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SELECTION OF THE MEANS OF AUXILIARY TRANSPORTATION FACILITIES AND ADAPTATION OF THEIR PARAMETERS TO SPECIFIC OPERATION CONDITIONS

Purpose. To improve selection methods of operation schedules as well as means of auxiliary transportation facilities involving adaptation of their parameters to the specific application environment while preparing new extraction pillars for coal mining.

Methodology. The current methods for substantiating the operational parameters of the means of internal mine transport do not take into account the impact of mining-geological and technological factors, which change inadequately in space and time, on their productivity. The recommended method for selecting transport and technological schemes and increasing their adaptability in the real conditions of the mine environment is based on the comprehensive use of methods of expert evaluation of the operational indicators of the new generation of auxiliary transport means and modeling of the conditions of their interaction with arch support and side rocks at the stages of mining and their operation when preparing new mining pillars for cleaning mining.

Findings. The expert evaluation concerning technological features of mining field preparation as well as assembling and dismantling operations has determined that for the specific conditions of Western Donbas mines, the suspended diesel monorail locomotive and self-propelled machines are the most promising options. Gear clutch rail diesel locomotives are recommended as the auxiliary transport for the accelerated preparation of extraction pillar and introduction of a longwall into operation.

Originality. New approaches have been substantiated to improve selection of the efficient means of auxiliary transportation facilities and identify their operational parameters for the well-timed preparation of extraction pillars for their removal under the intensified underground mining conditions. A transportation schedule has been proposed to supply heavy tonnage loads by means of the suspended diesel rail locomotives as well as methods to calculate the expected loads on suspension members of the monorail road taking into consideration physico-mechanical characteristics of roof rocks within a development mine working.

Practical value. It has been proved that under the conditions of the intensified mining operations, the recommended engineering solutions meet the requirements of the well-timed preparation of new extraction pillars. In addition, they are considered as a new tendency to improve current schemes of auxiliary transportation facilities for regional mines and provide operational reliability of the available underground transport equipment.

Keywords: *anchor fastening, diesel locomotive, auxiliary transportation, preparation of extraction pillars, weight-handling system*

Introduction. Large-scale implementation of the powered new generation mining systems in Western Donbas (WD) mines has stipulated the necessity to intensify rates of coal preparation for extraction. Nevertheless, mining deepening increases rock pressure, temperature, and gas content of coal seams and minerals, which negatively impacts the rates of a new extraction pillar preparation for coal production. Practices have proved that if stratal mine workings are driven and operate within the environment where rocks prone to heaving are available, then a need arises in the repeated scheduled maintenances of areal transportation mine workings to support their design sections and capacity. In this connection, designing of operation schedules to prepare reserves for mining should fulfil specific requirements as for the selection of means of auxiliary transportation facilities and substantiation of their performance parameters to function efficiently at different stages of life cycle.

Topicality of the issue. According to the current standards of a coal mine design, a velocity of the development mine working driving for the well-timed preparation of new extraction pillars should exceed face velocity by 25 % [1]. In the context of intensive coal seam mining, the current operation schemes and schedules of assembling and dismantling operations (ADOs) involves dismantlement of power-intensive mining equipment from the worked-out longwall and its delivery to a mounting chamber of a new extraction pillar without any disassembling (or with partial disassembling) of the powered support sections. In terms of such requirements, the acting procedures and methods to select means of auxiliary transportation facilities and calculate their operational parameters need cardinal changes as well adaptation for the specific conditions of mine environment experiencing constant temporal and spatial variations.

Literature review. Several generations of scientists and researchers have analyzed both operational parameters of transportation schedules and processes of well-timed coal preparation for mining [2, 3]. The papers have proved theoretically and experimentally that under the specific WD conditions, intensification of development operations (DOs) should involve the use of overland rope roads in the straightway areal mine workings and new-generation diesel suspended monorail roads (SMRs) in the curved areal mine workings with a complex rail profile [4, 5].

Numerous papers by national and foreign authors consider mostly the problems of well-timed coal preparation for mining from the viewpoint of the improved roof stability in assembling and dismantling chambers or from the viewpoint of the chamber supplying with the specific equipment for safe assembling and dismantling operations [6, 7]. The papers deal with current methods for mounting timber dismantling chambers by means of two-level anchoring and high-strength mesh coverage. At the same time, the lion's share of coal preparation for mining belongs to transport and technological processes and operations which performance is still understudied.

