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RESEARCH AND DEVELOPMENT OF BUNTON STRUCTURES OF DOUBLE-ROW ROPE-PROFILE GUIDES FOR MOVEMENT OF LIFTING CAGES

[1]Rubel A.A., [2]Kuraieva O.V.

[1]State Enterprise «United Company «Ukrvuglerestrukturyzatsiya», [2]Limited Liability Company «Pfizer Ukraine»

Abstract. The paper studies the existing options of rigid reinforcement of vertical shafts, consisting of buntons and guides of various types, which ensure the movement of vehicles in the shaft reinforcement with double-row rope-profile guides. We have considered various layouts and structures of tiers for various number of vehicles moving in the shaft and their purpose (skips, cages, counterweights), and analyzed their advantages and disadvantages. On the basis of analysis and research, the structures of buntons for double-row rope-profile guides and the legs with grips have been developed that allow the guides to move up and down relative to the tier, to transfer horizontal dynamic forces in the frontal and lateral planes. Research, analysis, development and implementation of bunton structures for double-row rope-profile guides and implementation with connecting rods, frames, which provide greater reliability while maintaining all the necessary clearances (according to the Safety Rules) between the vehicles and the shaft lining, in the "vehicle-reinforcement" system. Using the results of these studies in the development of existing structures will achieve the following results: - increasing the safety level while observing the standard clearances in the elements of shaft reinforcement; - reducing capital costs due to a decrease in the metal consumption of the tier of shaft reinforcement; - reducing the labor intensity of maintenance and repair by reducing the number of buntons and their fastening elements; - reducing the effect of clogging and corrosion on the durability of rope-profile guides and buntons; - reducing the impact of shaft lining violation on the reinforcement; - increasing the reliability level of kinematic connection in the "guide-bunton" system; - providing standard clearances in the shaft section at a safe level; - ensuring a high reliability level and safe operation of the shaft reinforcement with rope-profile guides.

The implementation of developed structures of double-row rope-profile guides of the vertical shaft reinforcement will lead to an increase in the level of safe operation, while reducing the metal consumption and the cost of maintenance and operation of the vertical shaft reinforcement.

Keywords: mine vertical shafts, double-row rope-profile guides, skips, cages, counterweights, console buntons, legs for fastening vehicles to guides.

1. Introduction

Reinforcements of vertical shafts of mining enterprises are designed to ensure the guided movement of vehicles (skips, counterweights, cages) for lifting minerals, lifting and lowering people and materials, as well as to ensure repair work and emergency exit of underground personnel from the mine.

With the growth of mining and their development at deeper horizons, shafts are deepening, which entails an increase in metal consumption and an increase in the requirements for the safe operation of the shaft reinforcement.

Widely used technologies are flexible and rigid reinforcement of vertical mine shafts.

Flexible reinforcement does not contain tiers, except for the presence of one or two tiers on intermediate horizons, and contains rigid reinforcement in a headframe for unloading vehicles in guides [1].

The main disadvantage of flexible reinforcement is large horizontal oscillations during the movement of vehicles, which leads to the provision of safety gaps: 350 mm per side for the skip shaft and 500 mm for the cage hoist. Also, the maximum standard service life of rope guides for stranded ropes according to GOST 7667-80 and GOST 7669-80 is limited to 4 years of operation, regardless of the load of lifting installations (clause 3.2.7 [2]). For ropes of a closed structure ac-

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cording to GOST 3090-73, GOST 7675-73 and GOST 18901-73, maximum normative operation is allowed up to 15 years (clause 3.2.7 [2]), however, often, the high cost does not allow them to be widely used [2]. For the safe operation of flexible reinforcement, it is necessary to hang fender ropes between adjacent lifting installations and fasten all ropes with tension weights located in the sump, which increases the labor intensity of their maintenance.

Rigid shaft reinforcement is made of metal or wood. Metal reinforcement usually has the following reinforcement step:

- for rail guides - 3.126, 4.168 and 6.252 m;
- for box-shaped guides - from 3 to 6 m;
- for wooden guides - from 2 to 4 m [2].

With an increase in the reinforcement step (installation of tiers), it is necessary to significantly increase the stiffness of buntons and guides. That is, rigid reinforcement has a significant number of tiers along the shaft depth, and their number only increases with depth, which accordingly leads to an increase in the metal intensity of the reinforcement.

Wooden reinforcement has a limited service life of guides and a high cost caused by the use of special types of wood as guides that are not susceptible to intense decay under the influence of a mine aggressive atmosphere and high humidity, in particular, larch, oak and beech. At the same time, wooden reinforcements are used at low lifting intensity because of their low strength.

The disadvantages of rigid reinforcement include:

- large number of tiers;
- high metal consumption;
- high number of bolted connections;
- significant labor intensity in maintenance and repair;
- high labor intensity of installation;
- corrosive wear of fasteners and metal buntons;
- high vulnerability in case of violation of the shaft lining, which lead to appearance of abnormal gaps and the risk of an accident;
- high number of tiers increases the aerodynamic resistance of the shaft as the main ventilation opening of the mine, which leads to a significant consumption of electrical energy during the operation of the main ventilation fans of the mine.

The advantages of rigid shaft reinforcement include:

- high reliability;
- long service life;
- optimum shaft diameter.

