e-ISSN 2719-3306 Mining Machines, 2023, Vol. 41 Issue 1, pp. 58-67

https://doi.org/10.32056/KOMAG2023.1.6

Justification of rational parameters of the support mounting device of the roadheader

Received: 28.02.2023

Accepted: 30.03.2023

Published online: 03.04.2023

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Abstract:

An expert assessment of the existing means of keeping roof rocks in the area of work of people and machines was carried out. On the basis of computer modeling of the processes of interaction of rocks of mine workings with arched design options, variants of the design of the roof and their elements for temporary fastenings support are proposed. The parameters of the four sectional support are presented. Temporary arched support was used in the area of operation of the roadheader, which helps to reduce a number of technological operations and the use of manual labor and to increase the safety of service personnel. The results of research aimed at the design improvement of the machine are described. The obtained parameters are checked by calculations and design solutions. The results can be applied in the passage of subway tunnels and other similar workings, in the construction of tunnels of roads and railways. The design of the device has the ability to adjust in height depending on the condition of the roof of the workings.

Keywords: temporary arched support, sectional hydraulic support, roadheader, state of breeds of roof and soil

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1. Introduction

Depending on the mining and geological conditions and the type of support of the development or exploitational workings of underground structures, the cost of support is from 30 to 45% of the total cost and the time spent on supporting reaches 20-25% of the time of the entire mining cycle. The workings that are carried out are supported with wooden, metal, bolting, precast concrete or monolithic concrete supports. The process of erecting supports, especially artificial ones made of wooden or reinforced concrete racks and arched metal, is still difficult to mechanize. To a greater extent, the process of bolting installations made of reinforced concrete tubing and monolithic concrete is convenient for mechanization. Mechanization of the construction of supports is complicated by the fact that it must be interconnected with other processes and machines in the workings, and especially with roadheader, drilling rigs, trucks, as well as with other means of transport. In addition, the variety of sections of mine workings and the occurrence of a continually changing rock pressure make it difficult to create a small number of uniformly shaped sizes of supports. These circumstances also complicate the task of mechanizing the construction of supports.

For temporary and permanent supporting of mine workings, mechanized supports are used, designed to support the roof above the machine in order to reduce the exposure of area near the face and transfer the machine, to a less compressed space, to install permanent support. The use of mechanized supports is very efficient, as it makes it possible to combine tunneling operations in the face and the construction of permanent supports and, in addition, ensures, due to the presence of overlap, the safety of machine operators. Mechanized supports are usually used in the roof, which is difficult to collapse, since otherwise there are phenomena of the so-called "trampling" of the roof and its collapse.

Work on the installation of a metal arched supports, using monoEIC supports [1-3] includes the delivery of a set of fasteners to the face, the installation of the frame and the movement of the monorail. Delivery of a package with elements of arched supports to the tail section of the machine is carried out in transport cars [4] on a special cargo monorail located in the drift. Arched supporting elements are stored on the platform.

In the work on the delivery of supports from the place of storage to the face, two operators are involved, one of which is the driver of the controlling device. Elements of the arched support from the drive are delivered to the mounting table, where the fastener is installed. The element is captured by the mounting boom, unfolded into a transport position and transported to the face for installation. This is a rather laborious and multi-way operation using manual labor. In addition, it is dangerous. Last few years presented works about temporary roof support in roadway development and tunneling [5-7].

Analysis of the state of the issue shows that the development and justification of the parameters of a fully mechanized, controlled and purposeful spacer-supporting device of a roadheader is an urgent task.

Conducting research on the work of a temporary mechanized support is an integral part of a roadheader. Depending on the condition of the roof, options for two- and four-units are considered. As a result of the analysis of two options, the results of software calculations for different roof loads were obtained. Comparing two designs, a two- or four-section design can be chosen. Given their weight and better adjustment to the unevenness of the workings, the weight reduction is possible due to the safety margin of the unit. Research results on the proposed options of the roof supports enable to protect the roof from collapse, protecting personnel and machines. To study this objective, an expert assessment of the existing means of supporting roof rocks in the area of work of people and machines was carried out.

