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ANALYSIS OF TECHNOLOGICAL DEVELOPMENTS FOR THE MAINTENANCE OF ORE AND URANIUM MINES OF UKRAINE

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Abstract. The purpose of this work is to establish the disadvantages and advantages of existing foreign and domestic technological developments for the maintenance of workings in iron ore and uranium mines and to determine the most promising ways to increase their reliability.The analysis of the existing technological developments for the maintenance of uranium and iron ore deposits workings made it possible to establish a variety of options for increasing the operational reliability of potentially dangerous areas. Taking into account these results and the peculiarities of the mining and geological conditions of deposits of iron and uranium ores in Ukraine, studies of the stability of mining workings with the application of various technological solutions have been carried out. As a result of the conducted research, it was proposed:

- the use of a rod support based on slag-silicate fast-hardening cartridge mixtures, consisting of a metal rod, a rubber sealing plug and cartridges with fast-hardening mixtures.
- the use of contour (smooth-wall) blasting technology during tunneling, which reduces the dynamic impact of blasting on the rock massif and the formation of additional fracture in its near-contour zone.

It has been established that in difficult mining and geological conditions, protection of workings should be carried out by combined methods. At the same time, both supports affecting the massif in the near-contour zone of the workings and special supports for specific conditions are used. The general scheme of implementation of such methods is given.

Thus, the experience of maintaining workings in difficult mining and geological conditions during underground mining of ore deposits showed the need to continue researching the patterns of deformation and destruction of unstable rocks and creating new technological solutions and supports to solve the problem of maintaining workings and increasing the duration and safety of their operation. The choice of supports for maintenance of workings in specific mining and geological conditions is determined, first of all, by the reliability factor. At the same time, using the existing developments, successfully tested in the underground mining of iron ore, as well as coal and non-mineral raw materials, which allow to increase the reliability and safety of the works, it is necessary to find out the possibility of their application also in the working of uranium mines.

Keywords: uranium and iron ore deposits, stability of workings, technological solutions, fastening of workings, support.

1. Introduction

Currently, the underground mining of ore deposits is characterized by the deterioration of mining-geological and mining technical conditions with a shortage of technical and material resources, a decrease in the content of useful components in the ore, an increase in the influence of environmental factors and an increase in the requirements for the safety of human life. A rock massif of ore deposits usually consists of strong (or medium strength) rocks prone to brittle destruction. The development of deformations in such an environment mainly occurs due to the development of fracture formation processes under the influence of man-made factors. At the "Inhulska" and "Smolinska" uranium ore mines of the state enterprise "SkhidHZK" a total of 1906 observations were made on 64 blocks [1, 2]. Manifestations of rock pressure associated with the destruction of the massif (as a percentage of the total number of blocks) were observed for:

- hanging side – 15.6%;
- roof – 20.3%;
- interchamber pillars– 4.7%;
- backfilling – 14.0%.

It was established that in the process of long horizontal workings, about 56% of rock outcrop lose their stability immediately upon outcrop or some time after outcrop (20–350 min depending on the thickness of the layer). This leads to a 40–50% decrease in the speed of workings, an increase in the costs of fastening and maintenance of workings by 20–30%. In addition, 35–40% of accidents occur directly during mining operations [3, 4].

Table 1 illustrates this situation, and contains information about collapses in mines with fatal consequences

Table 1 – Examples of cases of collapses in mines with fatal consequences

Year	Country	Deposit (mine)	
2004	Congo	Shinkolobwe	Eight people died and thirteen were injured
2005	South Africa	Ezulwini	One person died
2009	Slovakia	Rožná	One person died
2016	India	Turamdih	Three people died
2021	Ukraine	«Artem mine»	One person died
2022	Niger	Cominac	Two people died and two were injured
2023	Ukraine	«Ternivska»	One person died

A means of controlling the process of deformation and destruction of the rocks surrounding the working are fastening and elements of technological schemes for conducting workings, which affect the nature of the interaction of rocks and supports. Modern scientific ideas, on which the majority of Ukrainian technologies for maintenance mine workings are based, are built on two main principles. The first principle is the resistance of the support to the destruction of the host rocks due to changes in their types, passports of the fastening and operating conditions. The second principle is the involvement of near-contour rocks in the work by combining the properties of the near-contour massif and supports elements.

