of mine workings of the K_8^l seam in the Pivdennyi passage (10/20/2006), the following was revealed: progressing corrosion of the support metal; rupture of yielding joists of the frame with their critical plastic deformations in the form of bending and buckling of a special profile; in some places, there are border rock falls to a depth of 3–5 m; the residual cross-sectional area of the mine working is 3.4–5.8 m^2. As a result, the general technical state of the mine working was declared as unsatisfactory. In this regard, it is quite fair to assume a further deterioration in the state of the Pivdennyi passage for the past 14 years after its survey in 2006.

Mining-and-geological characteristics of the host rocks. According to a general preliminary assessment, the host rocks state can be characterized as moderately stable, but the presence of factors weakening the rock in the form of water cut, moisture saturation and the presence of textural disturbances (stratification, fracturing, individual inclusions) suggests rather intense rock pressure manifestations in the Pivdennyi passage. In addition, it is necessary to take into account the rheological factor influence of the lithotypes behaviour, especially argillite and siltstones in a moisture-saturated state. The rheological factor in the form of a deformation creep of rocks has already been implicitly included into the main calculation provisions of the normative methodology.

The Pivdennyi passage contour displacements are calculated by the methodology [21, 22]. The fundamental differences between the methodology for predicting the rock pressure manifestations from the normative one are as follows (for the conditions of maintaining mine working outside the zone of stope operations impact).

Firstly, there are displacements in a number of the contour sections, which are fundamental in terms of assessing the operational state of mine working.

Secondly, the methodology is based on the results of extensive studies on the stress-strain state of the surrounding mass and support, the behaviour of which is described by the full diagram of the body deformation, that is, taking into account the stages of the rock weakening and loosening, and for metal – by the yield plateau and the subsequent segment of hardening. The Pivdennyi passage can be considered quite accessible for performing operations for dismantling the metal structures in the process of its decommissioning. This conclusion, based on calculations by the methodology [21], is quite consistent with the previous conclusion, formulated on the basis of calculations by the normative methodology. At the same time, mine instrumental observations unambiguously indicate the persistent process of deformation creep, which is recorded by the degree of displacement development along the contour of mine workings in many cases throughout the entire period of their operation (Fig. 1).

Fig. 1. Development of the mine working contour displacements

Therefore, we consider it expedient to assess the state of the Pivdennyi passage using the methodology [20].

The source data for performing calculations are the same. Then the displacements of the roof and bottom rocks for the first year of the Pivdennyi passage maintenance will be

$$U^r = 391;\ U^b = 642.$$

It should be reminded that the calculations performed relate to the initial period of the Pivdennyi passage operation, and our objective is to assess its 41-year state after its construction. For this purpose, the dependences of the methodology [20] are used for calculating the displacements in the roof U_t^r and bottom U_t^b for the entire period t of the mine working existence

$$U_t^r = U^r + 365V_{st}\left(t-1\right)K_{ar}; \quad (1)$$

$$U_t^b = U^b + 365V_{st}\left(t-1\right)K_{ar}, \quad (2)$$

where $t = 41$ years is the period of the Pivdennyi passage existence from the moment of its construction to the present time; K_{ar} is the coefficient of influence of the cross-sectional area of the working on he displacement rocks.

By the (1, 2), we determine: $U_t^r = 6891$ mm; $U_t^b = 7142$ mm.

Thus, the total displacement of the roof and bottom rocks in the Pivdennyi passage over the period of its existence of 41 years not only indicates the complete destruction of the mine working, but also evidences a more than 4.6-fold excess of the adjacent mass displacements over the initial height of the Pivdennyi passage. The conclusion is obvious – the Pivdennyi passage of slope No. 2 of the K_8^l seam, 310 m horizon has definitely ceased to exist, which excludes any possibility of dismantling metal structures from this mine working.

Another approach to assessing the state of in-seam working, which is fundamentally different from the methodologies discussed above, is described in the work [22], where the problem of calculating its contour displacements is solved by conducting a computational experiment using the finite element method (FEM).

