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RESEARCH OF OPERATION FEATURES AND DEVELOPMENT OF REQUIREMENTS FOR MAINTENANCE OF STRUCTURES OF ROPE-PROFILE GUIDES IN THE SHAFT EQUIPMENT

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Abstract. In this work, the existing normative methods for maintaining shaft equipment of mine vertical shafts were investigated and methods for maintaining shaft equipment with rope-profile guides, console-damper buntons, tension devices in the sump part of the shaft and in the pile driver were developed. Interrelations of processes: operation - maintenance - repair in the system of mechanisms were investigated for developing decision-making algorithms to determine the actual state and predict the residual life of the elements, on the basis of which the choice of a system for repair and maintenance of equipment is made. This article contains a study of the advantages and disadvantages of existing types of reinforcement and their comparative analysis with cable-profile reinforcement.

The use of this study results in relation to the mine shaft equipment with rope-profile guides (hereinafter – the RPG) will allow:

- to reduce the risk of emergencies;
- to develop an optimal system for carrying out repair and maintenance work;
- to optimize repair and maintenance costs (spare parts, components, labor resources, number of repair personnel, etc.);

– reduced labor intensity of maintenance and operation, compared to rigid reinforcement;

– reduced metal consumption compared to rigid reinforcement;

– increased reliability of the kinematic connection in the "vehicle–RPG" system due to the use of bunton legs with connecting inserts;

– reduced safety gaps per side – 350 mm for skip hoists, and – 500 mm per side for cage hoists along the entire depth of the shaft as for flexible reinforcements;

– exclusion of the use of fender ropes;

– increased service life of rope-profile guides to the level of guides for rigid shaft reinforcement.

Keywords: mine vertical shafts, rope-profile guides, console-damper buntons, technical maintenance, tension extensions, rope production, repair, technical maintenance.

1. Introduction

Vertical shafts are especially important mine workings providing: - the main traffic flows of the mine; - ventilation of mine workings; - operation of power supply systems; - laying of pipelines for drainage, pneumatic pipelines, fire extinguishing; - laying of communication systems; - arrangement of flights of stairs for emergency exits from the mine; and so on.

Technical condition of the vertical shaft equipment determines the uninterrupted and reliable operation of the entire winding complex, safety transporting of people, cargo and materials in the mine, bringing minerals to the surface, pumping out water, supplying power to the entire underground part, providing communications, ventilation of underground workings, emergency exit of people to the surface, etc.

The operation of the complex mechanisms of vertical shafts is provided by the system of maintenance and repair of equipment.

Regulatory documents adopted to date [8], namely: - section 7 "Requirements for the maintenance of shaft equipment"; section 6 "Types and frequency of maintenance of vertical shaft equipment" [9], and section 2 "Types of inspection of vertical shafts" [10], set cyclical calendar intervals for repair and maintenance work, which do not fully take into account the actual loading of equipment, the intensity of its and the conditions of its operation.

2. Methods

The purpose of the research - the study was based on the task to draw up an algorithm for developing a system for the maintenance and repair of shaft equipment consisting of rope-profile guides (hereinafter - RPG , or guides), console-damper buntons, tension devices located in the shaft sump and other equipment of vertical shaft with a RPG on the basis of analysis of existing systems for the maintenance of shaft equipment with taking into account design features and actual dynamics of wear of the elements of the system,

The result of these studies is the development of a maintenance methodology for rope-profile guides systems, the implementation of which will allow to:

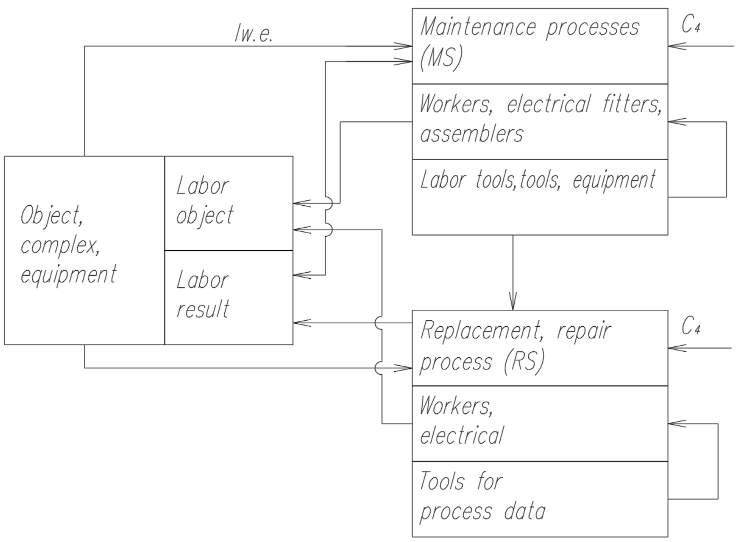
- increase the service life of the guide system;
- extend the service life of the main shaft equipment elements;
- reduce the effect of corrosion processes in the shaft equipment;
- reduce repair and maintenance costs;
- improve the overall level of safety in the operation of the shaft equipment.

3. Results and discussion

In accordance with the standard "System of maintenance and repair of equipment", GOST 18322-78, maintenance is understood as a set of operations to maintain the operability or serviceability of equipment when used for its intended purpose.

Repair of equipment is a complex of operations to restore serviceability or operability, as well as to restore the service life of an object or its components.

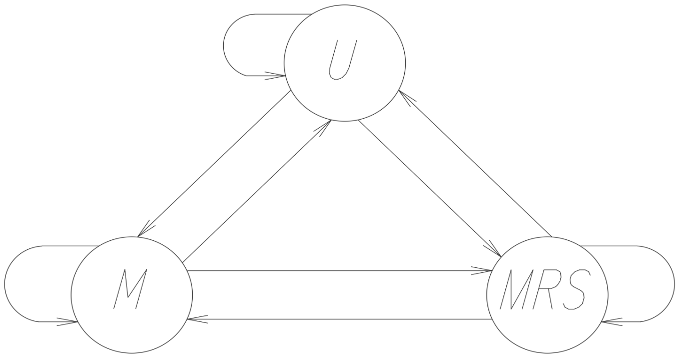
The processes of maintenance (hereinafter referred to as MS) and repair (hereinafter referred to as RS) are supporting services in relation to the main process (operation of the equipment for its intended purpose) and are associated with it by material and information flows [12] (see Fig. 1).