Due to the reasons, domestic coal enterprises slowly implement the world practices as well as technologies to prepare reserves for mining with the use of innovative methods for timbering development mine workings, mounting chambers, and suspended monorail roads with highly adaptive diesel locomotives.

Earlier papers [8] considered only mechanical characteristics of rope and monorail roads and ignored complex evaluation of their parameters from the viewpoint of interaction between SMR components and rock mass in the process of the monorail carrying equipment traffic. In this connection, paper [4] proposes to consider rock mass, mine working supports, and SMR elements as an interactive *rock mass-support-transport vehicle* system. The approach necessity is especially topical while determining performance parameters of the system components in the context of intensification of transport and technological processes and narrowing the gap between mining and development operations while preparing new extraction pillars.

Purpose. Papers [5, 9] represent the generalized practices of the suspended monorail and overland rope roads (ORRs) as well as theoretical and experimental results of analysis of their parameters in mines. The proposed innovative engineering solutions have helped improved efficiency of ORRs, and their reliability under standard and nonstandard operations.

Recommendations have been elaborated to use the suspended monorail roads for the watered mine workings as well as transport networks with intensive rock bottom heaving [4, 10]. Comprehensive analysis of *rock mass-anchoring-SMR* system interaction has helped conclude that if a load carrier passes through the connection joints of a monorail, the supporting frames become stress concentrators resulting in the structure from rock pressure forces. Moreover, dynamic loads, transmitting repeatedly to bearing arches of the support when carrier is passing through the connection joints of a monorail, provokes roof rock lamination putting it into motion which curves the monorail profile and varies parameters of design section of the transport mine workings (Fig. 1).

Theoretical and experimental studies [11] on the dynamic processes, arising when rolling equipment is moving through the suspended monorail road, have made it possible to propose the ways reducing the load with the help of unique structural concepts. However, the studies did not take into consideration the load on the areal mine working supports while transporting super-heavy goods (i.e. rail packs, coal shearer assemblies, and powered support sections) under the specific mine conditions.

While assessing the results of previous studies, it is possible to conclude that further search for engineering solutions in the field of new extraction pillar preparation under the intensified mining operations should be aimed at the determination of SMR performance while transporting super-heavy goods through irregular-shape underground mine working.

The research task is as follows. Improvement of the methods for selecting operation schedules of the auxiliary transportation facilities for well-timed preparation of extraction pillars for mining is based upon the implementation of a transport logistics concept while optimizing:

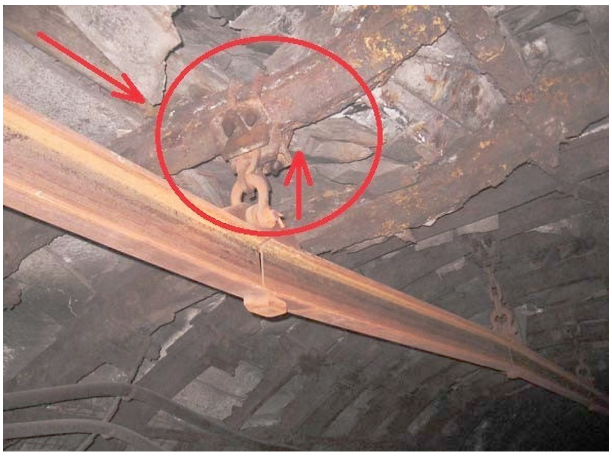

Fig. 1. Negative results of impact by dynamic loads of rolling SMR equipment of arching and the mine working roof [4]

- performance parameters of development mine workings for different stages of their life cycle;
- way and means to transport goods at the stages of development mine working construction and ADO performance;
- operating parameters of vehicles under specific mining conditions;
- conditions for interaction between *rock mass-frame anchoring-SMR* system components while performing technological mining processes.

The necessity to carry out the last-mentioned task depends upon the fact that a technology of frame anchoring to support development mine workings has been designed and implemented for the specific conditions of WD mines.

The key idea of transport logistics (i.e. *right on time*) has become the foundation of the well-timed technique providing processes helping prepare a field of mining operations involving safe delivery of personnel and auxiliary materials to development faces and mounting chambers.

The main part. According to the represented research algorithm for improving methods to select operation schedules of the auxiliary transportation facilities for well-timed preparation of extraction pillars to be mined, it is recommended to do the work in stages.