At present, the structures of tiers for rope-profile reinforcements (hereinafter referred to as RPR) and double-row rope-profile guides (hereinafter referred to as a RPG or guide) are being researched and developed, where structures consisting of ropes and an enclosing profile are used as guides [3, 4]. The use of RPR will allow the use of discrete reinforcement steps of 60 m or more, in the area of movement of vehicles at a constant speed, with a decrease in the place where the vehicles meet (in the middle of the shaft) [5], this can significantly reduce the gaps between moving vehicles and reinforcement elements in accordance with all established regulatory requirements of "Safety rules for coal mines: NPAOP 10.0-1.01-10" (hereinafter referred to as SR) [8]. In the RPG, the ropes are located inside the box and protected against abrasion by protective legs of the vehicles by the enclosing profile. In addition, there is a waterproof lubricant inside that protects the rope products from corrosive wear, so the service life is significantly increased and comparable to the service life of rigid guides.

For additional damping of oscillations in the "vehicle-reinforcement" system, console buntons have been developed that have a lower metal consumption, since in this case the guide's weight hangs on the ropes, but not on buntons of a tier as in rigid reinforcements. Damping block consists of rubber elements [5].

The existing schemes of tiers were developed for rigid guides taking into account their structural features, and for double RPGs it is necessary to develop their own optimal layouts for the location of console buntons in a tier.

2. Methods

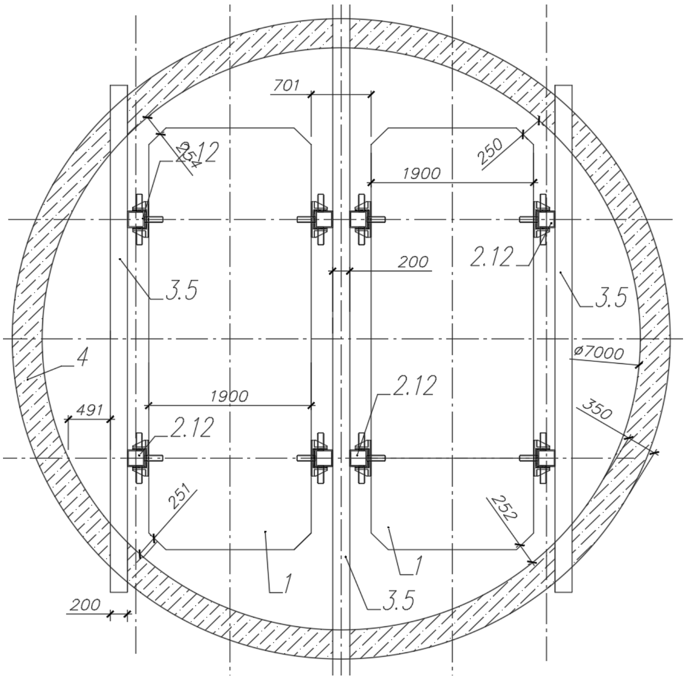
The research is based on the task of finding and developing layouts for double-row RPRs that will reduce the above disadvantages and achieve the following results:

- ensure a long trouble-free service life;
- reduce construction costs, due to a decrease in the number of buntons in the shaft reinforcement compared to rigid reinforcement and conventional tiers with RPGs;
- reduce the labor intensity of maintenance and operation;
- reduce the metal consumption of buntons;
- ensure a high level of safety in case of violation of the shaft lining;
- reduce the number of fastenings by reducing the number of buntons;
- ensure a reliable level of kinematic connection in the "vehicle-reinforcement" system;
- ensure a high level of reliability and safe operation of all shaft equipment.

3. Theoretical and experimental parts

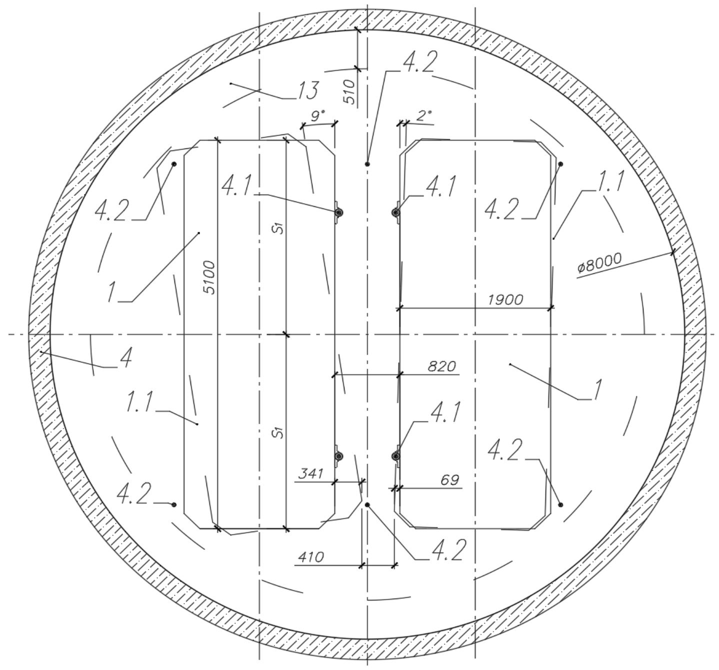
Guides of the rigid shaft reinforcement are fastened on horizontal tiers with a certain step along the shaft depth (see Fig. 1), while the legs of vehicles do not cover the box-shaped guide, therefore, in order to observe the gaps between the vehicles and the shaft lining, it is necessary to have rigid buntons and guides, which entails all above disadvantages of this system. A tier of flexible reinforcement with the angles of rotation of vehicles at the point of their meeting in the middle of the shaft is shown in Fig. 2 [6, 7]. The use of a tier of a two-cage hoist which use console buntons [6, 7] and RPGs with guiding legs with grippers as buntons, makes it possible to reduce their number and the length of buntons, and taking into account the fact that the reinforcement step for RPGs is 60 m or more [5] (except for the area where the vehicles meet), the metal consumption of the reinforcement decreases even more (see Fig. 3).