Iw.e - information about the operation and condition of the equipment; C_4- components, parts, assembly units

Figure 1 – Scheme of the relationship between MS and RS processes

When the equipment, parts and components become inoperable, the object is taken by the maintenance and repair service as an object of labor, where the maintenance and repair processes (MRS) are performed cyclically. Refurbished equipment is re-introduced into work. The information necessary for the organization and management of processes (MRS) concerning the equipment technical conditions, state, duration of the residual life of its components and assembly units comes from the object of use according to the scheme (see Fig. 2):



M is the mounting; *U*- use of equipment for its intended purpose;
MRS- maintenance and repair service

Figure 2 – Scheme of information flows necessary for organizing the operation of vertical shaft equipment

At present, two main strategies for the repair of equipment of mining enterprises are adopted: by operating time; and according to the actual technical condition. In practice, as a rule, both of these strategies are used in mixed versions. The operating time and resource standards established by manufacturers are imperfect and do not fully take into account wear factors, therefore, components, parts, assembly units with a significant residual resource (up to 50%) are often replaced. When repairing equipment due to its condition on the basis of statistical data on failures of assembly units and components, it is necessary to arrange distribution of their operating time by equivalent time and, in the future, determine the mathematical expectation of the average resource T_{e1}. These data are obtained on the basis of observations of similar objects and from regulatory and technical documentation.

The criteria can be: T_e - equivalent time taking into account the time of the object use for its intended purpose (see Fig. 4); T_m - the operating mode of the system based on the properties of the weakest element through the indicator of the assembly fatigue curve in double logarithmic coordinates, the number of cycles, aggressiveness and abrasiveness of the working environment, etc. When assessing the resource by equivalent time, the coefficient of variation is 3-7 times less than when assessing the resource by cycles. If you set the time for repairs according to T_{ea}, then there will always be a situation where a sudden failure can occur with a probability of 0.5 (see Fig. 3), since some components of the system have already worked out their resource. At the same time, repairs are often carried out with an underutilized resource of individual assemblies and assembly units.

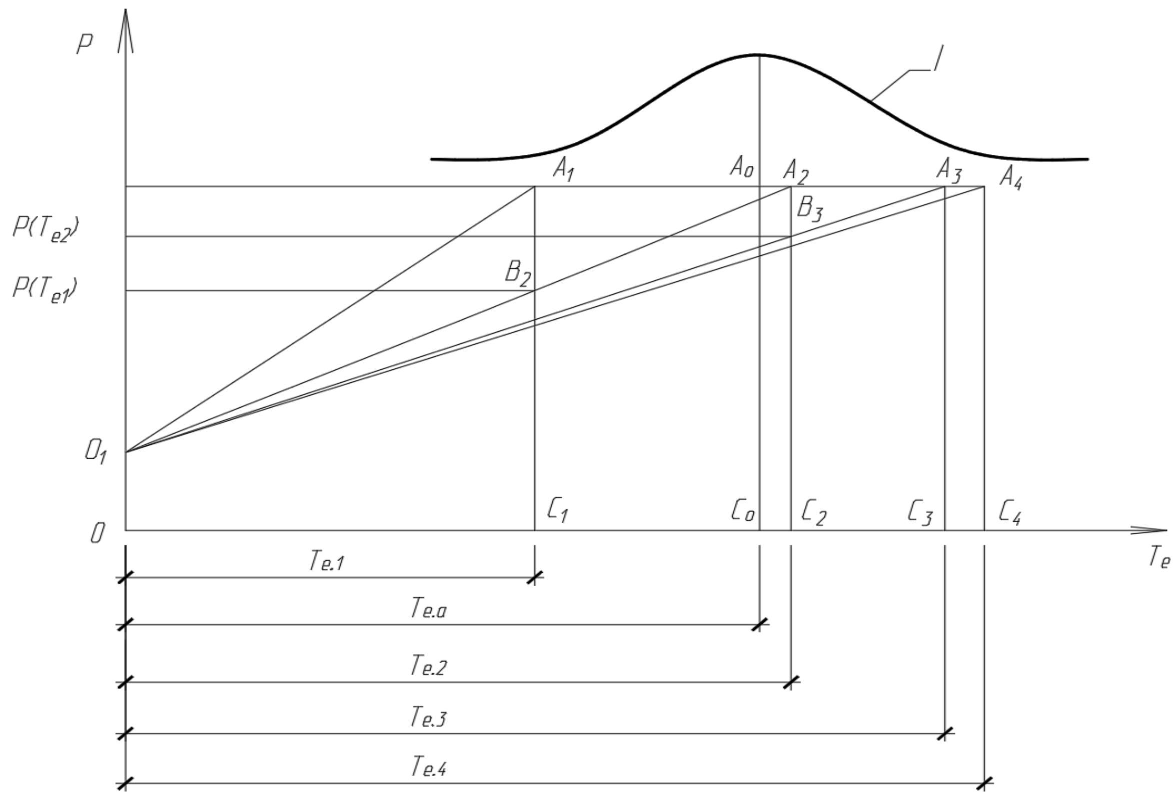


Figure 3 – Schedule of assigning maintenance periods for the repair of the RPG according to the technical condition and wear of the equipment of vertical shafts

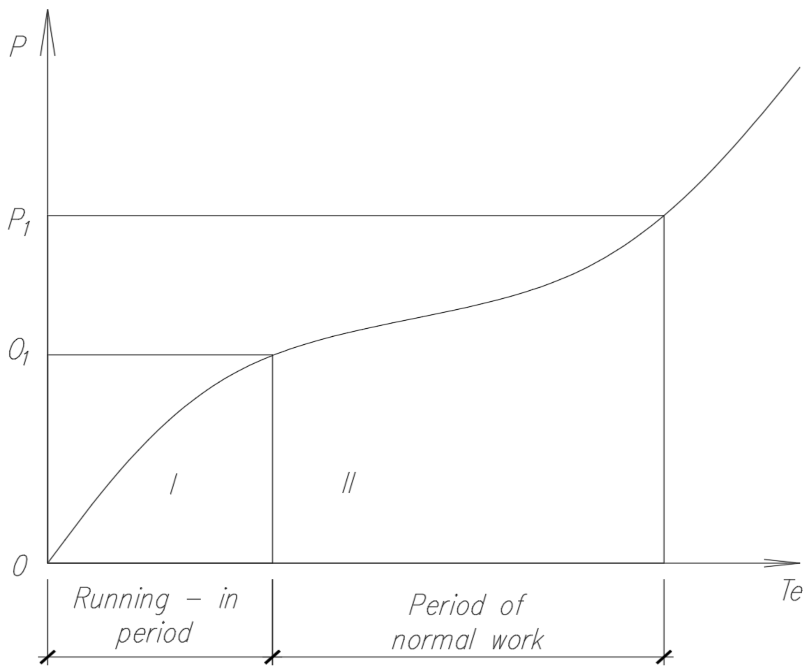


Figure 4 – Schedule of assigning maintenance periods for the repair of the RPG according to the wear of the equipment of vertical shafts

The following symbols are used in the figures:

I – distribution of operating time of controlled equipment according to T_e;

T_e - the period of operation, upon reaching which it is required to review the technical condition of the equipment;

P - controlled parameter characterizing the technical condition of the assembly unit;

$P_п$ - the limit value of the parameter, upon reaching which the adjustment or replacement of the unit is required;

$P(_{Te1})$ and $P(_{Te2})$ - is the value of the parameters corresponding to the operating time T_{e1} and T_{e2}.