In practice, structural and operational parameters of development mine workings for different stages of their life cycles are selected relying upon the current norms taking into consideration parameters of the vehicles as well as maximum dimensions of the mining equipment to be delivered to a mounting chamber through a mine working.

It should be mentioned that modern ADO techniques involve transportation of specific out-of-gauge goods (i.e. rods, and pipes) as well as the assembled powered support sections to mountain chambers. Thus, while delivering such out-of-gauge goods to mounting chambers, the procedure forming a system of auxiliary transportation facilities should involve both features and characteristics of the vehicles in addition to the specific nature of a new extraction pillar preparation under complex (critical) mining and geological conditions.

To prepare new extraction pillars, the improved methods involve selection of transportation ways and means based upon a system of criteria and their expert evaluation; selection of the parameters of vehicles should take into consideration their adaptive capabilities under actual underground conditions.

While selecting certain means of mining equipment transportation as well as a vehicle type, the following is considered as the basic criteria:

- minimal expenditures connected with delivery;
- order of PS component transportation to mounting chambers;
- preset time of the goods delivery;
- maximal reliability and safety;
- capability to transport the out-of-gauge goods in the underground mine workings;
- capacity and availability of the vehicle.

Traditionally, the recommended method of expert evaluations and its basic alternatives are used to forecast development of engineering systems. They are applied to assess the factors influencing a decision-making process as well as the qualitative and quantitative indicators [12]. According to the structure of activities by underground transportation and technological systems for development mine working construction, and ADOs, a rank correlation method is considered as the most accessible alternative of an expert evaluation method. The system is based upon professional conclusions by a group of experts in the field with long experience of auxiliary transport operation under the specific conditions of WD mines.

To identify the most efficient way of auxiliary goods and equipment delivery in curvilinear in-seam mine workings with alternating-sign road profile, each expert j ($j = 1, \ldots, m$) was presented with a group of i ($i = 1, \ldots, n$) factors; the expert was accorded a right to evaluate their value and share, and assign a certain rank. A factor, having the heaviest influence on the problem solution, was assigned the highest (the first) rank; others were assigned the second, the third etc. rank according to their values.

Under the intensified mining conditions, a shaping process of new extraction pillars considers dismantling of the powered support sections after longwall was worked-out and their transportation through network of underground mine workings to a mounting chamber of a new longwall in the disassembled state as the most labour-intensive operation. In this connection, a group of characteristic factors has been formed influencing directly performance indices of vehicles as well as their adaptive capabilities. To support the independent expert evaluation of out-of-gauge goods delivery within the underground irregular shape mine workings, each of the indicators was symbolized as follows (Table):

*i*1 – operational efficiency of a vehicle;

*i*2 – reliability and safety;

*i*3 – possibility to transport diverse goods simultaneously;

*i*4 – possibility to control a transportation process remotely;

*i*5 – possibility to deliver out-of-gauge goods through the underground mine workings;

*i*6 – possibility to transport large tonnage goods;

*i*7 – possibility to be used within the curvilinear mine workings both in profile and in plan;

*i*8 – traction force;

*i*9 – compliance with the specified delivery time;

*i*10 – duration of the loading-unloading activities;

*i*11 – dependence of the performance parameters upon the floor rock stability;

*i*12 – dependence of the performance parameters upon the roof rock stability;

*i*13 – possibility to be used as the only vehicle;

*i*14 – degree of safety of the goods;

*i*15 – productivity per shift.

Summary of the matrix Table processing is columnwise computation of the rank sums. The most influential factor or reliable alternative will be that one whose rank sum is the smallest. According to recommendations by [12], more accurate qualitative evaluation of expert survey needs determination of a consistency index of expert opinion and concordance.

Average consistency ratio r is calculated in accordance with expression [12]

$$r = 1 - \left[\frac{2m(2n+1)12\sum_{i=1}^{n}\left(\sum_{j=1}^{m} r_{ij}\right)^2}{(m-1)9n - 10m(m-1)n(n^2-1)} \right],$$

where m is the number of experts participating in the survey; n is the number of the evaluated objects.