2. Materials and Methods

In general, the supporting device is a hydraulic manipulator (Fig. 1) with a hydraulic cylinder 1 and an overlapping component 2. There may be several devices (Fig. 2), which are installed according to different schemes on the base of the machine. The top part is in contact with the roof and (or) with the side wall of the workings [8]. Depending on the working conditions, the design solutions of the

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devices may be different [9]. Local support of the workings according to the results of the predicted data of the stress state in front of the lying mountain range at a distance of up to one meter deep into the rock [9] is even assumed.

To calculate the loads [10], as the initial data, geometric parameters of the main or development mine workings can be taken, as well as mining and geological conditions, for example, in the following form: S_{cs} – cross-sectional area of the workings in the penetration, m^2 ; S_{ml} – the area of the workings in light, taking into account the profile of fastening and tightening, m^2 ; B – the width of the workings in the light, taking into account the profile of fastening and tightening, m; B_m – additional width of the workings in the light, taking into account the profile of fastening and tightening, m; γ_r – volumetric weight of rocks, kN/m³; H_m – height of workings in the penetration, m; H – depth of development, m.

Calculation of the coefficients required to determine the load from the rocks acting on the device

The coefficient of influence of the workings in the penetration

$$B_p = 1.1B + B_m, \text{ m} \quad (1)$$

The coefficient of influence of the geometric dimensions of the workings

$$K_s = 0.2(B_p - 1) \quad (2)$$

Coefficient of α type of support for the workings in the case of its implementation or operation.

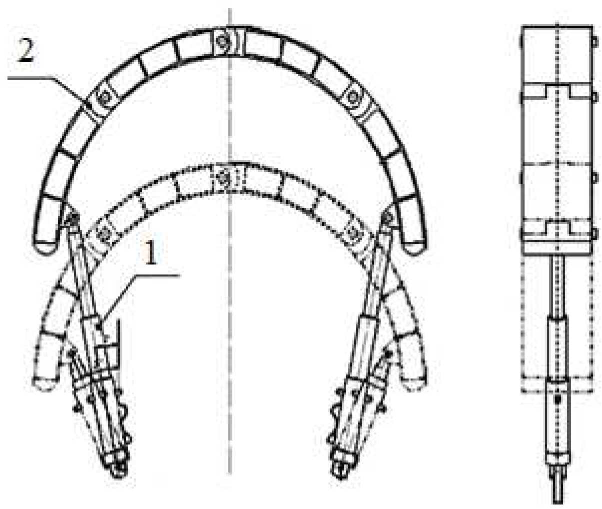

Fig. 1. Hydraulic manipulator of the supporting device:
1 - hydraulic cylinder; 2 - overlapping (component)

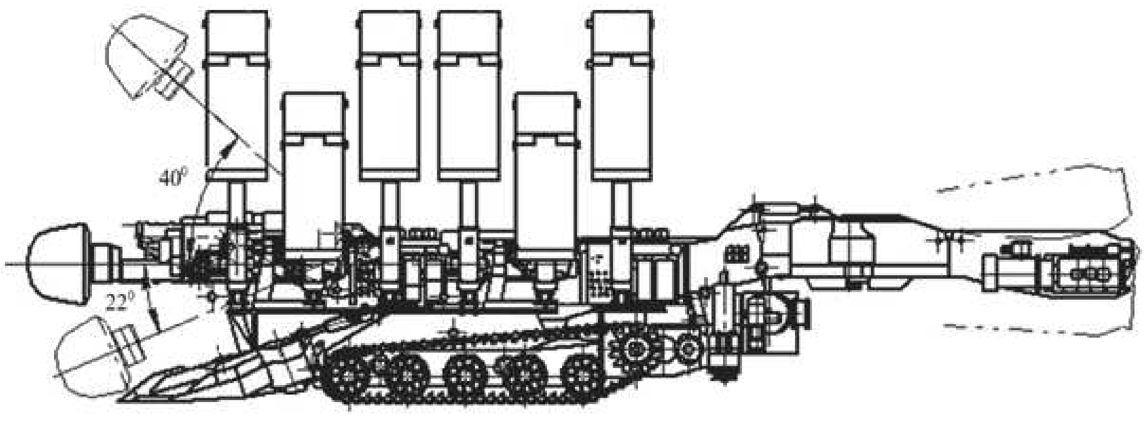

Fig. 2. Tunneling machine with support-mounting device

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Calculation of strength from individual layers of the roof