To take into account the rheological factor of the displacements development in the mine working rock contour in the time t of its maintenance, a visco-plastic physical model of the rocks behaviour is used, which in the FEM software is usually represented by a generalized creep equation of the form

$$\varepsilon(t) = \varepsilon_{el} + a_1\sigma^{a_2}t^{a_3},$$

where $\varepsilon(t)$ is current relative rock deformation; ε_{el} is an elastic component of relative deformation; σ is principal stress when testing rock samples; t is rock deformation time (period for assessing the mine working state); a_1, a_2 and a_3 are coefficients of approximation of experimentally determined creep diagrams in coordinates "ε–t".

Coefficients a_1, a_2 and a_3 were determined using the methods of correlation-dispersion analysis based on experimental data from the Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine.

A fragment from the geomechanical model calculation is presented in Fig. 2 in the form of a curve of total displacements for the period of mine working operation $t = 10$ years. In this case, the maximum roof subsidence is $U_t^r = 1859$ mm, and the bottom upheaving is $U_t^b = 1853$ mm. As can be seen, if it were not for periodic repair and restoration work, then according to this prediction, in 10 years, Pivdennyi passage would be completely unusable.

Proceeding from the applied use of numerical modelling in the noted areas of knowledge, the most important argument in favour of one method or another is taking into account the spectrum of natural and technological factors when solving the problem, which is assessed by engineering logic and is determined by the correctness degree of solutions. When substantiating the choice of the form for solving the problem, it is necessary to determine the characteristic features of the hydrogeomechanical processes that accompany the current mining operations and their gradual cessation when closing the mines.

Based on the analysis results of the existing ideas, problems and methods for their solution during the coal mine closure in the process of a general decrease in coal consumption, primarily in Europe, a number of main directions have been identified. These include three factors that should be studied (geomechanical, technological and hydrogeological ones), and limiting their negative impact will make it possible to successfully implement environmental, economic and social tasks on the territory of the coal-bearing regions of Ukraine.

Substantiation of the approach and criteria for assessing the state of mine working for the entire period of its maintenance. A peculiarity of the methodology takes into account the development of mine working contour displacements U in the time t of its maintenance, and this accounting is made in an explicit form, where the parameter t is included in the calculated expressions for determining the displacements U. If to plot the dependency graph of two parameters, then the function $U(t)$ is a bilinear link consisting of two straight sections (Fig. 3). The first expresses the period of the mine working advance, when the most active displacement of the adjacent mass occurs at a distance of up to several hundred meters from the drifting face. The second linear section characterizes the process of decaying displacements of the mine working contour during the time of its maintenance.

To extend the recommendations for assessing the mine working state to a wide range of mining-and-geological conditions, the functions $U^r(t)$, $U^b(t)$ and $U^s(t)$ are determined depending on the main geomechanical factors: the depth H of the mine working placement and the average calculated compressive resistance R of the adjacent coal-bearing mass.

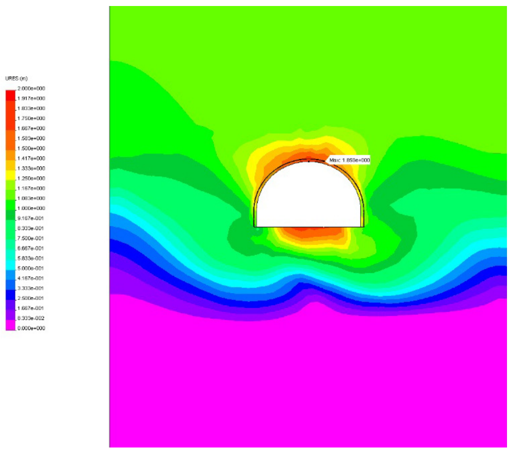

Fig. 2. Total displacements curve in the vicinity of a mine working

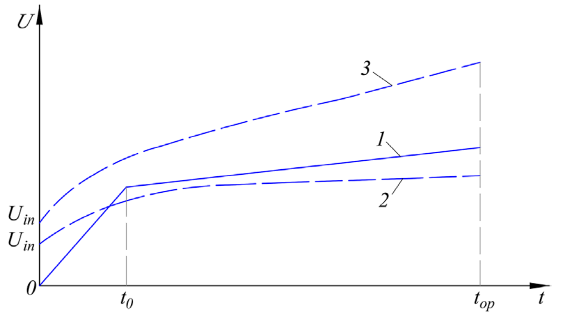

Fig. 3. Graphical representation of the qualitative dependences of the U displacement development along the mine working contour in the time t of its maintenance:

1 – according to methodology; 2 and 3 – measurements of displacements during decaying and persistent creep, respectively; U_{in} – initial conventionally instantaneous contour displacement in the drifting face; t_0 – the duration of intense displacements, up to 30–50 days; t_{op} – time of mine working operation

This problem solution is complicated by the need for long-term instrumental observations of the rock pressure manifestations in a particular mine working, for which a new original methodology has been developed for constructing empirical dependences of its contour displacements development.