The first control period corresponds to the moment when a failure of the assembly unit (point C_1) can be expected with a probability of 0.5 (see Fig. 3);

The wear of assemblies in the section OC_1 proceeds at a constant speed and obeys a linear law (segment O_1A_1), the process of "normal" wear (period). Upon reaching the period T_{e1}, we measure the controlled parameter $P(T_{e1})$ (see Fig. 3).

If the $P(T_{e1}) \geq P_l$, assembly (assembly unit) should be adjusted or replaced. In cases when $P(T_{e1}) \leq P_l$, the distribution of this parameter is constructed, and a point B_2 is found (probability of the occurrence of this event is 0.95, the value of this parameter corresponds to the point B_2). If we extend the line O_1B_2 to the intersection with the line P_l, then at their intersection we get a point A_2. By dropping a perpendicular from the point A_2 to the axis T_e, we get the segment $OC_2=T_{e2}$, if $P(T_{e2}) \geq P_l$ then the assembly unit should be adjusted or replaced.

If $P(T_{e2}) \leq P_l$, the equipment is used for its intended purpose, as the equipment operates, the frequency of monitoring of its condition increases $(OC_1 \geq C_1C_2 \geq C_2C_3 \geq C_3C_4)$, therefore, the frequency of repair cycles is uneven and should be set with taking into account all wear factors and the limit state of all elements of the system.

The maintenance of vertical mine shafts is carried out primarily in accordance with the current "Safety rules for coal mines: NPAOP 10.0-1.01-10" [7], and such regulatory documents as [9, 10, 11, 12]. In particular, these documents state the following:

- section 7 "Requirements for the maintenance of shaft equipment" [8]:
- Clause 7.1 "The task of maintaining the rigid shaft equipment of the vertical shaft of the mine is: ensuring long service life of all its constituent elements; failure prevention; elimination of the reasons causing these malfunctions".
- Clause 7.2 Regulatory requirements [10] requires:
- maintenance (MS);
- scheduled daily maintenance (MS-2);
- weekly maintenance (MS-3);
- monthly repair service (RS-1), or maintenance service (MS-1);
- technical inspection, instrumental check of wear of guides.

Unscheduled maintenance of the shaft equipment with checking safety clearances throughout the entire depth of the shaft is carried out before putting into operation a newly mounted winding cage (counterweight) with indicators differ from the design specification, as well as after repair work in the shaft connected with straightening of the buntons, adjusting of the guides position, restoring of the shaft lining, etc.

- clause 7.2.1: daily maintenance (MS-2) is necessary for the timely detection of initial defects of the shaft equipment; it is carried out throughout the entire depth of the shaft from top to bottom by highly qualified locksmiths appointed by the order of the mine administration in accordance with [11].

Daily maintenance service (MS-2) of the shaft equipment consists in its visual inspection from the observation deck of a winding cage moving at a speed of up to 1 m/s. For combined hoists (two or three hoists in one shaft), it is allowed to inspect simultaneously the shaft equipment in adjacent sections of the shaft: in this case, difference in height between the winding cage, from which the inspection is carried out, should be not more than 5 m. The sections of the shaft under repair should be inspected at speed 0.3 m/s.

When examining the shaft equipment, visible defects should be fixed, namely:

- deformations of buntons and guides;
- weakening of the tightening and sliding of the clamping brackets;
- loosening of bolted connections;
- the presence of backlashes in the guide attachment points;
- absence of impacts at the joints;
- state of the shaft;
- pieces of rock, coal, and other large objects should be removed from buntons; and so on.

At MS-2, at the base mark of the shaft [11], the following are measured:

- total gaps between slideways and guides;
- and wear of the working surfaces of the guides.

If the wear of any of them exceeds the standard values, the slideway or its corresponding replaceable insert is replaced. The results of the inspection are recorded in the Winding Installation Inspection Book, where the nature of the defects found and measures to eliminate them are recorded.

7.2.2 Weekly maintenance (MS-3). The task of MS-3 is a detailed visual inspection of the shaft equipment, check of condition of its elements and attachment points. The speed of movement of the winding cage when performing MS-3 should be not more than 0.3 m/s. Work is performed in the presence of the chief or senior mechanical engineer.

If the winding cage moves with gaps in the pair "slideways - guide", the following should be made:

- to control changed width of the guide gauge;
- to clean buntons from foreign objects;
- to check reliability of tightening the threaded connections by tapping them with a hammer;
- to inspect condition of butt tongs and clamping brackets;
- to examine seals of buntons and the lining of the shaft;
- to drawn attention to the condition of the guides and points of their attachment to the buntons (the absence of cracks, the reliability of welding of the "floorbeam" to the bunton flanges);

- to check size of the gap between the rail sole and the "floorbeam" socket. The shaft equipment elements in the "critical" sections of the shaft should be inspected with particular carefulness. If any defects are found, the winding cage should be stopped till determining the causes of defects and developing measures to eliminate them.

The results of the inspection and the measures taken to eliminate the found defects are recorded in the "Book of Inspection of Mine Shafts".

7.2.3 Monthly repair service (RS-1).

In accordance with the requirements of the “Safety rules for coal mines: NPAOP 10.0-1.01-10” [7], director or chief engineer of the mine inspects the shaft equipment on a monthly basis in the amount provided for by weekly maintenance (MS-3). In addition, in the process of the inspection, “critical” sections of the shaft are specified, the amount of repair work is determined, and the smoothness of the movement of the winding cage at operating speed is checked. In places where impacts are felt, the tightening of bolted connections, the presence of ledges at the joints of the guide are checked, i.e. the causes of impacts are clarified and measures are taken to eliminate them, the results of the inspection are entered in the "Book of Inspection of Mine Shafts".