However, to further improve the installation schemes of buntons in order to reduce the metal consumption, the labor intensity of installation, and maintenance, it is possible to use connecting rods between adjacent guides of different vehicles, which allow them to be fastened on one or two console buntons (see Fig. 4).



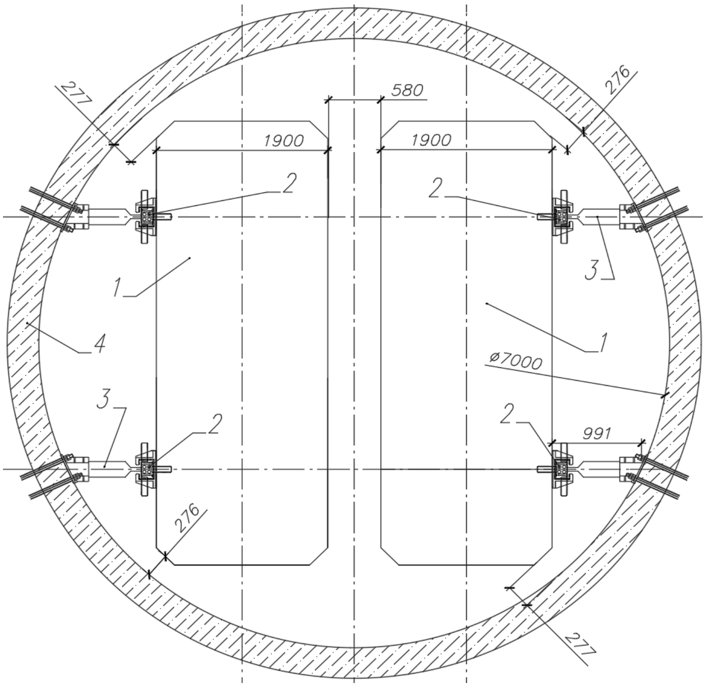
1 - lifting vehicle (cage of 2KN4-2 type); 2.12 – rigin guide; 3.5 – rigin bunton; 4 - shaft lining; 7 - anchor

Figure 1 - Scheme of rigid reinforcement of a tier of a two-cage hoist (cage of 2KN4-2 type)



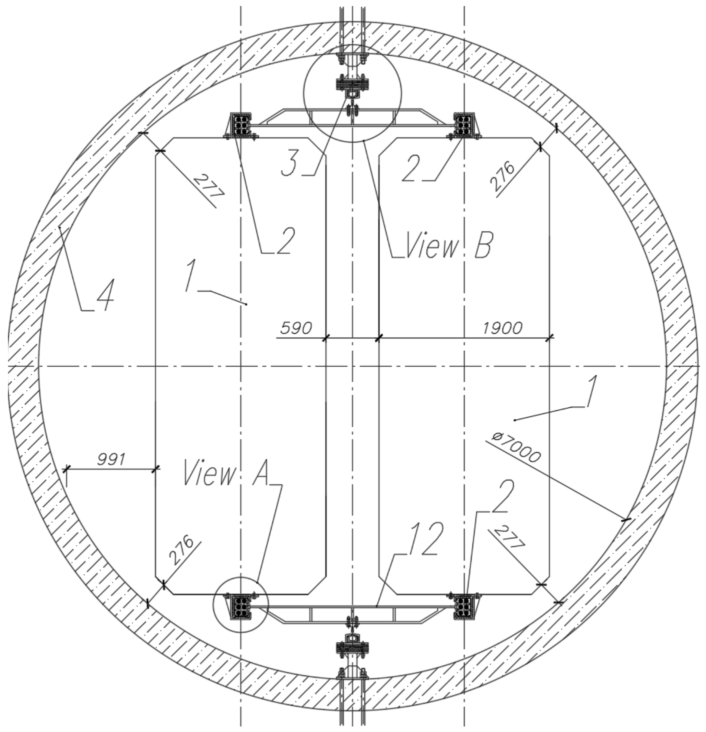
1 – lifting cage (2KN4-2); 4.2 - turned cage; 4 - shaft lining; 4.1 - rope guides; 4.2 - rope protection; 13 - safety gap

Figure 2 - Scheme of flexible reinforcement of a two-cage hoist



1 - lifting vehicle (cage of 2KN4-2 type); 2 - RPG; 3 - console bunton; 4 - shaft lining