It should be noted that uranium ore mining technologies in domestic and foreign practice copy in many ways the technical solutions tested in iron ore mining [5–9].

However, for example, in contrast to coal deposits, the arsenal of supports at ore enterprises has not been significantly updated in recent years. The most common means of fastening workings in ore mines at the present time include:

– frame support with tightening and backfill;
– anchor (rod) support with a net or flexible grips;
– anchor-sprayed concrete support;
– combined support (anchor + net + sprayed concrete);
– injection strengthening of the massif (tamponage);
– monolithic concrete support (capital workings);
– monolithic reinforced concrete support (capital workings);
– tubing support (capital workings).

In Ukraine, even today, frame support remains the main technical means of workings protection in areas of geological disturbances.

However, the use of traditional arch support, based on the theory of the formation of an equilibrium vault in the upper part of the working in conditions of great depths, is not always effective. In addition, the contact of the roof with the arch is point-like with a random distribution of points in the cross-sectional plane. This factor causes additional uneven distribution of loads on the arch in addition to the main component of asymmetry caused by geomechanical factors. In difficult mining and geological conditions (in case of unstable rocks) with an increased stress-strain state, the frame metal support is significantly deformed, due to the collapse of the roof rocks, "vault" of rather large volumes are formed, which leads to an emergency state or the need to pass overtaking mine workings. The experience of some mines in Kazakhstan showed that frame supports in a fragmented and highly fractured massif do not fully ensure the maintenance of mine workings in working state [10].

One of the reasons for the insufficiently efficient operation of the arch support is the non-homogeneous loading of adjacent frames, caused not by the patterns of changes in rock pressure along the length of the working, but by the combined effect of random factors. Back in 1969, German specialists carried out the first studies on tamponage of cavities behind a frame attachment in order to equalize loads on the load-bearing surface, and in 1973 mechanized means for tamponage work were created.

According to its functions, the tamponaged space should be considered as one of the equal elements of the combined protection structure. Over many years of experience, it has been established that the optimal strength of the tamponage solution after hardening should be about 20 MPa. Foreign experience has shown the high efficiency of timely performance of tamponage works to eliminate cavities between the tightening of the frame support and the rock contour of the working, regardless of its configuration. A more even distribution of the load on the frame increases the bearing capacity of the support by 30–40%. When performing tamponage, it is advisable to use a light tight.

Despite the positive foreign experience of performing tamponage in cavities behind frame support, which significantly improves the efficiency of its work under conditions of asymmetric loading, in domestic practice it was used only in the construction and repair of capital workings.

As an alternative to frame support under a combination of certain conditions, at the end of the 40s of the last century, in the mines of the USA, and then in Australia, anchor support began to be used on an industrial scale [11].

Foreign and domestic experience in the application of anchor support has shown that it also has certain limitations regarding the scope of application. The potentially expected result of the complete displacement of frame support due to anchor systems was not confirmed, and the further direction of development of fastening means went through the synthesis of combined protection systems, which included primarily frames and anchors. In the process of improving the combined frame-anchor support, the concept of its operation in the mode of increasing resistance was developed. Practically, it is implemented by the fact that at the first stage one of the elements of the protection structure works, and in the future, other elements come into operation in parallel, without removing the load from the one installed at the beginning.

Concrete, reinforced concrete, and tubing supports due to their cost-effective construction are used either in mining and capital workings, or in individual sections of workings with difficult geological conditions.

A study of domestic and foreign information sources devoted to the safety of personnel during underground mining of uranium ore showed that the majority of information concerns radiation safety. Measures related to maintenance of workings in a safe condition are covered very briefly. From the point of view of geomechanics, uranium mines are safer than coal mines, for example. But neglecting to take precautionary measures to maintenance of workings can lead to catastrophic consequences.

Unfortunately, the main existing scientific provisions regarding the effective and safe use of mining maintenance technologies of ore and uranium mines do not fully meet the requirements of modern technologies and ideas about geomechanical processes occurring in underground workings and near-contour massif of rocks. Therefore, the research of technologies for maintenance of mining workings of mines for the extraction of iron ore and uranium-containing raw materials is timely. Thus, the purpose of this work is to establish the disadvantages and advantages of existing foreign and domestic technological developments for the maintenance of workings in iron ore and uranium mines and to determine the most promising ways to increase their reliability. To achieve the purpose, the following tasks were formulated: to conduct an analysis of foreign and domestic technological developments for the maintenance of workings at iron ore and uranium mines; to conduct an analysis of the main types of supports of ore mines for various types of workings to increase the duration and safety of their operation; carry out experimental studies to determine the geomechanical condition of workings using the example of transport workings at the "Nova" mine of "SkhidRuda"; to propose ways to ensure maintenance of workings in an accident-free condition in difficult mining and geological conditions.