Concordance coefficient W, taking into consideration the scatter of the survey results of the average level, is calculated using formula [12]

$$W = \frac{12\sum_{i=1}^{n} a_i^2}{m^2(n^3 - n)}.$$

At the same time,

$$a_i = \sum_{j=1}^{m} \frac{r_{ij} - m(n-1)}{2}.$$

Both coefficients are interconnected with the ratios

$$W = \frac{|r|(m-1)+1}{m}; \quad r = \frac{mW-1}{m-1}.$$

$W = 0$ value corresponds to the case when opinions vary; if $W = 1$, then opinions coincide in full.

In practice, expert opinion consistency is evaluated by means of their confidence level, i.e. by means of a concordance coefficient determined according to Pearson distribution (x^2).

Table

Results of expert evaluation of the alternatives of out-of-gauge goods delivery

Evaluation parameters	Alternatives of out-of-gauge goods delivery				
	Accumulator locomotive	Overland rope road	Truck	Diesel locomotive with gear clutch	Diesel suspended monorail road
	Rank assigned to the factor by an expert				
i1	1	1	3	3	2
i2	1	3	4	1	2
i3	2	3	1	3	2
i4	2	1	2	1	1
i5	3	3	1	2	2
i6	3	1	3	2	2
i7	3	3	2	1	2
i8	2	1	2	1	1
i9	3	4	3	1	2
i10	3	3	2	2	2
i11	3	2	1	3	1
i12	1	3	2	2	3
i13	2	3	1	4	2
i14	3	3	2	1	1
i15	4	1	2	2	2
$\sum_i r_{ij}^* = h_i$	36	35	31	29	27

In the general case,

$$x^2 = \frac{\sum_{i=1}^{n} a_i^2}{\frac{1}{12mn(n+1)} - \frac{1}{(n-1)\sum_j (t_j^2 - t_j)}},$$

where t_j is the number of similar ranks in j line of the matrix Table; $(n - 1)$ is the number of degrees of freedom.

In line with the described methods, Table demonstrates the results of expert evaluation of means to deliver large-tonnage goods from the mined-out longwall to a mounting chamber of a new extraction pillar.

While determining the concordance coefficient, it is necessary and sufficient for the calculated value

$$x^2 - (n-1)mW,$$

to excess a Table value identified by the number of degrees of freedom $n = 1$ as well as by a confidence level assumed as 0.9–0.95.

Relying upon the evaluation results of performance indicators of the recommended vehicles (Table), rapid preparation of extraction pillars under the conditions of WD mines should prefer operation schedules of large tonnage goods delivery by means of the suspended diesel monorail roads.

It should be mentioned that *DTEK Pavlohradvuhillia* PJSC is the first company in the region which implemented the innovative engineering solution. Under its specific conditions, *Stepova* mine uses the suspended monorail road with Czech diesel locomotive Ferrit DLZ110F for fast delivery of auxiliary materials, equipment, and personnel to development and mining faces. High adaptive capability of the diesel locomotive confirms expert opinion. However, nonavailability of feasibility study on performance parameters needs implementation of particular research to improve the obtained TTS indicators under the specific conditions of WD mines. It depends upon the fact that low load-carrying capacity of rocks in the neighbourhood of areal mine workings in addition to intensive water inflows impose significant constraints on transportation conditions while excluding the possibility of safe delivery of the equipment which mass is more than 8 tons [13].

The negative factors decreases efficiency of vehicles and prolongate the periods required to prepare new extraction pillars. The abovementioned causes significant damages due to late commissioning of high-productive mining equipment. Hence, well-timed support of extraction activities needs correction of the rates of in-seam development mine working construction relative to the active stope advance velocity and consideration of adaptive capability of transport facilities to actual conditions of underground environment.

According to [14], operation schedules as well as parameters of the in-seam areal mine workings construction, needed for well-time resumption of mining activities, are determined for the specific technique of the extraction pillar preparation, a system of coal seam removal involving technical and operational parameters of transportation means, and for their efficiency. At the same time, structural and power parameters of the recommended vehicles should be adapted to various operational conditions of development mine workings, i.e. comply with the requirements at each stage of their life cycle being construction of mine workings, implementation of ADOs, and during mining operations.

SMR practices in *Pokrovska* and *Stakhanov* mines confirm [4] that different stages of the new extraction pillar preparation need adaptation of SMR performance indicators to actual underground environment as well as to the ones of development mine workings varying throughout time and space.