Figure 3 - Scheme of the RPR of a two-cage hoist



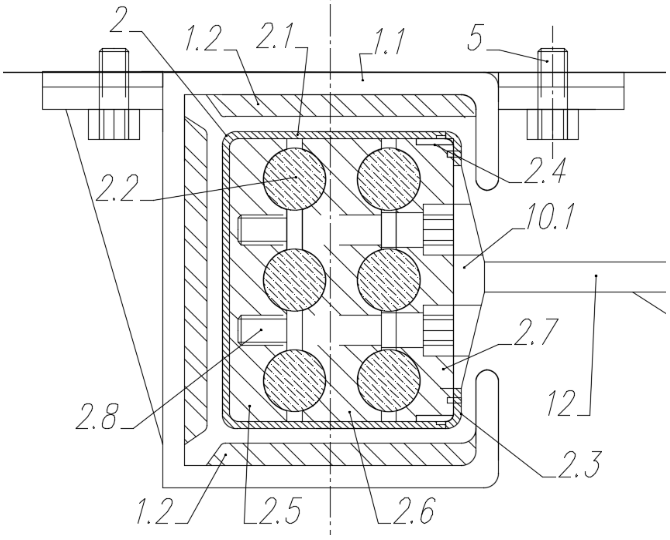
1 - lifting vehicle (cage of 2KN4-2 type); 2 - RPG; 3 - console bunton; 4 - shaft lining;
12 - connecting frame

Figure 4 - Scheme of a two-cage hoist with a double-row RPR

In the proposed scheme with two lifting vehicles (cages), RPGs [3] are used as vertical guides, located at opposite ends of the vehicles, connected to each other by a rod and fixed on a separate console bunton 3 with a damper block [6, 7]. At the opposite end of the vehicle, the fastening is repeated (see Fig. 4).

The movement of the vehicle along the RPG is carried out using rollers of the NKP type [1] from three sides and a protective guide leg.

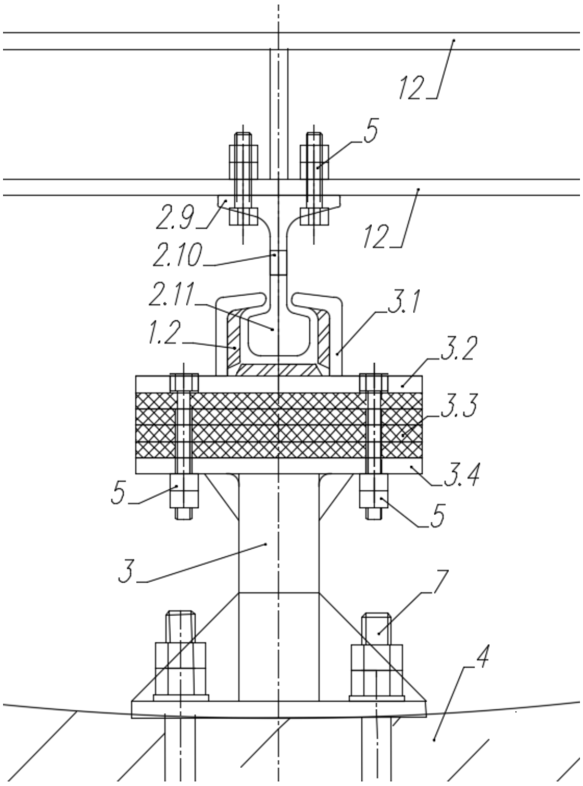
The location of the RPG relative to the vehicle is shown in Fig. 6 (View B), where the guiding leg 1.1 of the vehicle with grippers is rotated by 90^0 and the enclosing profile of the RPG 2.1 with ropes 2.2 is also rotated by 90^0. Further, the parts of the bracket 2.5, 2.6, 2.7, the ropes 2.2 and the fastening of the rod 10.1 with the help of hexagonal bolted joints 2.8 are pulled together and fixed in the enclosing profile 2.1, which is closed by the cover 2.3, and has a hole for fastening the rod 10.1 with holes for the bolts 2.8. Frame 12 connects two guides together, limiting the approach of the guides to each other and not allowing them to diverge from each other (see Fig. 5).



1.1 - guiding leg; 1.2 - liners; 2 - RPG; 2.1 - enclosing profile of the RPG; 2.2 - rope (of Ø 42- G-1-N-1372 type with a steel core according to GOST 7669-80); 2.3 - rear cover; 2.4 - rear cover fastening unit; 2.5 - rear part of the bracket; 2.6 - intermediate part of the bracket; 2.7 - extreme part of the bracket; 2.8 - hexagonal bolted joint; 5 - bolted joint; 10.1 - rod fastening; 12 - connecting frame