2. Methods

The work uses critical analysis and generalization of both own research results and the results of domestic and foreign authors.

3. Results and discussion

In uranium mining and iron ore mines, long-life workings are fastened by three main types of supports: sprayed concrete, frame and rod supports. The last type of support is, in fact, a type of anchor support. The most common types of supports are sprayed concrete and anchor. Frame support is used, as a rule, in areas of tectonic or high structural disorder of the massif.

Deliverable workings are mainly fixed with anchors or cables and a net. If the massif is prone to weathering, then the workings are covered with a layer of sprayed concrete or sealant. For fastening workings that must be stored for many years, supports from monolithic, less often prefabricated, concrete and reinforced concrete are used. Moreover, the greater the rock pressure and the weaker the rock, the stronger the fastening. Round shafts in weak water-bearing rocks are fastened with cast-iron tubing. If the roof of the workings is broken by fractures or has a layered nature, the most common anchor support is used, which is considered one of the most advanced systems for fastening rock massifs. There are certain geomechanical differences in the behavior of the rock massif in the workings fastened by frame and anchor supports. The frame support installed in the working (for example, from a special profile) affects the displacement, but does not affect the physical properties of the massif. Rod support changes the strength characteristics of the containing rocks, increasing the adhesion of the layers when they are tightened and the holes are filled with binding material. Therefore, it is active in the redistribution of stresses around the working, playing the same role as the coefficient of lateral repulsion. Mining contours are also the load-bearing elements of the technological structure. Especially if sprayed concrete is used to prevent the destruction of the near-contoured part of the massif.

The studies carried out in works [12, 13] showed that with any of the considered types of support of mining workings, with the improvement of the controllability of the containing (side) rocks, the stresses in the massif grow according to a linear relationship. Moreover, a minimal and approximately equal increase in vertical stresses is typical for frame and anchor supports. Longitudinal stress during frame support, compared to anchor support, is less than half, and tangential - more than four times.

The properties of the massif are affected by the shape and size of the cross-section of the working. Usually, the shape of the cross-section of the working is determined by the convenience of its operation, the conditions for maintaining long-term stability, the material and construction of the support, and other factors. The most stable round shape of the cross-section of workings with a smooth contour, but its implementation is very time-consuming, and in the conditions of massifs with a difficult structure, it is practically impossible. Therefore, in uranium mining mines, as a rule, only vertical shafts are made round, and in weak rocks, sometimes also the main horizontal rolling workings. Horizontal and inclined workings have, as a rule, a cross-section in the form of a vault in stable rocks, and a trapezoidal one in insufficiently stable ones, because a flat sole of the workings is necessary for the organization of the movement of people and goods.

The characteristics of the main underground workings of ore mines are given in the table 2.

The dimensions of the cross-section of the workings are determined depending on the type and size of the transport devices, the sizes of the gaps between the equipment and the support or the walls of the working, and in some cases - the required amount of air that needs to be supplied to the working. In addition, it is necessary to take into account that the dimensions of the cross-section of the working, especially its width, cannot be greater than a certain value – the permissible span. It depends on the stability of the surrounding rocks. The dimensions of the workings are taken according to the typical cross-sections, because the cross-sections of the workings are standardized. The cross-sectional area of the shafts varies from 12 m^2 to 60 m^2. For a round section, this corresponds to a shaft diameter of 4 m to 9 m.

Evaluating the degree of influence of the "working - support" system on the massif of rocks, it is also necessary to take into account the working life of the mining. The longer the service life of the working, the higher the stresses in the massif, which can bring it out of order and cause accidents and casualties.

In general, the support of mining workings must meet the following basic technical and economic requirements:

– to be strong, stable, durable, to ensure the working condition of workings and safe conditions of work during the entire service life;

– have minimal costs for manufacturing, delivery, construction and operation;

– not to interfere with the performance of production processes during workings and its operation;

– occupy the minimum cross-sectional area of the working;

– have a minimum coefficient of aerodynamic resistance.