7.2.4 Technical inspection of shaft equipment.

This inspection is carried out 6 months after the revision and adjustment of the hoister installation under the supervision of the chief mechanical engineer of the mine in accordance with the “Safety rules for coal mines: NPAOP 10.0-1.01-10” [7]. During the inspection, general condition of the shaft equipment is checked - the reliability of fastening of guides and buntons, wear as a result of corrosion, the correspondence of the gaps between the maximum protruding parts of the winding cages, lining and buntons. In previously identified places of guide curvature, the change in the magnitude of the relative displacement of guides on adjacent tiers over the past period is estimated. The results of the technical inspection are recorded in the "Book of Inspection of Mine Shafts".

7.2.5 Instrumental check of wear of guides.

In accordance with the requirements of the “Safety rules for coal mines: NPAOP 10.0-1.01-10” [7], metal guides are checked in one year, wooden guides - in six months by using technical means.

The nature of the wear of the working surfaces of the guides allows finding the "critical" sections of the shaft. In areas of increased wear of the guides, the presence of such defects as narrowing of the gauge and a large relative displacement of the guides on two adjacent tiers is most likely.

Periodic monitoring of the geometrical parameters of the guides in the indicated sections of the shaft and analysis of their changes over time makes it possible to establish the nature and causes of the development of defects, i.e. to classify them into: - actively developing; - fading; - stable. In addition, the result of the controlled parameters analysis should be used for developing measures to eliminate and prevent these defects in future and ensure a stable operation of the hoist.

According to section 6 "Types and frequency of maintenance of vertical shaft equipment" [10]:

- p. 6.1 Maintenance of vertical shaft equipment must be carried out in accordance with the maintenance and current repair schedule.

- Clause 6.2 Schedules for maintenance and current repair of equipment for each shaft are developed by the power and mechanical service.

- Clause 6.3. The dates of work on maintenance and technical repair of equipment are accepted in accordance with [7], as well as with the operating instructions of the equipment manufacturer and other current regulatory documentation.

- Clause 6.4 “The following types of maintenance and current repair of the equipment of mine vertical shafts are determined:

- shift maintenance (MR-1);
- daily maintenance (MR-2);
- weekly maintenance (MR-3);
- two-week maintenance (MR-4);
- monthly repair service (RS1);
- two-month repair service (RS2);
- quarterly maintenance (T1);
- semi-annual maintenance (T2);
- annual maintenance (T3);
- semi-annual revision and adjustment (NRP проверить);
- annual revision and adjustment (NRG).

- Clause 6.5 Maintenance and current repair of equipment should be carried out in accordance with the established procedure and accepted cycle of maintenance and repair.

- p. 6.6 The scheme of equipment maintenance cycle for four-shift maintenance has the form: 28 (MR-1) - 6 (MR-2) - (MR-3) - 28 (MR-1) - 6 (MR-2) - (MR -4), where the figure before the type of maintenance means the amount of maintenance until the next type.

- p. 6.7 the cycle of maintenance and current repair of the equipment of mine hoisting installations should not be changed during its operation.

- p 6.8 The sequence of types of current repairs is repeated every year without changes. In this case, the annual part of the repair cycle scheme without RS2 has the form: 2RS1 - T1 - 2RS1 - (T2-NRP) - 2RS1 - T1-2RS1- (T3-NRG).

- p. 6.9 When drawing up a maintenance cycle scheme and a repair cycle scheme, it should be taken into account that each next type of maintenance and repair includes all the work provided for by the previous types, that is, the scope of MR-3 includes the scope of MR-2, MR -4 - scope of work MR-3.

- p. 6.10 Planning of work on maintenance and current repair of the equipment of the shaft should be carried out on the basis of the schedules for the annual current repair of the shaft (Appendix D) and the monthly maintenance of the equipment.

- p. 6.11 It is allowed to plan repair work based on the actual condition of the technical equipment of the shaft. At the same time, a system of technical diagnostics must be developed at the mine, and technical diagnostics work must be carried out by the relevant technical diagnostic services or a specialized organization that has a license.

In accordance with Section 2 "Types of Inspection of Vertical Shafts" [10], the scope of works for the inspection of the lining of the shaft equipment includes:

- visual inspection;
- instrumental observations and measurements;
- determination of the actual parameters of the lining and shaft equipment and the strength of the lining material;
- chemical analysis of mine waters;
- study of technical documentation, etc.;

The inspections are divided into:

a) scheduled (daily and monthly inspections of all shafts, annual inspections of shafts with cargo-man cages and shafts with man cages);

b) unscheduled (complex).

Daily and monthly inspections and annual checks are carried out in a planned manner, regardless of the condition of the shaft.

2.1 Daily inspection

The purpose of the daily inspection is to timely identify initial defects of the lining and shaft equipment, as well as to monitor the areas of the shaft that are subject to deformation. Inspection of the lining and shaft equipment is carried out by highly qualified locksmiths and fasteners in the process of technical maintenance throughout the entire depth of the shaft and in all compartments with winding cages.

The following defects are recorded:

- when examining the lining - surface peeling, leaching (sagging, crusting), cracks, shells, stabs, fallout, extrusion of the lining into the shaft, water seepage through the seams and grout plugs of cast-iron tubing, rotten and broken crowns (beams), swellings, no connection in locks, weakening of the struts, gaps between the rims, extrusion of individual rims into the shaft;
- when examining the shaft equipment - deformed buntons and guides, breaks of rail guides in the joints, protrusions in the joints of guides, loosening and slipping of crowfoots and clamps, loosening of bolted connections, expansion or narrowing of the gauge of guides, breakage of external wires in rope guides, weakening and wear of the guide and balance ropes, wear of the bushings of the guide couplings, serviceability of the fender skis and bars on the receiving platforms of the working horizons. In addition, the tightness (by tapping and tightening) of clamping devices (Briar staples, clamps, etc.), guides for buntons, as well as of guides between themselves in places of cage loading and unloading is checked (randomly).

With deformed shaft equipment, the tightness of the clamping devices is checked along the entire length of the shaft. Particularly should be fixed the reduced gaps between the winding cages and the lining, as well as the shaft equipment.

The results of inspections are entered in the "Book of Inspections of Mine Shafts" and "Passport of the Vertical Shaft".

2.2 Monthly inspection

Monthly inspections of all shafts are performed by the director or chief engineer of the mine and responsible persons of the relevant production services.

During the inspection, special attention is paid to the entire scope of work provided for in clause 2.1.

Particular attention should be paid to the sections of the shaft with defects in the lining and reinforcement. In case of detecting sites which do not meet the requirements of the “Safety Rules for Coal Mines: NPAOP 10.0-1.01-10” [7], it is necessary to work out appropriate measures to eliminate these defects.