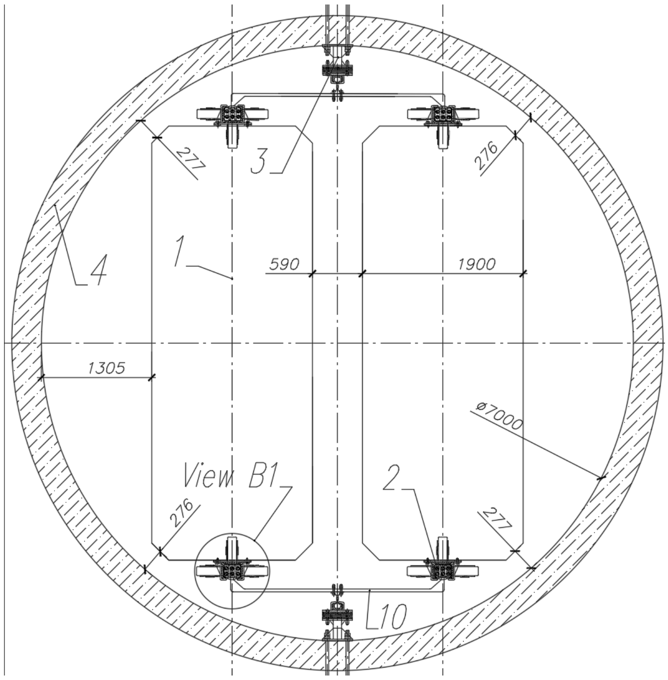
Figure 5 - View A

On the connecting frame 12, the RPGs of adjacent lifting vehicles are fixed at both ends, and in the middle, there is a fastening for bunton in the form of a rail section 2.9 fixed with bolted joints 5 (see Fig. 5). The connecting rod can be made from a rectangular box with holes to reduce its weight, or an I-beam with minimum legs. The rail section 2.9 is attached to the bunton with the help of a leg 3.1 with grippers, allowing the frame 12 and the RPG to move up and down and limit oscillations in the horizontal plane. Bunton leg 3.1 is welded to the bunton bar 3.2, which is fixed to the bunton stop 3.4 with bolted joints 5 through the damper block 3.3, and the console bunton 3 is attached with the help of anchors 7 to the reinforced concrete shaft lining 4 (see Fig. 5).



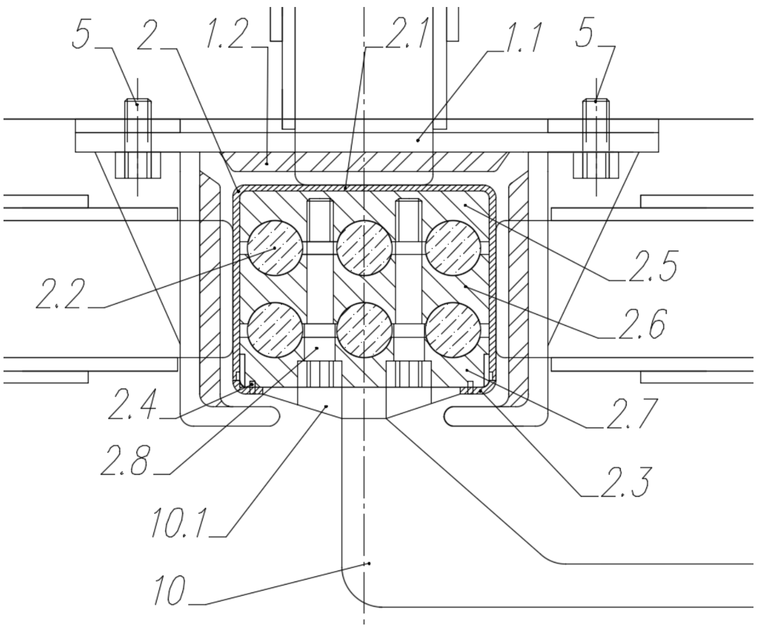
1.2 - liners; 2 - RPG; 2.9 - rail; 2.10 - hole in the rail; 2.11 - rail head; 3.1 - bunton leg; 3.2 - bunton bar; 3.3 - damper block; 3.4 - bunton stop; 4 - shaft lining; 5 - bolted joint; 7 - anchor; 12 - connecting frame

Figure 6 - View B



1 - lifting vehicle (cage of 2KN4-2 type); 2 - console bunton; 3 - RPG; 4 - shaft lining; 10 - connecting rod

Figure 7 - Scheme of a tier of a two-cage hoist with a double-row RPG



1.1 - guiding leg; 1.2 - liners; 2 - RPG; 2.1 - enclosing profile of the RPG;
2.2 - rope (of Ø 42- G-1-N-1372 type with a steel core according to GOST 7669-80);
2.3 - rear cover; 2.4 - rear cover fastening unit; 2.5 - rear part of the bracket;
2.6 - intermediate part of the bracket; 2.7 - extreme part of the bracket; 2.8 - hexagonal bolted joint;
5 - bolted joint; 10 - connecting rod; 10.1 - rod fastening

Figure 8 - View B1

Figure 4 shows the scheme of the reinforcement for a two-cage hoist, where the RPGs are arranged as in Fig. 8 View B1, and the connecting rod is made in a C-shaped form and fixed on the console bunton 3 which length is less and stiffness is greater.

Based on the layout of two 2KN4-2 cages in a shaft with a diameter of 7 m and 8 m shown in Figures 1-8, we will calculate the number of elements and the metal consumption of various types of reinforcement, namely:

- rigid reinforcement (see Fig. 1);
- flexible (see Fig. 2) [10];
- rope-profile reinforcement (see Fig. 3);
- double-row RPR (see Fig. 4)

based on the initial data presented in Table 1.

4. Results and discussion

The calculation results are summarized in a comparative table of parameters of various types of reinforcement (see Table 2).

Based on the calculation results presented in Table 2, the metal consumption of the double-row RPR of the shaft decreased by 1.97 times compared to the rigid reinforcement, and decreased slightly compared to the RPR.