In terms of traditional procedures preparing for preparing in-seam areal mine working, monorail SMR track is fastened to anchoring girders of *АКП* type. Under the conditions of WD mines, arching of *КШПУ* type is applied. *A*, *B*, and *C* alternatives of possible monorail SMR structure fastening to arched frame *КШПУ* (Fig. 2) are identified by means of composition of vehicles, applied in the mine working, and their type and parameters.

Studies [4, 14] have identified that to improve stability of development mine workings, equipped with SMRs, it is required to fasten monorail road to a roof by means of extra chains with the use of anchors. Fig. 3 demonstrates potential SMR anchoring to a development mine working roof.

According to the structural and logical research framework, calculation of the performance SMR parameters under

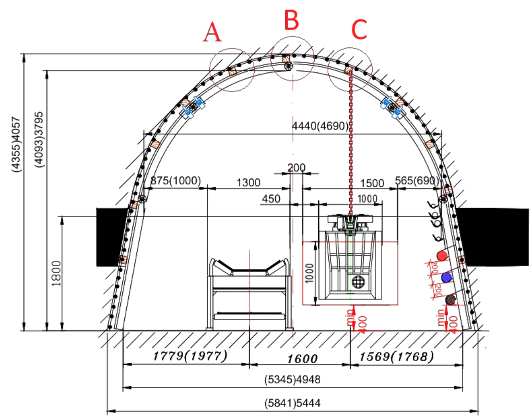

Fig. 2. Schemes of possible SMR structure anchoring within the in-seam areal mine workings:

A, B, C – alternatives of possible monorail SMR structure anchoring

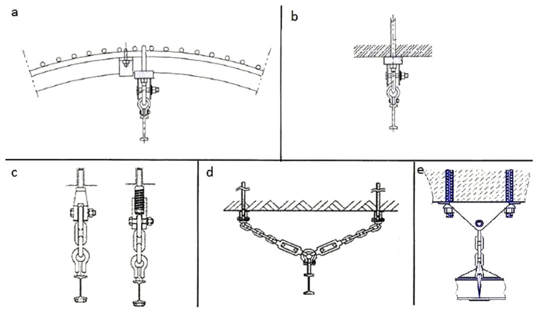

Fig. 3. Alternatives of the suspended monorail road fastening to a mine working roof:

a – rigid fastening to metal frame anchor; b – rigid one anchor fastening; c – chain fastening on one anchor; d – chain fastening on two anchors; e – rigid fastening on two anchors with a chain

the actual environment of WD mines, rock mass, frame anchoring of development mine workings, monorail road structure, and anchors for its fastening should be considered as interacting *wall rocks-frame anchoring-rolling equipment* transportation and a technological scheme.

Earlier studies have helped understand that in the process of SMR activities, roof of the in-seam development mine working experiences extra dynamic loads which should be taken into consideration while determining frame anchoring parameters. The abovementioned can be achieved if some extra load on bearing anchors (i.e. deep laying anchors) is involved. The last-mentioned anchors are applied to fasten monorail SMR structure to a development mine working roof. Deep laying anchors are mounted between the lines of the first-level anchors. The number of deep laying anchors within the line depends upon B width of a mine working. If $B \le 5.5$ m, then there should be at least two deep lying anchors.

Extra loads on the bearing anchors arise when SMR is passing through the connection joints of a monorail structure, i.e. at the expense of increase in analytical specific load P_a by additional weight ΔP_a value determined by the expression

$$\Delta P_a = \frac{P_s^{\max} k_d}{BC_s},$$

where $P_s^{\max}$ is maximal static load on one suspender, kN; C_s is distance between SMR suspenders, m; k_d is coefficient taking into consideration the impact of dynamic loads on a roof arising during the goods transportation.

According to recommendations by [15, 16], the coefficient of dynamic load on the anchor is $k_d \ge 2$.

Selection of an anchor, complying with the operational conditions, and its parameters are determined involving analytical total load $P_a + \Delta P_a$. Hence, parameters of bearing anchors, applied to fasten the suspended monorail road, are calculated inclusive of maximum weight of goods being transported, the working load on one suspender of a monorail road, the required safety margin determined by the SMR manufacturer, and the potential dynamic stresses on carriages and suspenders.

In line with the recommendations, maximum static load on one suspender is defined by means of the expression

$$P_s^{\max} = \frac{(Q_w^{\max} + Q_T)k_T}{q},$$

where $Q_w^{\max}$ is maximum allowed weight of goods falling at the road section C_s, kN; C_s is the distance between the suspenders, m; Q_T is total weight of the attachments within a road section, kN; k_T is the coefficient of load distribution by large tonnage goods on carriages; q is the number of the carriages.