2.3 Annual inspections of shafts with cargo-man cages and shafts with man cages.

Annual inspections of shafts with cargo-man and man cages, regardless of their condition, are carried out by a special commission with the participation of the director or chief engineer of the mine and responsible persons in accordance with job descriptions.

During the inspection, the following is checked: general condition of the lining and equipment of the shaft, conjunction of all roadways and chambers with the shaft; compliance of gaps between the cages and lining and buntons with the requirements of the "Safety Rules for Coal Mines: NPAOP 10.0-1.01-10". [7]; the strength of bunton ends embedment; the degree of wear and the strength of the fastening of the guides to the buntons; their corrosive wear.

When detecting defects in the lining and equipment and deviations from the requirements of the "Safety Rules for Coal Mines: NPAOP 10.0-1.01-10". [7], appropriate measures are planned to eliminate them.

2.4.Complex inspection

Depending on the size and nature of the shaft lining and equipment defects, the need for a complex inspection is established. It is carried out by a special commission formed by organizations that operate or construct the mine shaft.

The volume and composition of work carried out as part of a complex inspection are also determined by a special commission depending on the condition of the shaft lining and equipment.

The purpose of the complex inspection is to:

- determine the reasons of the shaft lining and equipment defects and their nature;
- develop measures to eliminate and prevent the shaft lining and equipment defects;
- organize instrumental observations of the shaft lining and equipment state.

2.4.1. Inspection of the shaft lining and equipment, study of technical documentation;

2.4.2. Mine water analysis;

2.4.3. Instrumental observations;

2.4.4. Establishment of the actual strength of the support material;

2.4.5. Determination of the shaft rigid reinforcement bearing capacity;

2.4.6. Establishment of the causes of the shaft lining and equipment defects.

In case of transport shaft systems with rope-profile guides (RPG), it is possible to achieve a significant reduction of volumes of repair and maintenance work due to the peculiarities of their design, essentially less metal consumption compared to rigid shaft equipment, including rail and box-shaped guides, the almost complete elimination of the destructive effect on the shaft lining due to the absence of tiered fastening of buntons; this also determines the feasibility of changing the cycles (MS) and (RS) from the calendar-time frequency, according to [8, 9, 10, 11] to the planning of repair service (RS) and maintenance service (MS) according to the actual technical condition (Fig. 3, 4). When using the RPG in the mine shafts, the following works are excluded:

- tightening and replacement of bolted connections for fastening guides (staples "Briar", "grip" and so on);
- replacement of buntons due to their complete absence;
- checking the rate of corrosion of buntons;
- checking the strength of the embedding of the ends of the buntons in the lining of the shaft;
- checking of presence of foreign objects, sticking of the rock mass on the tiers;
- wear control and elimination of weakening of the fender ropes, due to the absence of these elements in the structure.

In addition, the work associated with the repair of the shaft lining is significantly reduced due to the absence of the influence of one of the main destructive factors - parametric vibrations transmitted to the sealing of the tiers through buntons when the cages move.

When building a system for maintenance and repair of shaft equipment with RPG, one should take into account the limiting state of the critical element P_l (the most subject to wear) (Fig. 4), upon reaching which adjustment or replacement is required.

Such elements in the structure of the RPG are:

- carrying ropes, which are protected from direct wear by a protective box, and from corrosive wear - by grease;
- enclosing box of RPG;
- safety guides of cages;
- guiding devices for cage movement;
- assemblies for fastening RPG to console buntons;

In addition, the following units require control: fastening of the enclosing box to the carrying ropes and tensioning devices in the sump part of the shaft and in the headframe.

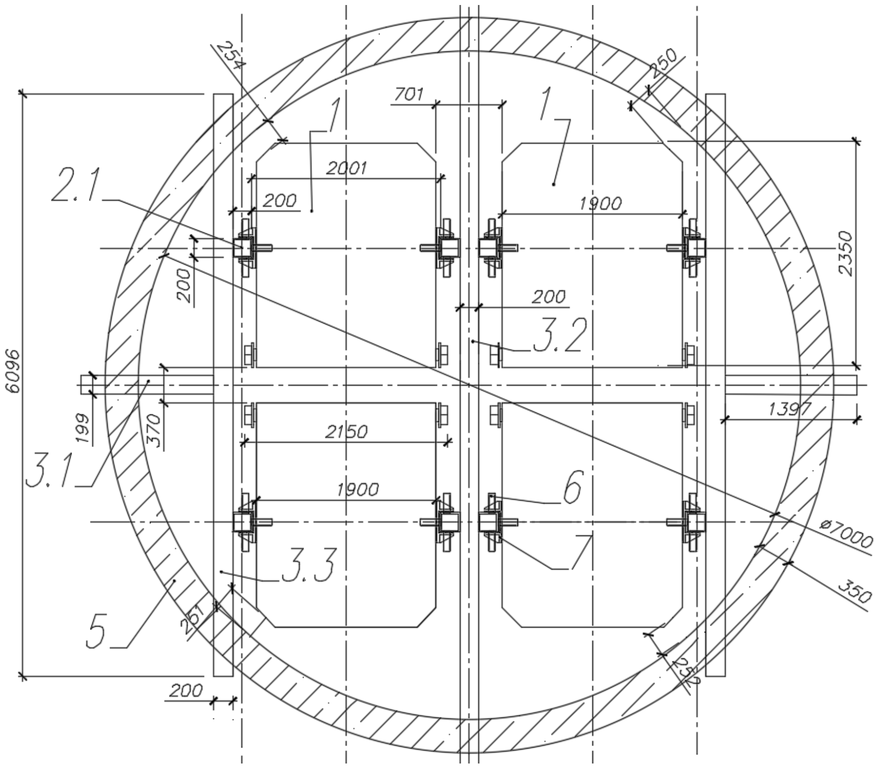
In accordance with the above algorithm of the MS and RS systems, shaft equipment with rope-profile guides, console buntons, tensioners, guide legs and other equipment of vertical shafts, in comparison with rigid and flexible shaft equipment, allow to:

- reduce labor intensity of the maintenance and repair works;
- increase durability of the system;
- prolong operational life of the main shaft equipment elements;
- reduce influence of corrosion processes in guides and console buntons;
- increase the overall level of safe operation [2].