Table 1 – Initial data of the parameters of various types of reinforcement

Designation	Name	Unit	Flexible reinforcement 4 ropes Ø =52	RPG 6 ropes Ø =42
1	2	3	4	5
GOST	Type of ropes used as guides	-	7,669-80	7,669-80
	Cross-section of the enclosing profile of the guide	mm	-	200×180×6
Ø	Guide rope diameter	mm	52.00	42.00
	Rope type		52,0- G-1-N - 1372	42,0-G-1-N-1372
	Number of rope guides in the shaft for 4 vehicles	pcs	16.00	48.00
	Number of fender ropes in the shaft for 4 vehicles	pcs	6.00	-
	Tension of one rope in the guide	N	111,806.47	78,712.82
A	Minimum coefficient of resistance of one rope guide against transverse deflecting forces	N/m	125.00	125.00
G_B	Estimated tensile strength of the wires of one rope	MPa	1,372.00	989.50
	Margin of safety of the rope	-	6.00	6.00
$\gamma = \frac{P}{S}$	The volumetric weight of the rope is determined from the expression	N/m^3	89,107.01	92,593.91
P	The weight of one meter of lubricated rope	N/m	116.2	78.14
S	Cross-sectional area of all wires of one rope	m^2 10^{-6}	1,304.05	843.90
n	Estimated margin of safety of the accepted rope	-	6.79	6.41
	The total breaking force of all wires in the rope	N	1,785,000.00	1,155,000.00
	The weight of one lubricated rope	N	151,060.00	101,582.00
	The value of additional tension of one rope, considering the estimated margin n=6	N	146,440.00	90,918.00
	Mass of tension weight per one rope	kg	14,936.88	9,273.64
	Mass of the enclosing box of one RPG	kg	-	39,429.00
	The mass of the tension weight of the RPG (6 ropes, d=42)	kg	-	16,212.82
-	Number of tension weights in the sump	pcs	22.00	8.00
-	Total mass of tension weights in the sump of the entire shaft	kg	328,611.36	129,702.53
	Type of lifting vehicle (2-storey cage)		2KN4-2	2KN4-2
	Weight (mass) of the load in the cage	N (kg)	92,186 (9,400)	92,186 (9,400)
	Weight (mass) of empty cage	N (kg)	91,147 (9,600)	91,147 (9,600)
$V_{c.max}\backslash.$	Maximum cage speed	m/s	12	12
$V_{air.max}.$	Maximum air jet speed	m/s	8	8

Continuation of Table 1

1	2	3	4	5
$d_{h.r.}$	Head rope	mm	33.0	33.0
$p_{h.r.}$	Weight (mass) of 1 rm of head rope	N/m (kg/m)	40.7 (4.155)	40.7 (4.155)
$n_{h.r.}$	Number of head ropes	pcs	4	4
$d_{b.r.}$	Balancing rope (type 45,5-G-1-N-1372 GOST 3088-80)	mm	45.5	45.5
$p_{w.r.}$	Weight (mass) of 1 rm of balancing rope	N/m (kg/m)	85.8 (8.75)	85.8 (8.75))
$n_{b.r.}$	Number of balancing ropes	pcs	2	2
a_w	Vehicle width in horizontal section	m	1.9	1.9
b_l	Vehicle length in horizontal section	m	2.35	2.35
h_b	Distance between guiding legs	m	14.34	14.34
S	Track width	m	2	2
A_1	Moment from the forces of aerodynamic influence on the loaded vehicle caused by the flow around the load	N	180	180
A_2	Moment from the forces of aerodynamic influence on the empty vehicle caused by the flow around the load	N	315	315
P^{ecc}_{fr}	The force from the eccentricity in frontal direction	N	-	6,946.7/2= 3,473.35
P^{ecc}_{lat}	The force from the eccentricity in lateral direction	N	-	803.3/2= 401.65
P^{ecc}_{gen}	The total force from the eccentricity of the vehicle with the center of mass of the vehicle displaced in an arbitrary direction under the action of frontal and lateral forces on the guides	N	-	3,496
M^{ecc}_{gen}	Torsion moment of the vehicle created by the resulting force of the load eccentricity	N·m	-	4,108
	Torsion moment of a rope	N·m	252.08	252.08
	Total torsion moment	N·m	567.08	4,675.49
	The angle of rotation of a loaded vehicle under the action of forces	deg.	1.14	0.239
	Angle of rotation of an empty vehicle under the action of forces	deg.	1.7	0.012
k_d	Dynamic coefficient	-	5	5
k_s	Margin of safety	-	1.5	1.5
	Total angle of rotation of a loaded cage taking into account $k_{б}$ and $k_{д}$	deg	8.61	1.79
	Total angle of rotation of an empty cage taking into account $k_{б}$	deg	1.17	0.018
Δ_n	The value of the vehicle translation under the action of aerodynamic forces	mm	100	100

Continuation of Table 1

1	2	3	4	5
Δ_3	Protective gap between vehicles	mm	50	50
$\Delta_{c.c.}$	Radial deviation of shaft lining walls in the center	mm	80	20
$\Delta_{gen.gap.}$	Total gap between moving vehicles of adjacent hoists	mm	410	330
σ_C	Protective gap for rope guides between the cage and the shaft lining	mm	510	250

Table 2 – Comparative table of parameters of various types of reinforcement

No.	Name	Unit	Rigid reinforcement (see Fig. 1)	Flexible reinforcement 16 ropes Ø=52 (see Fig. 2)	RPR (RPG and CDB) (see Fig. 3)	Double RPR RPG and CDB (see Fig. 4)
1	2	3	4	5	6	7
	Buntons					
1	Shaft depth	m	1,200.00	1,200.00	1,200.00	1,200.00
2	Bunton type		box beam	-	CDB	CDB
3	GOST		8509-06	7669-80	7669-80; 26020-83	7669-80; 26020-83
4	Bunton cross section	mm	200×200×14	-	160×80×5×7.4	160×80×5×7.4
5	Bunton weight	kg/rm	85.60	-	15.8	15.8
6	Buntons length in the tier	rm	24	-	3.960	1.320
7	Reinforcement step	m	4.168	-	60	60
8	Number of tiers	pcs	288	-	27	27
9	Number of buntons	pcs	864	-	108	54
	Bunton weight in the shaft	**t**	**601.29**	**-**	**1.37**	**0.45**
	Guides					
1	Guide rope diameter	mm		52.00	42.00	42.00
2	Rope type			52,0-G-1-N-1372	42,0-G-1-N-1372	42,0-G-1-N-1372
3	Number of rope guides in the shaft for 4 vehicles	pcs		16.00	48.00	48.00
4	Number of fender ropes in the shaft for 4 vehicles	pcs		6.00	-	-
5	Guide cross section	mm	200×200×14	-	200×180×6	200×180×6
6	Guide weight	kg/rm	85.60	23.70	77.12	77.12