Table 2 – Characteristics of the main mining workings of ore mines

Name working	Using	Cross section shape
Vertical shaft	Dissection of the deposit; descent and ascent of people, equipment, materials; ventilation	Round
Exploring shaft	Exploration of deposits; ventilation; descent of materials; emergency exit	Round, rectangular
Blind shaft	Descent and ascent of people, equipment, materials from lower horizons	Round, rectangular
Vertical winze	Descent of rock from the upper horizons; movement of people; ventilation	Often rectangular
Inclined shaft	Dissection of the deposit; descent and ascent of people, equipment, materials; ventilation	Arched, polygonal
Inclined winze	Descent of rock from the upper horizons; movement of people; ventilation	Often rectangular
Slope	Transportation of ore from lower to higher horizons at an angle of up to 18^0	Arched, trapezoidal
Passway	Pipe-cable and cargo-human transportation	Arched, trapezoidal
Gallery	Transportation in mountainous terrain	Vaulted, rectangular
Cross stroke	Movement of people, materials, equipment; air supply	Arched, trapezoidal
Drift	Rollback and ventilation. It is carried out along the extension of the ore body	Arched, trapezoidal, vault-like, round, rectangular
Ort	The working, which was passed across the horizon of the deposit	Arched, rectangular

The stability of the elements of the chamber system is determined both by the natural factors of the occurrence of the ore body, and by the choice of the parameters of the deposit development (Fig. 1). The general principles of choosing the elements of the chamber system and the technology of working out of the chambers in conditions of intensification of production, regardless of the type of ore, boil down to choosing the maximum possible height of the floor and minimizing the time of working out of the chamber.

When considering the features of the influence of technology during the simultaneous mining of uranium-bearing ores on the state of the system "massif - working - support and protective structures", the dominant is the stressed state of the massif of rocks, which determines the stability of the working outcrop. The stress state of the massif is formed under the influence of mining and geological factors and technological means, the main ones of which are: fractured rocks; depth of development; the angle of outcrop to the horizon; equivalent outcrop span; outcrop time; nature of support or sequence of part-time work; support systems and protective structures.

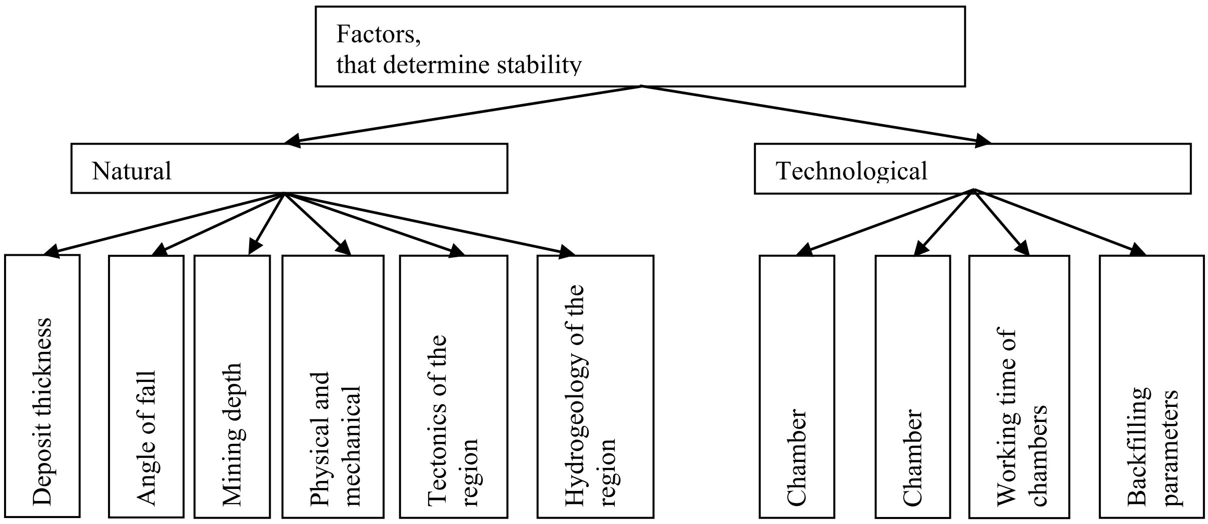

Figure 1 – A complex of factors that determine the stability of the elements of the chamber system

The essence of the processes of extraction of uranium-containing raw materials differs from the extraction of most other minerals by the higher complexity of production technological cycles and their inherent features. This high dependence of the technological process of extraction on mining and geological conditions has a steady tendency to complication. The constant change of mining and geological conditions in the ore bodies that are worked out, the lack of technical possibilities of their accurate forecasting introduce elements of uncertainty and randomness, which makes it difficult to choose rational technologies.