A distance between C_s suspenders is a distance between SMR suspenders, i.e. a monorail road section within which maximum load happens. It is defined with the help of the number of q carriages falling at it. Its calculation is based upon SMR specifications, permissible weight of the transported goods, and capacity of the carriage.

Value of k_T coefficient depends upon the number of carriages getting on two adjacent rails relative to a suspension point. It is defined using the expression

$$k_T = 1 \quad \text{if} \quad \frac{L_k}{C_s} \geq 1 \quad \text{and} \quad k_T = 2 - \frac{L_k}{C_s} \quad \text{if} \quad \frac{L_k}{C_s} < 1,$$

where L_k is minimal distance between the carriages, m; C_s is distance between SMR suspenders, m.

In practice [13], to deliver out-of-gauge goods, SMR carriages are united to be loading platforms; in this context, maximum allowable dynamic stresses falling at the monorail structure and its suspenders are ignored.

A suspender is a structure involving bracing rods, i.e. a system of pivots, chains, collars, and bolts interconnected in one point of a monorail mounting. In such a way, one suspender can consist of one as well as of several bracing rods (Fig. 3). If the last-mentioned ones meet at a certain point of monorail mounting, then bearing capacity of the whole suspender may not be equal to the total of bearing capacities of its separate bracing rods [17, 18].

The approach can provide neither out-of-gauge goods with the total $Q_w > 8t$ weight (i. e. rail pack, the powered support section etc.) nor safe SMR operation. Simulation results of interaction between *rock mass-frame anchoring-SMR* system components show that to transport large tonnage goods, carriages should be united into loading platforms (Fig. 4); moreover, distance between their centres should be selected in such a way to meet following condition

$$P_s^{\max} k_m \leq N_s, \tag{1}$$

where k_m is safety margin; N_s is bearing capacity of the suspenders.

N_s value should be understood as the minimum load in terms of which at least one component of a suspender is damaged, which results in breakdown. Safety margin k_m, taking into consideration dynamic stresses of the system, is defined by SMR manufacturer; in addition, it should not be less than three.

If inequality (1) cannot be solved, then it is necessary either to decrease weight of loads $Q_w^{\max}$ or to increase load-carrying ability of suspenders N_s. It can be achieved while aggregating carriages into the loading platforms forming together a weight-handling system. In this context, the total goods weight combined with the attached equipment $Q_w^{\max} + Q_T$, falling at platform trucks, should not exceed bearing capacity of suspenders N_s. The weight-handling system of a monorail road, shown in Fig. 4, represents distribution of large-tonnage load on the platform trucks as well as the monorail structure suspenders being spaced C_s apart.

Hence, to deliver large-tonnage loads through the curvilinear underground mine workings, the problem is solved while forming a highly adaptive weight-handling system. Structural features of the recommended weight-handling system help decrease the maximal load on a monorail. It is possible owing to redistribution of the total weight onto two common load platforms each of which involves two carriages.

Simulation results of the interaction between the components of a weight-handling system in the process of large-tonnage goods transportation using monorail made it possible to identify that the requirements [16] on the maximum permissible bend of monorail chain $f\partial \leq L/200$ are provided by means of the total load redistribution into load platforms as well as adjustment of the distance between their centres.

Transportation of the highly adaptive weight-handling system by means of the monorail results in redistribution as well as simultaneous self-control of static load from the central parts of monorail structure chains 1 to adjoining chains *11* and *12* providing the required bearing capacity of the monorail structure, permissible bend, and performance reliability. As a consequence, load on bearing support arches *3* decreases despite the loads weight; their carrying capacity is achieved as well as safe environment while transporting large-tonnage loads in the period of assembling and dismantling activities.

The determined distance C_s between the suspenders of a monorail structure (Fig. 4) defines the interval to mount anchors. The abovementioned meets the requirements, represented by [16] while providing bearing capacity of SMR monorail structure links if large-tonnage goods are transported.

To apply SMR efficiently under the specific conditions of WD mines, the composed scheme of frame anchoring for a development mine working roof is proposed involving the use of definite anchors for the monorail structure suspenders. Fig. 5 explains the composed scheme of frame anchoring for a development mine working as well as arrangement of anchors for the monorail structure suspenders (A_{sm}).