Continuation of Table 2

7	Guide length	rm	1,200.00	1,200.00	1,200.00	1,200.00
8	Weight of fender ropes		-	11.85	-	-
9	Number of guides and fender ropes	pcs	8.00	22.00	8.00	8.00
	Weight of shaft guides	**t**	**821.76**	**625.68**	**740.35**	**740.35**
Tension weights in the sump						
1	Mass of tension weight for one rope	t	-	14,936.88	9,273.64	9,273.64
2	Mass of the enclosing box of one RPG	t	-	-	39.429	39.429
3	Mass of tension weight for RPG (6 ropes, Ø =42)	t	-	-	16,212.82	16,212.82
4	Number of tension weights in the sump		-	22.00	8.00	8.00
	Total mass of tension weights in the sump of the entire shaft	**t**	**-**	**328,611.36**	**129,702.53**	**129,702.53**
	Fastenings (embeddings)					
1	Weight of embeddings in the shaft lining	kg/pc	10.00	-	23.216*	23.216*
2	Number of embeddings per tier	pcs	6.00	-	4.00	2.00
3	Number of embeddings per shaft	pcs	1,728.00	-	108.00	54.00
	Weight of shaft fastenings	t	17.28	-	2.507	1.253
	Total weight of shaft reinforcement:	t	**1,465.19**	**625.68**	**744.23**	**742.053**
1	Designed shaft lining	mm	300	300	300	300
2	Actual (average) shaft lining	mm	410	410	410	410
3	Ring area	m^2	18.5	21.13	18.5	18.5
	Amount of concrete	m^3	**22,261.72**	**25,351.48**	**22,261.72**	**22,261.72**

Note: Four M24 anchors (L=2 m) are used as embedding for one console-damping bunton

(CDB) in the shaft lining, and in case of poor condition of the host rocks, chemical fastening ampoules are used, and in case of distortion of the shaft geometry, faults, fracturing of rocks, etc., at least 2 rope anchors per CDB are installed.

As can be seen from the data given in Table 2, flexible reinforcement is the least metal-intensive, but it is necessary to use a shaft with a design diameter of Ø7939 mm (the closest standard diameter is Ø8000 mm), which is 1000 mm more than shaft diameter of Ø7000 mm for rigid reinforcement, RPR, and double-row RPR.

It can also be seen from Table 2 that the number of tension weights compared to flexible reinforcement, RPR and double-row RPR decreased by 22/8=2.75 times. Total mass of tension weights in the sump of the entire shaft decreased by 328,611/129,702=2,53 times.

The number of tier embeddings in the lining of a vertical shaft (1200 m deep) is 1,728 pieces for rigid reinforcement, 108 pieces for RPR, and 54 pieces for double-row RPR (see Table 2), i.e. the labor intensity of replacing buntons of a double-row RPR is reduced by 1,728/54=32 times compared to rigid reinforcement and by 2 times compared to RPR.

The cost of installation of rigid reinforcement is approximately UAH 77,011,660.00 in prices of 2023 (excluding the cost of auxiliary infrastructure):

- installation and purchase of sinking hoists for 1200 m;
- installation of shelves;
- construction of an industrial site;
- laying power supply lines, water supply and other utilities;
- installation of power supply, heat supply, water supply sources;
- installation of auxiliary winches;
- purchasing and installation of rope products required for installation;
- deployment of a construction camp (housing, catering, bathhouse, first-aid post, office building, workshops, warehouses, access roads, etc.);
- motor transport;
- land allotment; etc.

The cost of the installation of reinforcement is (approximately) UAH 39,622,800.00 for RPR and UAH 32,504,080.00 for a double-row RPR, i.e. the reduction in installation cost is 2.36 times compared to rigid reinforcement.

As can be seen from Table 2, the amount of concrete required for fixing the shaft with flexible reinforcement, with the same arrangement of lifting vehicles (cages), increases by about 1.14 times (i.e. approximately by 3090 m^3) without taking into account faults, distortion of the shaft geometry and the cost of the shaft sinking by drilling and blasting operations, etc.

The use of a connecting frame 12 (see Fig. 4) and a connecting rod 10 (Fig. 7) located between the RPGs of adjacent vehicles (cages of 2KN4-2 type) makes it possible to increase the level of safety due to the exclusion of the rotation of moving vehicles (cages of 2KN4-2 type) in the place of their meeting, as is the case for the flexible shaft reinforcement - 9 degrees (see Table 1 and Fig. 2), which leads to the appearance of safety gaps of 510 mm per side (see Table 1 and Fig. 2), according to the current regulation [2].