The list of negative natural factors that complicate the extraction of uranium-containing ore by the underground method is given in the table 3.

Horizontal and inclined mining workingss in ore mines are carried out mainly with the help of blasting. At present, fastening of most workings at enterprises of the mining industry is carried out as follows. Fastening of drill orts is performed using either sprayed concrete support or without support, but during their passage, some places of drilling orts can be strengthened with anchor or combined support. If the operating time of the drilling ort is expected to be less than 18 months, then the working is not fastened. If the drill ort is expected to be in operation for more than 18 months, then the working is fastened using sprayed concrete 50 mm thick [14], [15].

In work [16], proposals are given for choosing a rational type of supports of workings and their connections (anchored, sprayed concrete or combined) in the conditions of operation of uranium mines of SE "SkhidHZK", which take into account, in addition to the class of stability of mining rocks and the level of their stress state, the width of the mining working and the necessary (allowable) time of its operation.

Fastening of cross strokes, which turn into ort-entrance, passed from underfloor drifts, is also performed by various types of supports.

Table 3 – Factors of deterioration of underground iron ore mining conditions

The natural factor of deterioration	Impact on technology	Impact on labor safety	Impact on ecology
The increase mountain pressure	The need to strengthen the support, reduce the cross-section of the workings	The threat of landslides during tunneling works	Absent
The increase of water tides	Conservation of flooded areas	Impossibility of controlling the condition of submerged workings	Pollution of the environment by mine waters
Geological disturbances	Conservation of violation areas, conducting mining works and fastening according to an individual project	The threat of unforeseeable collapse of large rock blocks due to the destruction of supports	The possibility of the formation of depressions on the earth's surface

The growth of rock pressure with the increase of the minning depth is the main factor in the deterioration of the geomechanical condition of the "massif - support" system. A significant problem is the maintenance of the mining operations workings, since the tensile stresses on the contour of the chambers naturally increase with the increase of the minning depth. Maintaining the stability of the hanging side is especially problematic.

Possibilities of effective open development of iron ore deposits have largely been exhausted. The depth of underground mining is also approaching the limit where the possibilities of traditional technological solutions are exhausted.

Brief information about the deepest iron ore mines of Ukraine is given in the table 4.

Table 4 – The deepest iron ore mines of Ukraine

Industrial structure	Mine	Depth reached, m
PJSC "Kryvbaszalizrudkom	“Rodina”	1465
	“Zhovtneva”	1340
	“Hvardiiska”	1350
	“Ternivska”	1500
PJSC “ArselorMittal Kryvyi Rih”	“Artem mine”	1135

Means of protection of preparatory and capital workings, corresponding to the deterioration of their operating conditions, are presented in the table 5.

Table 5 – Means of protection of workings with deterioration of their operating conditions

Mining and geological conditions of operation	Method of protection
The rocks are weakly fractured, resistant, strength $f \geq 14$	Local fastening with anchors
Rocks of medium and low fracturing, medium resistance, strength $f \geq 12$	Anchoring with sprayed concrete
Rocks of medium and low fracturing, medium resistance, strength $f = 7 – 11$	Anchoring with net and application of sprayed concrete
Rocks with strong fracturing and low resistance, $f = 4–6$	Metal arch flexible support with timber tightening
Rocks with strong fracturing and low resistance, saturated with water	Reinforced concrete support
Rocks with strong fracturing and low resistance, prone to breakdowns	Tubing metal or concrete support

The most characteristic type of support in such workings is temporary reinforced concrete support or fastening with tubular anchors located on a grid of 1.0×1.0 m. Sprayed concrete 30–50 mm thick is used as a permanent support.

Seismic and dynamic effects from blasting will have a significant impact on all drill holes that have direct access to the chambers before the face chambers are of design size. These factors usually lead to the collapse of rocks and flaking of the surface of the workings. The main types of manifestations of rock pressure after the end of face operation in the chambers are fracturing and collapse of the containing rocks and deformation of the supports in the threaded workings.