Methodology for gathering information and presenting results. The methodology is based on the results of mine instrumental observations of the rock pressure manifestations, their processing by methods of correlation-dispersion analysis for setting a link between the mine working contour displacements $U^r(t)$, $U^b(t)$, $U^s(t)$ and geomechanical factors during the entire period of its existence.

More specifically, the methodology for predicting the mine working contour displacements for the entire period of its maintenance involves the sequential execution of a number of tasks with the following algorithm of actions.

1. A complex of mine workings is selected, for which a variety of geomechanical factors covers the entire range of their variation both in strength properties R of the adjacent coal-bearing stratum and in depth H of placement.

2. The dependency graphs $U^r(t)$, $U^b(t)$, $U^s(t)$ are plotted for each of the selected mine workings. If the mine working is still in operation, then additional measurements of its contour displacement are made for up to 4–6 months, but at different periods of its maintenance; in this case, repair and restoration work (for example, bottom ripping) must be taken into account, if it is carried out during the study period. As a result, discrete graphical dependences were obtained, corresponding to certain periods of maintaining mine working, as shown in Fig. 4, and in order to visually cover the entire period of its operation, a logarithmic time scale is used when plotting

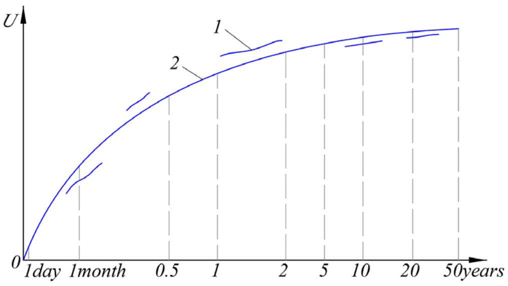

Fig. 4. Schematic representation of the methodology for plotting the graphs of the U displacement development along the mine working contour in the time t:

1 – discrete periods of fixing the displacements; 2 – generalized dependence U(t)

graphs. Then, a generalizing graph (line *2*) of the $U(t)$ dependence is plotted on discrete sections (line *1*) for each specific mine working.

3. The set of graphs $U(t)$ is a source data base for the studied range of geomechanical factors H and R variation. The most reliable link function is determined by the generalizing graphical dependences using the methods of correlation-dispersion analysis

$$U = \Phi(t),$$

which (if appropriate information is available) is divided into several functions

$$\left.\begin{aligned} U^r &= \Phi^r(t) \\ U^b &= \Phi^b(t) \\ U^s &= \Phi^s(t) \\ U^{r,b} &= \Phi^{r,b}(t) \end{aligned}\right\}.$$

4. Using the methods of correlation-dispersion analysis, the patterns of link between the function $U(t)$ parameters and the geomechanical factors H and R, are studied. For mine workings with approximately the same values of H and R (deviations up to 10 %), generalizing graphs are combined (line *2* in Fig. 4) and, thus, the amount of source information increases.

A combined representation of the patterns of link is used in the developed methodology (in the course of the analysis)

$$U(t) = F(H, R)$$

in the form of functional and graphical dependences.

5. Dependences (6) are grouped in two directions:

- peculiarities of the texture and properties of lithotypes composing the adjacent mass to a height (depth) of up to 20 m;
- peculiarities of the rheological properties of lithotypes, which determine the development of decaying and persistent creep in time t, which manifests itself in the form of displacements $U(t)$ on the mine working contour.