The strength of rocks according to the design scheme of its definition [11] is determined. The effect of flattening [12] must be taken into account at least 20 m from the centre of the workings in the roof and floor. In this layer, rocks of considerable thickness should be divided into layers with a thickness of slightly more than 5 m [8, 13]. If the workings are watered, the resistance of the rocks is reduced by: 20% – for sandstones, 30% – for limestone, 40% – for aleurolites, 50% – for argillites.

$$R_j = R_r \cdot K_c, \text{ MPa} \tag{3}$$

where:

R_r – rock resistance to uniaxial compression, MPa,

K_c – coefficient that takes into account the violation of the breed array; $K_c = 1$ for an unbroken array; $K_c = 0.7$ – for a significantly disturbed array; $K_c = 0.4$ – in the zones of crushing, folds,

R_j – strength of individual layers of rocks, MPa.

Determination of the distance from the center of the workings to the center of the reservoir

According to the formula (4), the coefficient of influence of rock layers on the strength, K_i is calculated.

$$K_i = exp(-\alpha(l_i - (h/2)) \tag{4}$$

where:

l_i – distance from the center of the workings to the center of the reservoir, m.

h – the width of the coal seam, m

Calculation of the average strength of rocks

Strength of roof and floor rocks (5)

$$R_r = (R_1 m_1 K_1 + R_2 m_2 K_2 + R_3 m_3 K_3 + \dots + R_i m_i K_i)/(m_1 K_1 + m_2 K_2 + m_3 K_3 + \dots + m_i K_i), \text{ MPa} \tag{5}$$

According to the formula (6), the average strength of rocks is determined

$$R_m = (R_r + R_p)/2, \text{ MPa} \tag{6}$$

where:

R_p – strength of rock layers in a coal seam, MPa

Calculation of the displacement of rocks in the workings

Expected displacement of rocks in the workings

$$U_r = U \cdot K_r, \text{ m} \tag{7}$$

where:

U – displacement of the roof and rock mass, m,

K_r – coefficient that characterizes part of the shifts.

$$К_r = R_p \cdot К_n \cdot/(R_r + R_p) \tag{8}$$

where:

$К_n = 1.2$ – coefficient of proportionality of the roof displacement relative to the soil depends on the condition of the roof and soil components.

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The magnitude of the displacements of lateral rocks in mm is calculated by the following formula $U_б$:

$$U_l = U \cdot K_l, \text{mm} \tag{9}$$

where:

K_l – coefficient characterizing the production layers changes in relation U_l to the total displacement of roof rocks from the total displacements of the roof and rock mass U .

The total displacement of rocks in the workings in a previously disturbed form is calculated according to the formula U_b:

$$U_b = 1.5 \cdot H \cdot K_s \cdot K_y, \text{m} \tag{10}$$

where:

N – depth of embedding, m,

K_s – coefficient of influence of rock stability,

K_y – coefficient of stability of rocks.

$$h_v = U_r / \alpha, \text{ m} \tag{11}$$

The weight of rocks in kN is calculated from the formula:

$$P = 2/3 \cdot B_p \cdot \gamma_r \cdot h_v, \text{kN} \tag{12}$$

Calculation of the required force in the cylinder

The scheme (Fig. 3) [11], necessary to determine the force in the hydraulic props is taken into consideration.