The labor intensity of maintenance and current repair of equipment for mine vertical shafts, namely:

- 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);
- annual revision and adjustment (NRG) [9].

is significantly decreased, since the number of serviced elements (buntons) for a double-row RPR has decreased by 16 times compared to rigid reinforcement, and by 2 times compared to RPR.

5. Conclusions

As a result of the studies of existing structures of tiers for the movement of two cages in rigid reinforcement, flexible reinforcement and RPR, their advantages and disadvantages were determined, and based on the analysis, reinforcement structures for double-row RPGs using connecting rods and frames were developed that allow overcoming existing shortcomings and achieving the following results:

- ensuring higher reliability of fastening the guide to the bunton;
- reducing capital costs due to a decrease in the metal consumption of the shaft reinforcement by 1.97 times compared to rigid reinforcement;
- reducing the labor intensity of maintenance due to a decrease in the number of buntons and their elements by 16 times compared to rigid reinforcement, and by 2 times for RPR (see Table 2);
- reducing the number and mass of tension weights by 2.53 times compared to flexible reinforcement;
- reducing the shaft diameter by 1000 mm compared to flexible reinforcement, reducing the amount of concrete shaft lining by 1.14 times (3090 m^3) without taking into account the cost of sinking the shaft;
- increasing the service life of guides by reducing the level of dynamic oscillations in the "vehicle-reinforcement" system;
- reducing the labor intensity of replacing buntons, by reducing their number by 16 times compared to rigid reinforcement and by 2 times compared to RPR;
- reducing the cost of bunton installation by 2.36 times compared to rigid reinforcement;
- increasing damping properties of the shaft reinforcement due to the use of connecting rods and frames;

- reducing the impact of clogging and corrosion on the wear of buntons;
- increasing the stiffness of the bunton by reducing its length;
- increasing the level of reliability at the meeting point of vehicles (in the middle of the shaft) by increasing the damping properties of the reinforcement and the bunton stiffness.

The implementation of the developed structures of a double-row RPR will increase the damping properties, durability and reliability of the entire shaft reinforcement, which will increase the time of uninterrupted operation of the entire lifting complex as a whole, in accordance with all the requirements of the "Safety Rules in Coal Mines: NPAOP 10.0-1.01-10" and other rules and requirements of Ukraine [1–10].

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About authors

Rubel Andrii Oleksandrovych, Candidate of Technical Sciences (Ph.D.), Chief Power Engineer, State Enterprise «United Company «Ukrvuglerestrukturyzatsiya», Kyiv, Ukraine, AORubel@gmail.com

Kuraieva Olena Viktorivna, Master of Science, LLC Pfizer Ukraine, Kyiv, Ukraine, AORubel@gmail.com

ДОСЛІДЖЕННЯ І РОЗРОБКА КОНСТРУКЦІЙ РОЗСТРІЛІВ ЗДВОЄНИХ КАНАТНО-ПРОФІЛЬНИХ ПРОВІДНИКІВ ДЛЯ РУХУ КЛІТІВ

Рубель А.О., Кураєва О.В.

Анотація. У роботі досліджено існуючі варіанти жорсткого армування вертикальних стовбурів, що складаються з розстрілів і провідників різного типу, які забезпечують рух транспортних засобів в армуванні стовбура дворядними канатно-профільними провідниками. Розглянуто різні схеми розміщення і конструкції ярусів для різної кількості транспортних засобів, що рухаються в стовбурі, і їх призначення (скіпи, кліті, противаги), проаналізовано їх переваги і недоліки. На основі проведеного аналізу та досліджень розроблено конструкції розстрілів для дворядних канатно-профільних провідників та лап із захопленнями, які дозволяють направляючим переміщатися вгору та вниз відносно ярусу, передавати горизонтальні динамічні зусилля в лобовому і бічному напрямку. Досліс дження, аналіз, розробка та впровадження розстрільних конструкцій для дворядних канатно-профільних провідників та виконання з шатунами, рамами, які забезпечують підвищену надійність при збереженні всіх необхідних зазорів (відповідно до Правил безпеки у вугільних шахтах: NPAOP 10.0-1.01-10) між транспортними засобами та кріпленням стовбуру, в системі "транспортний засіб-підсилення". Використання результатів цих досліджень при розробці існуючих конструкцій дозволить досягти наступних результатів: - підвищення рівня безпеки при дотриманні нормативних зазорів в елементах армування стовбуру; - зниження капітальних витрат за рахунок зменшення металомісткості ярусу армування стовбура;- зниження трудомісткості технічного обслуговування та ремонту за рахунок зменшення кількості кнопок та елементів їх кріплення; - зменшення впливу засмічення та корозії на довговічність направляючих та кріплень канатного профілю; - зменшення впливу порушення кріпи стовбура на армування; - підвищення рівня надійності кінематичного зв'язку в системі «провідника - лапа»; - забезпечення нормативних зазорів в перетині стовбура на безпечному рівні; - забезпечення високого рівня надійності та безпечної експлуатації армування стовбура канатно-профільними провідниками.

Впровадження розроблених конструкцій дворядних канатно-профільних провідників армування вертикального стовбура призведе до підвищення рівня безпечності експлуатації при зменшенні металомісткості та вартості утримання та експлуатації армування вертикального стовбура.

Ключові слова: шахтні вертикальні стовбури, дворядні канатно-профільні провідники, скіпи, кліті, противаги, консольні кріплення, опори для кріплення транспортних засобів до напрямних.