For a more detailed study of the manifestation of rock pressure in drilling workings, an analysis of information on the behavior of supports in workings after the end of face operations and preparation of face chambers for backfilling was carried out [15].

In Fig. 2 shows the state of the drilling orts from the hanging side at the end of the face operation in the chambers.

a) nonfastened ort b) fastened ort

Figure 2 – Manifestations of rock pressure in the drilling orts at the end of the face operations in the chambers [15]

In Fig. 2a shows the state of the drilling ort from the side of the hanging side 16 m from the face chamber. Exfoliation of ore from the ore massif is observed in the roof and in the floor of the left side of the drill ort. The dimensions of these detachments are from 0.1 m^2 to 0.4 m^2. Near the roof of the left side of the working, at a distance of 15 m from the face chamber, a fracture with a length of about 1.0 m with a separation of wings of 0.01–0.015 m stands out.

Fastening of the drill ort along its entire length was not carried out due to the fact that the service life of this drill ort was less than 18 months.

In Fig. 2b shows the collapse of pieces of ore together with a sprayed concrete attachment on the right side of the drill ort from the side of the hanging side at a distance of 18 m from the face chamber. The width of the collapse zone reaches 1–3 m.

The thickness of the collapsed ore fragments, together with the sprayed concrete, is 0.7–1.3 m.

The height of the zone of collapsed rocks reaches the roof of the drill ort. Separate fractures are observed on the sprayed concrete support, which originate in the roof of the working and end at a distance of 1.5 m from the floor. The drill ort was fastened with sprayed concrete 0.05 m thick.

The analysis of production information from 20 drilling orts at different horizons allowed us to establish that after the end of the face operations in the chambers, the main types of manifestations of rock pressure are stratification and collapse of ore, fracturing of the roof and sides of the threaded workings. Along the length of the drill orts, the manifestation of rock pressure occurred at a distance of 4 to 44 m from the chambers in the direction of the rocks of the hanging side [15].

One of the most frequent problems in the development of ore deposits using the floor-chamber system of development is also the stability of transport workings. With the shallow depth of the workings, as well as the high strength of the ore and contain rocks in some areas of the mine field, it is possible to ensure the long-term stability of the workings without fastening. However, zones of geological disruption and the connection of workings are problematic.

Comprehensive experimental work was carried out to determine the geomechanical condition of transport workings at the "Nova" mine of "Shid-Ruda" of the Zhovtorichenske deposit.

The urgency of performing this work was connected with periodic rock fallouts in mining workings in areas of geological disturbance of the massif recorded by the geological surveying service of the enterprise.

The investigated workings are located in floors 94–545 m, in axes 36–130 of the Vilkhiv system in the area of the ore deposit of the Western layer. Instrumental-visual control and vibro-acoustic (shock-wave) diagnosis of the sections condition of the inclined ramp in the floor 545–433 m (axes 54–78 of the Vilkhiv system), the drift of the eastern field horizon 475 m (axes 98–108), the drift of the delivery (axes 76–102), orts of delivery blocks ZP545-7, ZP545-9 and ZP545-11 of the horizon 535 m. In the process of work, the own equipment and methodical developments of the IGTM of the National Academy of Sciences of Ukraine, which is the leading organization in

Ukraine for the development and implementation of vibroacoustic monitoring of the mining workings state, were used.

Comprehensive studies have shown the presence of multiple violations of rock integrity in the nearcontour zone of the investigated workings in the form of delamination of rocks of different thicknesses not only in nonfastened areas, but also in areas where arch support is installed.

In Fig. 3 shows fragments of the ort roof delivery block ZP545-9, horizon 535 m, and the section of the upper part of the inclined ramp fastened by an arch support.

a) – the roof of ort delivery b) – the roof of ramp

Figure – 3 A fragment of the roof of the upper part of the surveyed workings

As a result of the conducted research, it was proposed:

- the use of a rod support based on slag-silicate fast-hardening cartridge mixtures, consisting of a metal rod, a rubber sealing plug and cartridges with fast-hardening mixtures. These cartridges consist of two polyethylene shells: the outer, filled with loose material (a mixture of slag, cement and aluminum powder), and the inner, filled with liquid sodium glass. The length of the cartridge is 300 mm. The rod is made of reinforcing steel with a diameter of 18–20 mm;
- the use of contour (smooth-wall) blasting technology during tunneling, the use of which reduces the dynamic impact of blasting on the rock massif and the formation of additional fracturing in its nearcontour zone.