From the equilibrium condition of loads P and the reactions in the hinges that reinforce the arch, the equation (13) is formulated

$$\sum F_{ix} = 0 \tag{13}$$

Given that, the effort in hydro-resistance can be defined as $d_s = r d_\varphi$.

$$N = \int_0^\pi \sin\varphi \cdot q \cdot r \cdot d\varphi = q \cdot r, \text{ N}$$

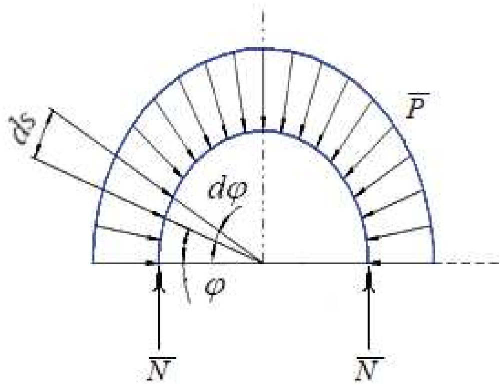

Fig. 3. Calculation scheme for determining the hydraulic resistance:
$d\varphi$ – elementary angle used during integration; φ – current angle, measured from 0 to π;
ds – the length of the elementary arc on the vault α

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The design scheme (Fig. 4) of the determination of the working resistance in the hydraulic props depending on the angle of their installation is considered.

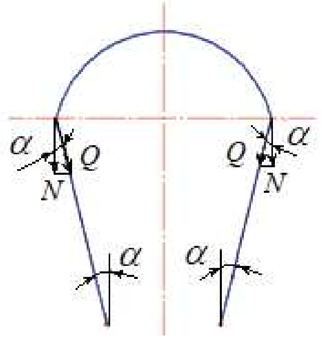

Fig. 4. Calculation scheme for determining the resistance in hydraulic props, depending on the angle of their installation: where α is the angle of installation of hydraulic props; Q – resistance of hydraulic prop, N

Resistance depending on the angle of support installation

$$Q = N / \cos\cdot(\alpha),\ \mathrm{N} \tag{14}$$

According to the magnitude of the resistance from the typical series, a mine hydraulic with 1 or 2 displacements are taken into account.

Overlapping options for support-mounting devices of the tunneling machine

It is necessary that the overlap (Fig. 5) [11] has the possibility to adapt to the irregularities of the roof. Existing overlapping structures are metal-intensive and have a large weight. It is necessary to create an overlap that will withstand the weight of the rocks, and at the same time the increasing stresses in the roof should not exceed the permissible values.

Justification of the parameters of the four sectional overlapping device.

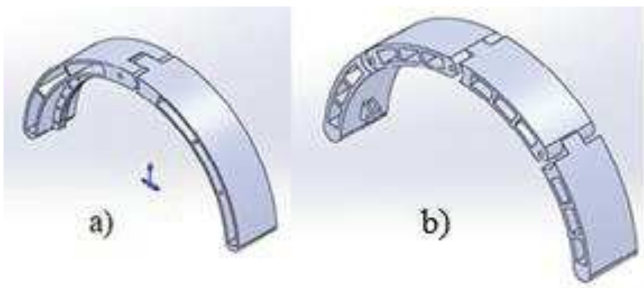

Fig. 5. Examples of overlapping devices: a) two-sectional, b) four sectional

These two constructions (Fig. 6) using the SolidWorks Simulation program are compared.

Set the load on the weight of the roof rocks P = 288.9 kN.

Set the alloy steel as material.

1) The weight of this structure is 2.5 tons.

The safety factor is approximately 10.

2) The weight of the 2-sectional overlap is 2.8 tons.

The safety factor is approximately equal to 17.