According to clause 3.2.7 [2], the service life limit for stranded ropes is 4 years; the service life of the carrying ropes of the RPG, due to the exclusion of friction between the legs and the guides (the main guides are roller guides), is determined on the basis of instrumental studies with taking into account the strength properties of the rope products used. The RPG is inspected weekly from the cover of the winding cage or the counterweight platform, by at least two persons at a speed of cage movement of not more than 0.3 m/s. At the same time, the structural integrity of the RPG, wear of the enclosing box, tightening of bolted connections, curvature of the box, the presence of joints between sections of the profile, the presence of lubricating grease to protect the ropes from corrosion are checked.

Let's consider a comparative version of the operation of two hoisting machines with four coal skips of the SNM 35-235-1.1 type when they move along various types of shaft equipment: - rigid with box-shaped guides (see Figure 5); - flexible, the scheme of the tier is shown in Figure 6; - rope-profile (see Fig. 7).

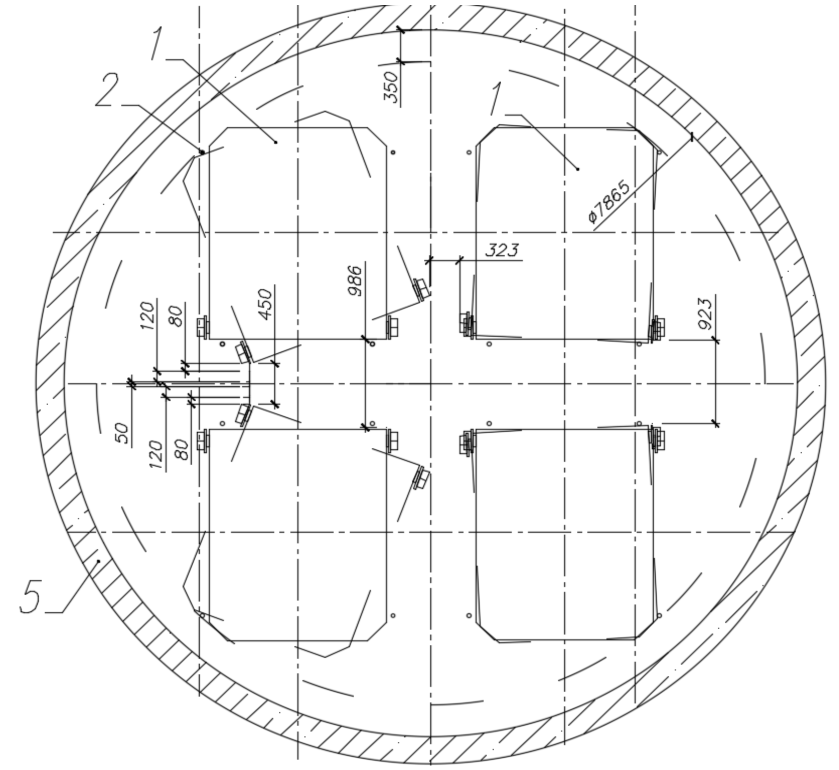
Based on the results of construction and with the help of calculations [3, 4, 5], the initial data and results are summarized in comparative table 1 for the weights of tension weights for various shaft equipment.



1 – winding cage (skip SNM 35-235-1.1); 2 - RPG; 3.1 - console bunton; 3.2 - central bunton; 3.3 - side buntons; 5 – shaft lining; 6 - roller guides; 7 - safety leg

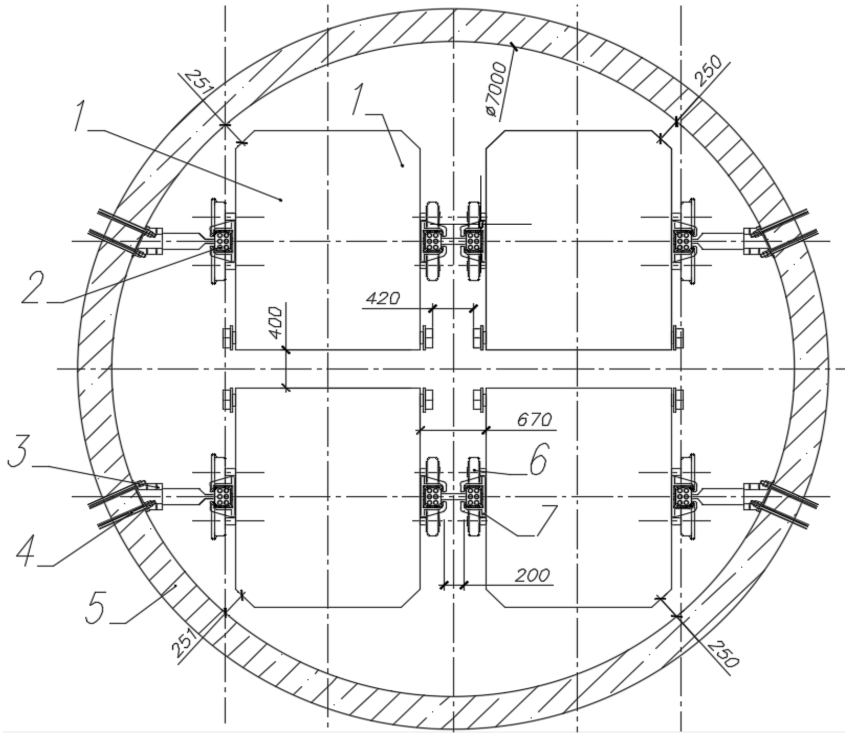
Figure 5 – Tier of rigid shaft equipment with four coal skips

Based on the requirements of regulatory documents [2, 6], the tension of the guide and fender ropes to the required value is carried out by tension weights attached to each rope separately, using serial trailed thimbles of the KKP-1, KRG type (Fig. 8), located in the sump part of the shaft.



1 – winding cage (skip SNM 35-235-1.1); 2 - rope guide; 5 – shaft lining

Figure 6 – Section of the shaft with four coal skips when turning them in rope guides with safety gaps



1 – winding cage (skip SNM 35-235-1.1); 2 - RPG; 3 - console bunton; 4 - anchors; 5 - shaft lining; 6 - roller guides; 7 - safety leg

Figure 7—Section of a shaft with four coal skips and RPG

Table 1 - Comparative table of the weight of tension weights of shaft equipment

Symbol	Name	Unit	Flexible shaft equipment 1 rope d=52	RPG 6 ropes d=42
	GOST		7669-80	7669-80
	Cross-section of the enclosing profile of the guide	mm	-	200x180x6
	Guide rope diameter	mm	52.00	42
	Rope type		52.0-Г-1-Н-1372	42.0-Г-1-Н-1372
	Number of rope guides	piece	16.00	48.00
	Number of fender ropes	piece	6.00	
$Q_{tension.c}$	Amount of additional tension with taking into account the estimated margin n=6	N	146 440.00	90 918.00
$Q_{weight.rope}$	Mass of tension weight for one rope	kg	14 936.88	9 273.64
$Q_{weight.profile}$	Mass of the enclosing box of one RPG	kg	-	39 429.00
$Q_{weight.RPG}$	The weight of the tension weight of the RPG (6 ropes of d=42)	kg	-	16 212.82
	Number of tension weights in the sump	pieces	22.00	8.00
	Total mass of tension weights in the sump	kg	328 611.36	129 702.53