It should be emphasized that in difficult mining and geological conditions protection of workings should be carried out by combined methods. At the same time, both supports affecting the massif in the nearcontour zone of the workings and special supports for specific conditions are used. In Fig. 4 shows the general scheme of implementation of such methods.

4. Conclusions

The analysis of the domestic and world experience in the development of maintenance of workings of uranium and iron ore deposits made it possible to establish a variety of options for increasing the operational reliability of potentially dangerous areas. However, not all foreign developments in this direction can be applied to the conditions of domestic mines.

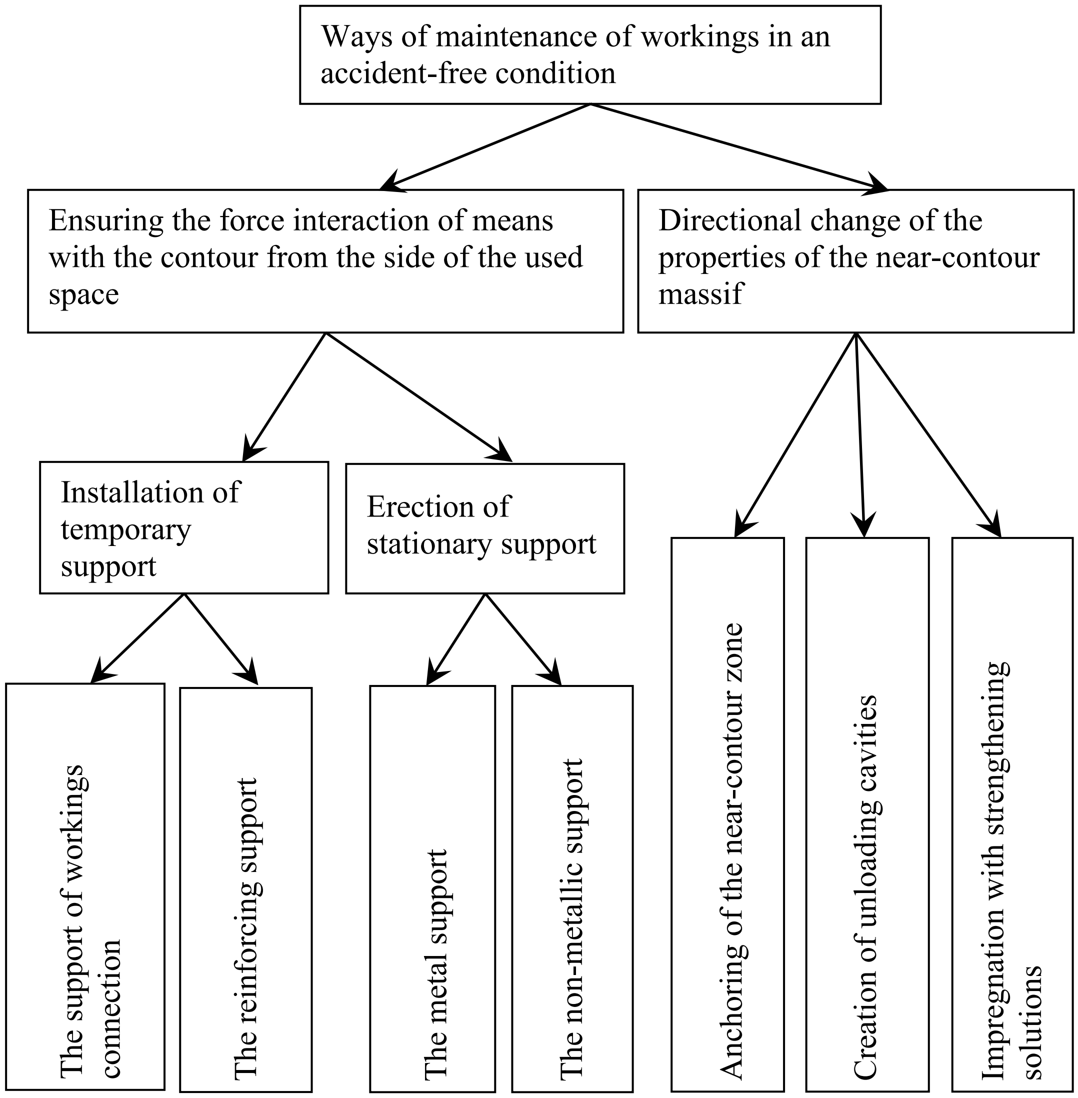

Figure 4 – The general scheme of maintenance of workings in an accident-free condition

With the transition to depths of more than 800 m, the rock pressure increases, so there is a need to search for new types of supports that have high working resistance and the ability to have higher flexibility, both in the vertical and horizontal planes.