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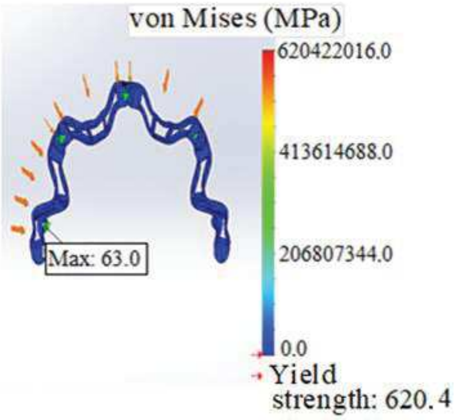

Fig. 6. The results of calculations of 2-sectional overlap

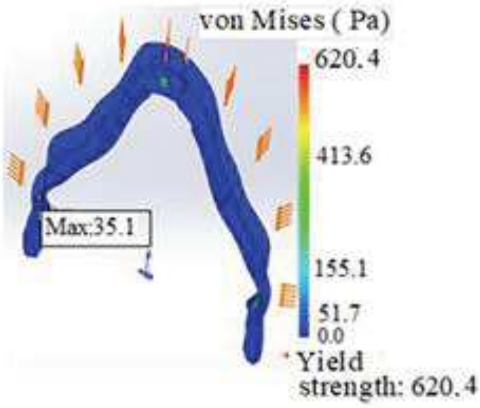

Fig. 7. The results of calculations of 4-sectional overlap

Comparing the two structures, based on the results (Fig. 6 and Fig. 7), a 4-sectional overlap is chosen, since it has a smaller weight and displacement, adapts better to the irregularities of the production, and has a lower strength coefficient.

Reducing the weight of 4-sectional overlapping element

Weight reduction is possible due to the large margin of safety factor of units [13].

With use of the Solid Works Simulation program, the overlapping units are analyzed.

Loading scheme of the 4-sectional overlapping unit (Fig. 8)

Estimated load *P*, kN;

material – alloy steel;

fasteners – fixed hinge.

The thickness of the overlap and of under-rib reinforcement is changed from 50 mm to 15 mm.

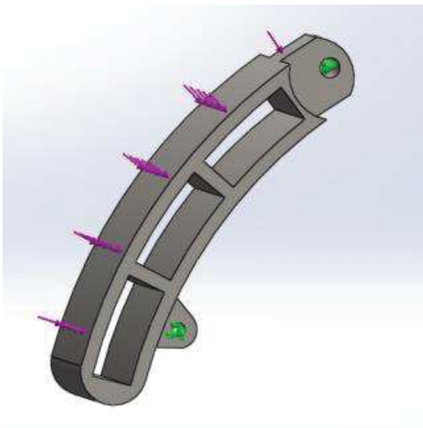

Fig. 8. Loading scheme of the 4-sectional overlapping unit

3. Results

The results of the study are listed in Table 1.

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Table 1. Overlapping results

Item	Indicators	Numerical values							
1	Thickness of overlap, mm	50	45	40	35	30	25	20	15
2	Stress, MPa	39	42	53	56	60	62	85	140
3	Displacement, mm	0.02	0.1	0.13	0.19	0.28	0.43	0.89	2.1
4	Mass. kg	670	655	628	596	565	539	522	501

According to the obtained data. the graphs are built:

a) graph of the dependence of stresses on the thickness of the overlap and the under-rib reinforcement of Fig. 9;

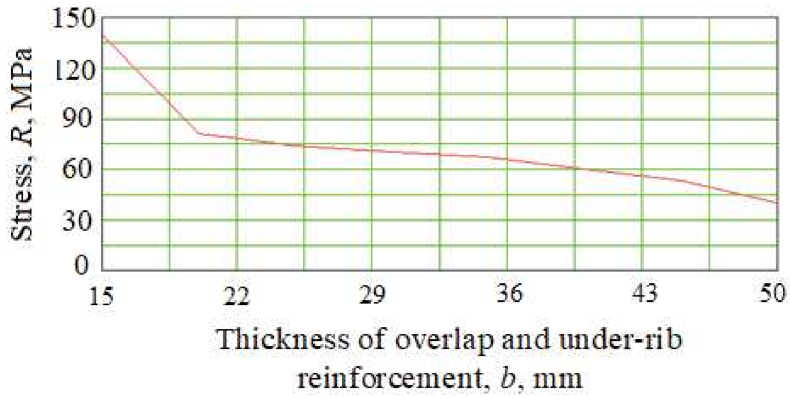

Fig. 9. Graph of stress dependence on overlap thickness and under-rib reinforcement

b) graph of the dependence of displacement on the thickness of the overlap and under-rib reinforcement (Fig. 10);