6. The generalizing dependences $U(t)$ are constructed based on the analysis results of mine measurements of a whole mine working group, characterized by different depths H of their placement and unequal value of the average calculated compressive resistance R of adjacent rock layers. To adequately generalize such experimental data obtained in different mine workings, it is necessary to introduce a criterion that ensures their joint consideration. This criterion is the H/R ratio of the geomechanical parameters H and R.

As an example, information has been collected on more than 160 mine workings. The analysis was performed for other mines, including DTEK Pavlohradvuhillia PRJSC. This made it possible, in the subsequent correlation-dispersion analysis of the sought patterns, to set aside the "uncharacteristic" cases (the calculation results of H/R and mine working contour displacements, which go beyond the generalized patterns). And a very extensive amount of the remaining source data provided a fairly close correlative relationship of the studied parameters.

Analysis of the patterns of the mine working contour displacement development during its maintenance. In accordance with p. 5 of the algorithm for the implementation of the proposed methodology, the patterns of U displacement development in the time t of the contour of various mine workings outside the zone of stope operations impact for the studied period of their maintenance have been grouped.

The first general criterion for grouping is the peculiarities of the texture and properties of the coal-bearing mass lithotypes adjacent to mine working. With respect to the mass texture, the following patterns of influence on the function $U(t)$ were determined. In the medium-hard rocks (with compressive resistance in the sample σ_{compr} = 40–70 MPa), mainly decaying creep takes place, and the function $U(t)$ is selected similarly to graph *2* in Fig. 3. The period of time for the beginning of displacements t_{st} stabilization is greater than the value of t_0, but it is different for different conditions (parameters H and R) of mine working maintenance, as shown in Fig. 5.

An example of the mine working contour displacements development with decaying creep (for the Western Donbas conditions) is shown in Fig. 6 and is characterized by the following peculiarities. First of all, it should be noted that for visual comparison, the generalized dependences $U(t)$ for the same values of the geomechanical criterion $H/R = 40$ m/MPa and $H/R = 20$ m/MPa are taken. Thus, at $H/R = 40$ m/MPa, the convergence of the roof and bottom over a long period of observations has reached $U_l^{r,b} = 2350$ mm. Further measurements show the insignificant increment in the convergence $U^{r,b}(t)$ and the indicated value can be considered as finite displacements. It was found that the roof and bottom convergence were stabilized almost 15 months later from the moment of mine working drivage and this is a significant difference in the Western Donbas geomechanical situation.

The determined patterns $U^{r,b}(t)$ and $U^s(t)$ form a database, which is studied by the methods of correlation-dispersion analysis and, as a result, the following empirical dependences of the link with the geomechanical criterion H/R were obtained (correlation coefficient 0.659–0.763)

$$U_l^{r,b} = 5.87(H/R)^{1.6};$$

$$U_l^s = 4.31(H/R)^{1.5};$$

$$t_{st}^{r,b} = 2.9(H/R)^{0.47};$$

$$t_{st}^s = 3.4(H/R)^{0.32}.$$

As an example of the mine working contour displacement development with persistent deformation creep in the lithotypes enclosing mine working, Fig. 7 shows the dependency graphs (with account of the periodic bottom ripping) of $U^{r,b}(t)$ and $U^s(t)$ at the same values of the geomechanical criterion H/R obtained earlier in other mining-and-geological conditions.

There are two main differences between the $U^{r,b}(t)$ and $U^s(t)$ dependences from the previous ones (Fig. 6). Firstly, the mine working contour displacements $U_{12}^{r,b}$ and even a

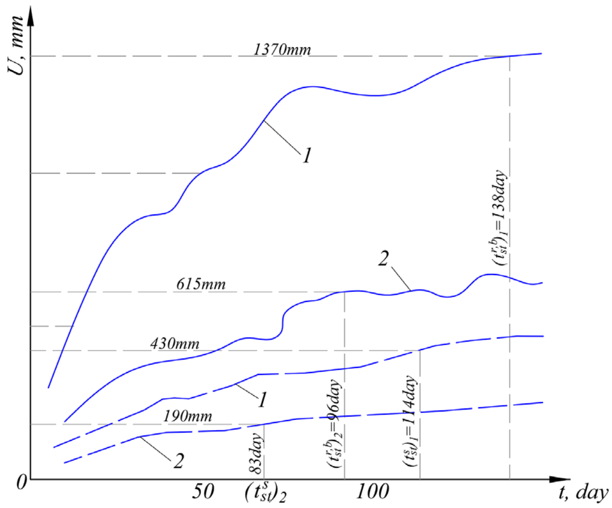

Fig. 5. Generalized dependences of the increase in the U displacements of the mine working contour in the time t of its maintenance in the conditions of the Krasnoarmiiskyi coal-bearing region:

1 – $H/R = 40$ m/MPa; 2 – $H/R = 20$ m/MPa; $U^{r,b}(t)$, $U^s(t)$

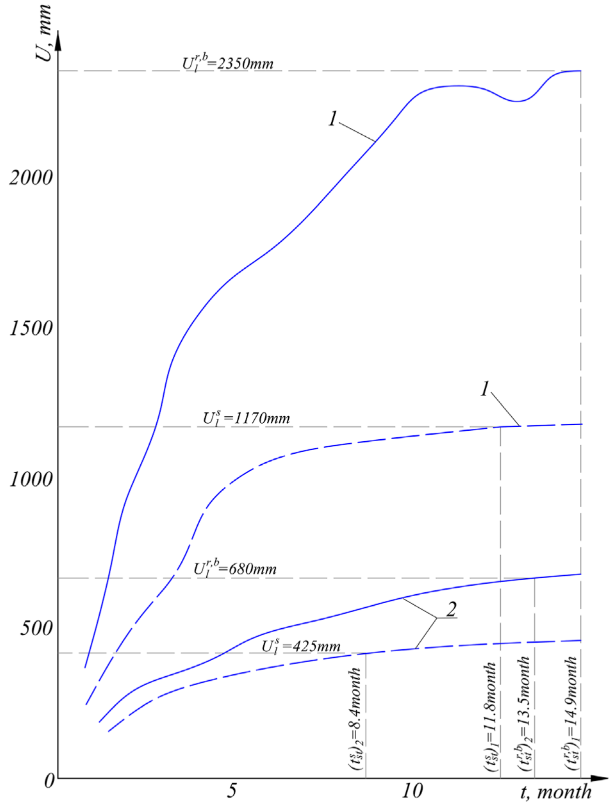

Fig. 6. Generalized dependences of the increase in the U displacements of the mine working contour in the time t of its maintenance in the Western Donbas conditions with a decaying deformation creep of the adjacent mass lithotypes:

1 – $H/R = 40$ m/MPa; 2 – $H/R = 20$ m/MPa; $U^{r,b}(t)$, $U^s(t)$

year after its construction exceed those for the case of decaying deformation creep of lithotypes in the main range by 25–35 %. Secondly, the patterns of the displacement in-

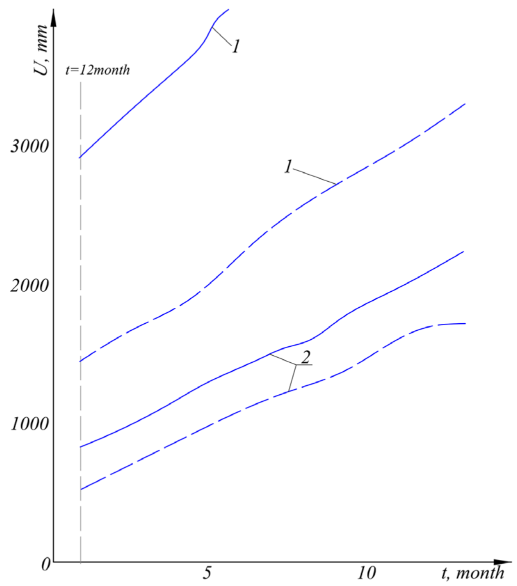

Fig. 7. Generalized dependences of the increase in the U displacements of the mine working contour in the time t of its maintenance in the Western Donbas conditions with a persistent deformation creep of the adjacent mass lithotypes:

1 – $H/R = 40$ m/MPa; 2 – $H/R = 20$ m/MPa; $U^{r,b}(t)$, $U^s(t)$

crease in time are close to linear ones and are adequately described by linear link function with time t with a satisfactory error. As a result of the performed analysis of the graphic information complex, the following calculated dependences are proposed

$$U^{r,b}(t) = U_{12}^{r,b} + V^{r,b}(t-12); \quad (3)$$

$$U_{12}^{s}(t) = U_{12}^{s} + V^{s}(t-12), \quad (4)$$

where and are convergence of the roof and bottom, as well as the sides of mine working after 12 months after its construction; $V^{r,b}$ and V^s are velocities of the roof, bottom and sides convergence of mine working during the period of time $t > 12$ months; have dimensionality mm/month.