In accordance with the recommendations by [4], a scheme to suspend SMR monorail structure to a development mine working roof is considered using chains and two anchors (Fig. 3, *d*).

Simulation results of the interaction between the components of a *rock mass-frame anchoring-SMR* system have helped identify that the required bearing capacity of suspender anchors N_{as}, applied to fasten a monorail SMR structure to a development mine working roof, is defined with the help of their design characteristics and parameters providing maximum

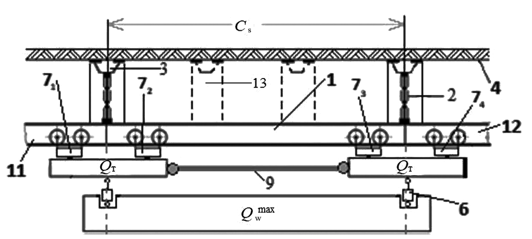

Fig. 4. Lifting and transporting system of a monorail road to deliver large tonnage goods:

1 – central bar of a monorail chain; 2 – suspenders; 3 – carrier beams of support; 4 – mine working; $Q_w^{\max}$ *– large-tonnage goods; 6 – hydraulic advancing cylinder;7 – carriers;* Q_T *– load platforms; 9 – connecting rod;* C_s *– distance between the centres of the load platforms; 11 and 12 – adjacent monorail chains; 13 – intermediate supporting arches*

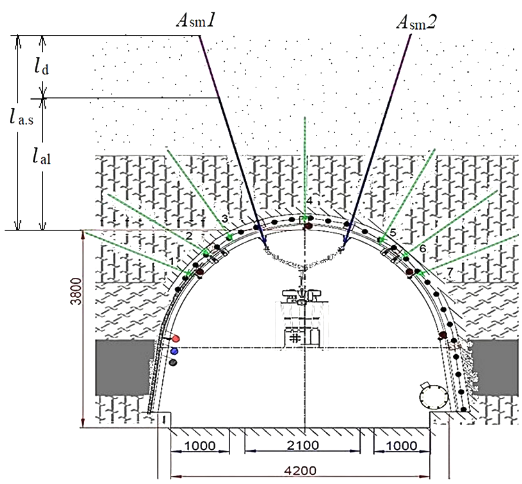

Fig. 5. Arrangement of the anchors for SMR monorail:

1–7 – anchors for a mine working roof; $A_{sm}1$ *and* $A_{sm}2$ *– anchors for the suspenders of SMR monorail structure* permissible dynamic stresses during large-tonnage goods transportation

$$N_{as} \geq \frac{N_s}{n_{as} k_m},$$

where N_s is bearing capacity of a monorail structure suspenders; n_{as} is a mounting interval for anchors of a monorail structure suspenders (A_{sm}); k_m is the safety coefficient of anchor suspenders.

The defined *N*as value helps select an adequate diameter of anchoring rods. Experiments have proved that anchor length of a monorail road suspenders $l_{a.s}$ (level two) should exceed anchor length l_{al} (level one) mounted to support a mine working roof. The required $l_{a.s}$ value is calculated using the expression

$$l_{a.s} = l_{al} + l_d,$$

where l_{al} is analytical length of level one anchors applied to support a mine working roof; l_d is deepening value of anchors of SMR suspenders over the level one anchors. The value is assumed as thet one being no less than 0.5 m for type two of a roof type in terms of its failure and no less than 1.0 m for roof types one, three, and four in terms of failure.

Relying upon the support designs for monorail structure suspenders, shown in Fig. 3, it is expedient to apply in WD mines the technique of frame anchoring of development mine workings using rope anchors with higher bearing capacity developed by the Anchoring Centre of the Institute of Geotechnical Mechanics Named after N. Poljakov of the NAS of Ukraine [19, 20].

Use of SMR with the elements of highly adaptive weight-handling system and the recommended engineering solutions on the combined anchoring of a monorail structure as well as transport mine workings comply with the requirements of well-timed preparation of new extraction pillars. Moreover, they are considered as a promising tendency to improve the available schedules of the auxiliary transportation facilities of regional mines.

Conclusions and prospects for future studies. In the context of intensive coal seam mining using longwalls advancing to the rise (to the dip), well-timed preparation of new extraction pillars needs increase in the rate of long area mine working and face entry construction and their supplying with transportation facilities corresponding to certain operational conditions.