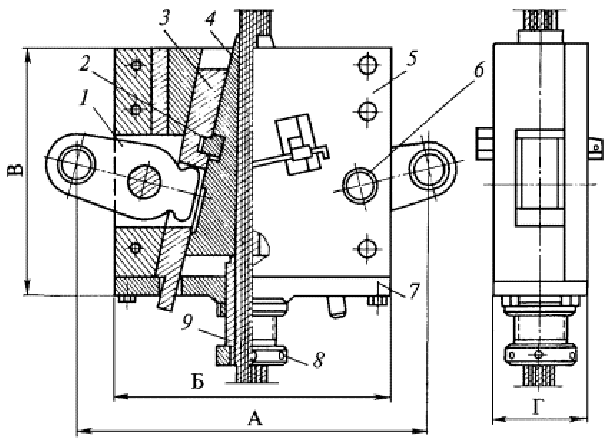


Figure 8 – Wedge type thimbles

Trailed thimbles of the KKP-1, KRG type, in accordance with the regulatory requirements of documents [2, 6], require constant maintenance (at least once a year) by a specialized organization that performs inspection and adjustment of the equipment. As can be seen from the comparative table 1, the number of trailed thimbles of the type KKP-1, KRG is much greater compared to the tensioners of the RPG.

The developed RPG tension structures [13] make it possible to tension all the ropes of one RPG at the same time, which significantly reduces: - the complexity of maintenance; - number of tension devices; - the level of dynamic impacts of trailers transmitted from ropes and tension loads.

Based on the initial layouts of winding equipment in various shaft equipment shown in Figures 4, 5, 6 for convergent shaft diameters, we will calculate the number of elements and metal intensity of shaft equipment of various types, namely: - rigid shaft equipment; - flexible shaft equipment; - rope-profile shaft equipment, and summarize the results in table 2.

Table 2 - Comparative table of the number of elements and metal intensity of shaft equipment

Number	Name	Unit	Rigid shaft equipment	Flexible shaft equipment 16 ropes d=52	RPG and CDB
	Buntons				
1	Shaft depth	m	1 200.00	1 200.00	1 200.00
2	Type of bunton		box beam	-	CDB
3	GOST		8509-06	7669-80	7669-80; 26020-83
4	Bunton cross section	mm	200x200x14	-	160x80x5x7.4
5	Bunton mass	kg/running meter	85.60	-	15.8
6	Length of buntons in a tier	running meter	24	-	3.2
7	Shaft equipment step	m	4.168	-	60
8	Number of tiers	pieces	288	-	27
	Mass of sump buntons	ton	601.29	-	1.37
	Guides				
1	Guide cross section	mm	200x200x14	-	200x180x6
2	Guide weight	kg/running meter	85.60	23.70	77.12
3	Guide length	running meter	1 200.00	1 200.00	1 200.00
4	Weight of fender ropes			11.85	
5	Number of guides and fender lines	piece	8.00	22.00	8.00
	Weight of shaft guides	ton	821.76	625.68	740.35
	Fasteners (embedments)				
1	Weight of embedment in the shaft lining	kg/piece.	9.00	-	23.216*
2	Number of embedments per tier	piece	16.00	-	8.00
3	Number of embedments in the shaft	piece	4 682.93	-	34.00
	Weight of fasteners in the shaft	ton	42.15	-	6.31
Total weight of shaft equipment:		ton	1 465.19	625.68	746.66

*four M24 anchor fasteners (L=2m) are used as embedment per one CDB (console-damper bunton) in the shaft lining, and in case of rock fracturing, chemical fastening ampoules are used

4. Conclusions

The results of the calculations presented in tables 1 and 2 are summarized in table 3 with added unaccounted shaft equipment structural elements, namely, rigid shaft equipment with rail guides.

Table 3 – The summary comparative table of the main structural elements of different types of shaft equipment requiring systematic maintenance and repair

Number	Name of the main components and parts	Unit	Rigid shaft equipment		Rope equipment	Equipment with RPG
			rail guides	box-shaped guides		
1	Guides:					
	- number of guides and fender ropes	piece	8	8	22	8
2	Shaft equipment buntons:					
	- number	piece	384 (step 3.126 m)	288 (step 4.168 m)	-	27
3	Fasteners:					
	- staples "Briar"	piece	2304	-	-	-
	- staples "Grip"	piece	4608	-	-	-
4	Bolted fasteners	piece				
	- staples "Briar"	set	2304	-	-	-
	- staples "Grip"	set	4608	-	-	-
	- fastening guides to buntons	set	-	4683	-	3200
	- fastening buntons in tiers	set	2304	2304	-	-
	-number of floorbeams	piece	3456	-	-	-
	- the number of butt staples of the RPG		-	-	-	100
	- the number of intermediate staples of the RPG	piece	-	-	-	200
5	Ropes (diameter):	mm	-	-	d=52	d=42
	- number of guide ropes;	piece	-	-	16	-
	- number of fastener ropes;	piece	-	-	6	-
	- the number of bearing ropes for RPG	piece	-	-	-	48
6	Tension devices:					
	- number of tie-downs	piece	-	-	12	8
	- number of tension weights;	piece	-	-	16	8

The direct interpolation method makes it possible to determine the reduction in the amount of work for maintenance and repair of rope-profile shaft equipment compared to rigid and flexible shaft equipment (it can be seen from the results given in tables 1, 2, 3). In the proposed shaft equipment with the RPG, there is no need to carry out a large amount of work on: maintenance, repair, replacement of components and parts due to a significant reduction in their number or complete absence. In addition, it provides:

- reduction of metal intensity compared to rigid shaft equipment - by 40-50%;
- reduction in the number of tension loads - by 36%;
- reduction in the mass of tension loads - 39.5%;
- reduction in the number of bolted connections compared to rigid equipment with box-shaped guides - by 45%;
- extension of the service life of the bearing ropes, compared to the rope shaft equipment - approximately by 5-7 times;
- reduction of labor costs for maintenance - by 50%.
- reduction of labor costs for RS - by 50%, due to no need to re-embed buntons into the shaft lining, reduction in the number of tension devices, reduction of corrosion and mechanical wear of the ropes.