The parameters included in expressions (3, 4) were studied using the methods of correlation-dispersion analysis for obtaining empirical dependences of their quantitative relationship with the geomechanical criterion H/R (correlation coefficient 0.624–0.831)

$$U_{12}^{r,b} = 5.33(H/R)^{1.7};$$

$$U_{12}^{s} = 5.0(H/R)^{1.55};$$

$$U^{r,b} = 0.55H/R - 0.8;$$

$$V^{S} = 0.28H / R + 2.7.$$

The calculation formulas for predicting the convergence of roof and bottom, as well as the sides of mine working have the following final form

$$U^{r,b}(t) = 5.33(H/R)^{1.7} + (0.55H/R - 0.8)(t - 12);$$

$$U^{s}(t) = 5.0(H/R)^{1.55} + (0.28H/R + 2.7)(t - 12).$$

Summing up the research results, it can be stated that the task of predicting the mine working contour displacements has in full been completed, which is as part of assessment of its operational state for making a decision on decommissioning of mine working with the removal of the support or the impossibility of these actions during the mine closure.

Conclusions. The methodology is an integral part of the program for a comprehensive assessment of the expediency of decommissioning mine workings with the removal of support during the mine closure in the Western Donbas and Chervonoarmiiskyi coal region. The methodology is intended to analyse the geomechanical situation by predicting the rock pressure manifestations in horizontal and inclined (low dip) mine workings, maintained outside the zone of stope operations impact at depths of up to 1000 m in the conditions of the Chervonoarmiiskyi coal region and Western Donbas. The parameters of the rock pressure manifestation in the form of rocks convergence in roof and bottom $V^{r,b}$, sides V^s of mine working and its residual cross-sectional area S_{res} are necessary criteria for making a technical decision on the expediency (or lack) of further mine working maintenance in conjunction with other technological and economic factors.

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Розробка методики оцінки доцільності ліквідації гірничих виробок за геомеханічним фактором

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Мета. Обгрунтування методики прогнозування стану виробок на основі досліджень геомеханічних процесів при оцінці наслідків закриття шахт з урахуванням усього їх терміну існування, протягом якого відбувається розвиток зрушення навколишнього вуглевмісного масиву різної інтенсивності.

Методика. В основу дослідження покладено методи аналізу й синтезу, методи порівняння, абстрагування, аналогії, розрахунково-конструктивний. Застосовані методи шахтних інструментальних спостережень за проявами гірського тиску та їх обробка методами кореляційно-дисперсійного аналізу на предмет встановлення зв'язку зсувів контуру виробки з геомеханічними факторами.

Результати. Обгрунтована можливість послідовної ліквідації виробок при групуванні гірничо-геологічних умов. Наведено приклад розрахунку зміщень порід у виробці при її ліквідації. Наведені розрахункові вирази дозволяють дати оцінку стану гірничої виробки у плані закономірностей впливу геомеханічного фактору на прийняття технічного рішення щодо доцільності її подальшої експлуатації.

Наукова новизна. Встановлені закономірності розвитку проявів гірського тиску в гірничих виробках, що послідовно ліквідуються. На основі методів кореляційно-дисперсійного аналізу встановлені зв'язки зсувів контуру виробки з геомеханічними факторами протягом усього терміну її існування.

Практична значимість. Розроблена методика оцінки стану виробок на момент їх ліквідації, що є складовою частиною рекомендацій щодо обмеження негативного впливу закриття шахт. Особливість методики полягає в урахуванні всього терміну існування виробок, що сприяє обгрунтованому прийняттю технічного рішення щодо можливості вилучення металоконструкцій при повному виключенні аварійних ситуацій.

Ключові слова: *гірський масив, зміщення, термін експлуатації, ліквідація виробок, геомеханічний фактор*

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