Under the specific conditions of WD mines, long development mine workings with complex coal seam hypsometry experience intensive impact by tectonic stresses demonstrated as parametric variations in stratal mine workings and rails; the abovementioned generates extra requirements for their operation.

Analysis of the performance indicators of areal mine workings, equipped with overland transport has helped identify that well-timed preparation of new extraction pillars is influenced heavily by low capacity of the available transportation and technological schedules during assembling and dismantling activities. In the world mining practices, the suspended monorail roads with diesel locomotive are alternative to overland transportation facilities.

To substantiate the area of efficient use of innovative tendencies under the specific conditions of regional mines, the performance indicators of a transportation and technological schedule using the suspended monorail roads were first considered as interactive *rock mass-frame anchoring-SMR* system.

Simulation results of the interaction conditions of the system elements have helped understand that the required bearing capability of suspender anchors, applied to fasten monorail SMR structure to a development mine working roof, are identified with the help of their design features as well as frame anchoring parameters providing maximum permissible dynamic stresses while transporting large-tonnage goods.

The experiments have proved that increase in weight-carrying capacity of SMR and the attached mechanisms needs substantiation of rational sections of mine workings as well as their supporting techniques.

The recommended method to transport large-tonnage goods (i.e. the powered support sections, coal shearer assemblies, rail packs etc.) involves extra auxiliary activities within the loading points as well as loading-unloading points saving their performance time while providing their safe assembled delivery.

It has been proved that under the intensified mining, the recommended engineering solutions comply with the requirements of well-timed preparation of new extraction pillars. In addition, they are considered as a promising tendency to improve operating schedules of the auxiliary transportation facilities for regional mines and provide performance reliability of functional equipment of the auxiliary transport facilities.

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Вибір засобів допоміжного транспорту та адаптація їх параметрів до специфічних умов експлуатації

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Мета. Удосконалення методики вибору технологічних схем і засобів допоміжного транспорту та адаптація їх параметрів до специфічних умов експлуатації при підготовці нових виїмкових стовпів до очисного виймання запасів вугілля.

Методика. Діючі методики обгрунтування експлуатаційних параметрів засобів внутрішньошахтного транспорту не враховують вплив на їх продуктивність гірничо-геологічних і технологічних факторів, що неадекватно змінюються у просторі й часі. Рекомендована методика вибору транспортно-технологічних схем і підвищення їх адаптаційної здатності в реальних умовах шахтного середовища базується на комплексному використанні методів експертної оцінки експлуатаційних показників засобів допоміжного транспорту нового покоління й моделюванні умов їх взаємодії з арковим кріпленням і бічними породами на етапах проведення гірничих виробок і їх експлуатації при підготовці нових виїмкових стовпів до очисного виймання.

Результати. За результатами експертної оцінки особливостей технології підготовки шахтного поля й монтажно-демонтажних робіт, встановлено, що для специфічних умов шахт Західного Донбасу найбільш перспективними є варіанти із застосуванням підвісного дизельного монорейкового локомотиву та самохідних машин. Як додатковий тип транспорту для прискореної підготовки виїмкового стовпа та введення лави в експлуатацію рекомендується застосовувати рейкові дизельні локомотиви із зубчастим зачепленням.

Наукова новизна. Обгрунтовані нові підходи щодо вдосконалення методів вибору раціональних засобів допоміжного транспорту й визначення їх експлуатаційних параметрів для своєчасної підготовки виїмкових стовпів до очисного виймання в умовах інтенсифікації гірничих робіт. Запропонована транспортно-технологічна схема для доставки великотоннажних вантажів підвісними дизельними монорейковими локомотивами та методика розрахунку очікуваних навантажень на підвіски монорейкової дороги з урахуванням фізико-механічних властивостей гірничих порід покрівлі підготовчої виробки.

Практична значимість. Доведено, що в умовах інтенсифікації очисних робіт рекомендовані технічні рішення відповідають вимогам своєчасної підготовки нових виїмкових стовпів і розглядаються як перспективний напрям із удосконалення діючих схем допоміжного транспорту для шахт регіону й забезпечення експлуатаційної надійності діючого гірничотранспортного обладнання.

Ключові слова: *анкерне кріплення, дизельний локомотив, допоміжний транспорт, підготовка виїмкових стовпів, підйомно-транспортна система*

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