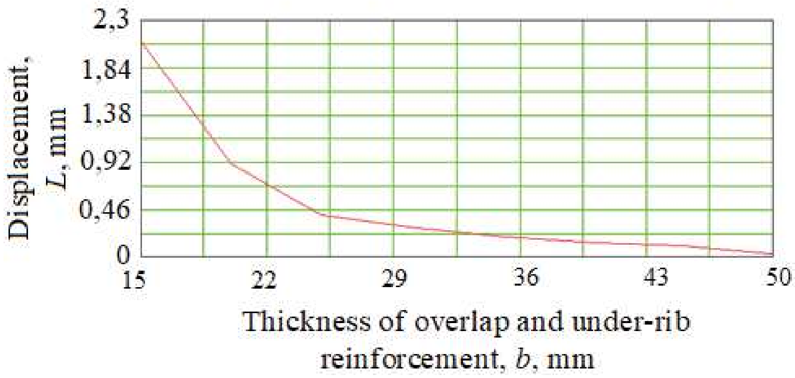

Fig. 10. Graph of displacement dependence on overlap thickness and under-rib reinforcement

c) graph of the mass dependence on the thickness of the overlap and the under-rib reinforcement (Fig. 11).

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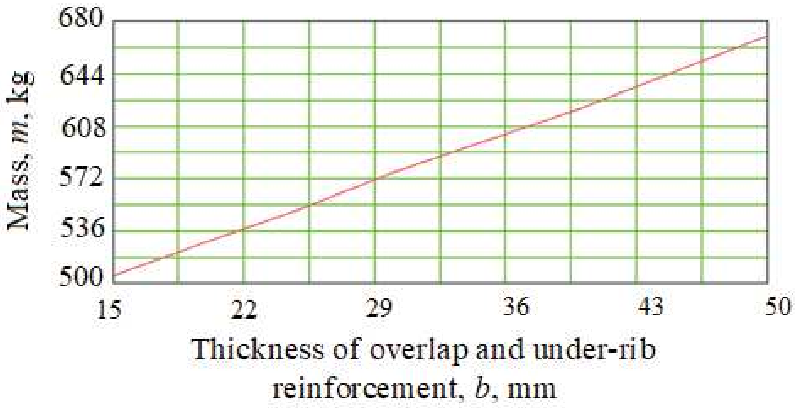

Fig. 11. Graph of mass dependence on overlap thickness and under-rib reinforcement

Depending on the condition of the roof and soil, the optimal structural parameters of the mechanized hydraulic fastening are chosen. Graphical dependences allow you to choose the working parameters of the roadheader with a spacer-fastening device. It is possible to remotely control the mining pressure control in the working area of the tunneling machine. According to the results of computer modeling, it was determined that the optimal design of the sections of the overlaps of the spacer-fastening device of the road combiner according to the criterion of the minimum mass with the specified strength and rigidity of the structure is a four-section overlap with the parameters: r = 2000 mm is upper radius; r = 1750 mm is lower radius; B = 20 mm is overlap thickness; k = 2 is the number of reinforcement edges.

4. Conclusions

Based on the operational analysis of a roadheader with a lightly collapsed roof some conclusions can be drawn. The results of research, aimed at the constructive improvement of the machine, are presented. The components may vary depending on the mining and geological conditions. The obtained parameters are checked by calculations and design solutions. The minimum mass of supporting device is significantly reduced, having a simultaneous impact on the rigidity and strength of the structure. The results can be applied to driving of subway tunnels and other similar workings, in the construction operations of roads and railways. The design of the device has the ability to adjust in height depending on the condition of the working roof.

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