In conclusion, it can be noted that several main types of supports are used in ore mine working. In mine shafts, this is a traditional tubular, (cast iron or reinforced concrete) or monolithic concrete support. In capital works it is rod (anchor) and continuous sprayed concrete. In the preparatory workings there are selectively (in some cases - continuously) sprayed concrete and rod support. In areas of tectonic and other structural disturbances, there may be a metal frame support.

It has been established that in difficult mining and geological conditions protection of workings should be carried out by combined methods. At the same time, both supports affecting the massif in the nearcontour zone of the workings and special supports for specific conditions are used. The general scheme of implementation of such methods is given.

Thus, the experience of maintenance of workings in difficult mining and geological conditions during the mining of ore deposits underground showed the need to continue researching the patterns of deformation and destruction of unstable rocks and creating new technological processes and supports to solve the problem of maintenance of workings and increasing the duration and safety of their operation. It should be noted that the choice of supports for maintenance of workings in specific mining and geological conditions is determined, first of all, by the reliability factor. At the same time, using the existing developments, successfully tested in the underground mining of iron ore, as well as coal and non-mineral raw materials, which allow to increase the reliability and safety of the works, it is necessary to find out the possibility of their application also in the working of uranium mines.

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АНАЛІЗ ТЕХНОЛОГІЧНИХ РОЗРОБОК З ПІДТРИМАННЯ ВИРОБОК НА ЗАЛІЗОРУДНИХ ТА УРАНОВИХ ШАХТАХ УКРАЇНИ

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Анотація. Метою даної роботи є встановлення недоліків та переваг існуючих зарубіжних та вітчизняних технологічних розробок з підтримання виробок на залізорудних та уранових шахтах та визначення найбільш перспективних шляхів для підвищення їх надійності. Проведений аналіз існуючих технологічних розробок з підтримання виробок уранових та залізорудних родовищ дозволив встановити різноманітність варіантів підвищення експлуатаційної надійності потенційно небезпечних ділянок. Враховуючи ці результати та особливості гірничо-геологічних умов залягання залізних та уранових руд в Україні виконані дослідження стійкості гірничих виробок при застосуванні різних технологічних рішень. В результаті проведених досліджень було запропоновано:

– використання штангового кріплення на основі шлакосилікатних швидкотвердіючих патронованих сумішей, що складається з металевого стрижня, гумової пробки ущільнювача і патронів з швидко твердіючими сумішами.

- використання під час проведення прохідницьких робіт технології контурного (гладкостінного) підривання, застосування якого знижує динамічний вплив вибухових робіт на породний масив та утворення додаткової тріщинуватості в його приконтурній зоні.

Встановлено, що в складних гірничо-геологічних умовах охорона виробок повинна здійснюватися комбінованими методами. При цьому застосовуються як кріплення, що впливають на масив в приконтурній зоні виробок, так і спеціальні кріплення для конкретних умов. Приведено загальну схему реалізації таких методів.

Таким чином, досвід підтримання виробок в складних гірничо-геологічних умовах при відпрацюванні рудних родовищ підземним способом показав необхідність у продовженні досліджень закономірностей деформування і руйнування нестійких порід та створення нових технологічних рішень і кріплення для вирішення проблеми підтримання виробок та збільшення тривалості та безпеки їх експлуатації. Вибір кріплення для підтримання виробок у конкретних гірничо-геологічних умовах обумовлюється, перш за все, фактором надійності. При цьому, використовуючи існуючі розробки, успішно апробовані при підземному видобутку залізної руди, а також вугілля і нерудної сировини, які дозволяють підвищити надійність та безпеку робіт, слід з'ясувати можливість їх застосування також у виробках уранових шахт.

Ключові слова: уранові та залізорудні родовища, стійкість виробок, технологічні рішення, кріплення виробок.