The application of the algorithms given in this article for the calculation and planning of maintenance and repair work in relation to each individual layout of the equipment of mine vertical shafts will optimize processes, reduce labor intensity of the work, increase the service life of the equipment and improve economic efficiency of the operation of the facility as a whole.

REFERENCES

1. Baklashov, I.V. (ed.) (1989), “*Manual for the structure and installation of rigid shaft equipment of vertical shafts of mines and mines (to SNiP II-94-80)”,* [Manual for the structure and installation of rigid shaft equipment of vertical shafts of mines and mines], Nedra, Moscow, Russia.

2. USSR Ministry of Coal Industry on 08/09/89 and Gosgortekhnadzor USSR 22.02.82, (1982), *"Safety standards for the structure and operation of rope guides of multi-rope winding installations", approved by the USSR Ministry of Coal Industry on 08/09/89 and Gosgortekhnadzor of the USSR on 02/22/82 and "Safety Standards for the structure and operation of rope guides of single-rope winding installations"*, Makeevka, Donbass.

3. Voloshin, A.I., Rubel, A.A. and Rubel, A.V. (2016), “Shaft equipment of vertical mine shafts and methods of refining” *Geotechnical mechanics: International collection of science practices*, no. 126, pp. 137-145.

4. Rubel, A.O. (2017), “Research of existing structures of tiers of shaft equipment of vertical shafts and development of tier schemes with rope-profile guides” *Geotechnical mechanics: International collection of science practices*, no. 134, pp. 211-227. https://doi.org/10.15407/geotm2017.134.211

5. Voloshin, A.I., Rubel A.A., and Rubel A.V. (2016), “Cantilever-damping buntons for the shaft equipment of vertical mine shafts” *Geotechnical mechanics: International collection of science practices*. no. 127 pp.89-98.

6. Ministry of Coal Industry of the USSR (1989), *Instructions for the operation of steel ropes in mine shafts,* Nedra, Moscow, Russia.

7. Minvugleprom of Ukraine (2010), *Safety rules for coal mines: NPAOP 10.0-1.01-10. - Dijsni vid 22.03.2010. - Officially seen.* [Regulatory document to the Minvugleprom of Ukraine. Standard], Kiev, Ukraine.

8. Ministry of Coal Industry of the USSR NIIGM im. MM. Fedorov (1999)*, Rigid shaft equipment of vertical mine shafts. Inspection, assessment of technical condition. Repair and reconstruction. Order and organization: KD 12.01.10.0601-99*, Donetsk, Ukraine.

9. Minvugleprom of Ukraine (2005), *Mine hanging extensions and parachutes. Wimogi before control: SOU 10.1.00174094.006:2005. - Officially seen.* [Regulatory document to the Minvugleprom of Ukraine. Standard], Kiev, Ukraine.

10. Ministry of Coal Industry of the USSR (1964), *Temporary industry guidelines for the inspection of the state of lining and shaft equipment of vertical shafts of mines. Approved by the on April 10, 1964: RTM 12.58.022-84*, VNIMI, VNIIOMSHS, Kharkov, Ukraine.

11. USSR Ministry of Coal Industry on 08/26/1976, the USSR Ministry of Color and Metallurgy on 08/17/1976, the USSR Minchermet on 08/23/1976, the USSR Ministry of Chemical Industry on 08/27/1976, the USSR Ministry of Construction Materials on 08/12/1976 (1976), *"Instruction for the technical inspection and testing of operational and tunneling lwinding installations"* Moscow, Russia.

12. Belfort, V.E., Gorlin, A.M. and Morozov, V.I. (1986), *Automation of equipment repair management at mining enterises,* Nedra, Moscow, Russia.

13. Rubel, A.O. and Rubel, O.V. (2018), "Decrease in the dynamics of the "cage-shaft equipment" system by the way of the construction of the damping tension extension" *Collection of scientific practices of the Donbass State Technical University*, no. 1, pp. 20-27.

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ДОСЛІДЖЕННЯ ОСОБЛИВОСТЕЙ ЕКСПЛУАТАЦІЇ І РОЗРОБКА ВИМОГ ДО ТЕХНІЧНОГО ОБСЛУГОВУВАННЯ КОНСТРУКЦІЙ КАНАТНО-ПРОФІЛЬНИХ ПРОВІДНИКІВ АРМУВАННЯ СТОВБУРА

Рубель А.О.

Анотація. В роботі досліджено існуючі нормативні методи технічного обслуговування стовбурового обладнання вертикальних стволів шахти та розроблено методи технічного обслуговування стовбурового обладнання з канатно-профільними направляючими, консольно-демпферними наконечниками, натяжними пристроями в зумпфовій частині стовбура та в палебійній частині. розроблений. Досліджено взаємозв'язки процесів: експлуатація – технічне обслуговування – ремонт у системі механізмів для розробки алгоритмів прийняття рішень щодо визначення фактичного стану та прогнозування залишкового ресурсу елементів, на основі яких здійснюється вибір системи ремонту та обслуговування. обладнання виготовлено. У статті проведено дослідження переваг і недоліків існуючих видів армування стовбурів, та виконано їх порівняльний аналіз з канатно-профільним армуванням.

Використання результатів даного дослідження щодо обладнання шахтного стовбура канатно-профільними провідниками (далі – КПП) дозволить:

- знизити ризик виникнення надзвичайних ситуацій;
- розробити оптимальну систему проведення ремонтно-профілактичних робіт;
- оптимізувати витрати на ремонт і обслуговування (запасні частини, комплектуючі, трудові ресурси, чисельність ремонтного персоналу тощо).

– знижена трудомісткість обслуговування та експлуатації в порівнянні з жорстким армуванням;

– зменшена витрата металу в порівнянні з жорсткою арматурою;

– підвищена надійність кінематичного зв'язку в системі «посудина–КПП» за рахунок використання лапок із з'єднувальними вставками;

– зменшені зазори безпеки на сторону – 350 мм для скіпових підйомників, та – 500 мм на сторону клітьових підйомів по всій глибині шахти, як для гнучкої арматури;

– виключення використання відбійних канатів;

– збільшення терміну служби канатно-профільних провідників до рівня провідників для жорсткого армування стовбура.

Ключові слова: шахтні вертикальні стовбури, канатно-профільні провідники, консольно-демпферні розстріли, технічне обслуговування, натяжні пристрої, канатне виробництво, ремонт, технічне обслуговування.

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