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The results of studies of the tunneling rescue complex for coal mines

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Abstract. The object of study was the rescue complex for carrying out high-speed workings of small section, the main task of which is to evacuate miners caught in an accident. The aim of the work was to determine the parameters of the rescue complex, part of which is a mechanized walking support. Laboratory studies of walking support parameters were carried out to determine the actual value of the coefficient of resistance to movement (k_{res}). It is established that the movement force of the section-jointed walking lining is based on the mass of its parts, size and physical and mechanical properties of the side rocks and roof, expressed in the steady state by an exponential dependence on the time and step of the advance. And the experimental value of the drag coefficient of the walking lining is in the interval of 3-5.

1. Introduction

Coal is a mineral that is used as a fuel, a raw material for the metallurgical and chemical industries. Taking into account current trends, when alternative sources of energy are actively promoted, coal is still the most important resource in the energy balance of many countries of the world, in particular, China, India, the USA, Russia [1]. Despite the advantages and enormous contribution to the development of mankind, this type of fossil is one of the main sources of pollution of the planet, and its mining is accompanied by the most difficult working conditions and risks for the life of miners. Accidents at coal mines are caused by the inconstancy of mining and geological conditions, the presence of flooded areas at the field, explosive coal dust, the tendency of coal to spontaneously ignite, the methane abundance of workings and the increase in natural temperature of the coal, as well as violation of safety rules during mining operations leads to group fatal accidents.

In order to prevent emergency situations in coal mines, professional training of miners for mining operations is provided, excavations are equipped with high-tech equipment and effective emergency protection systems are used. Figure 1 shows that these measures to prevent accidents significantly reduced the accident rate in coal mines, but the task of saving people is still relevant [2].

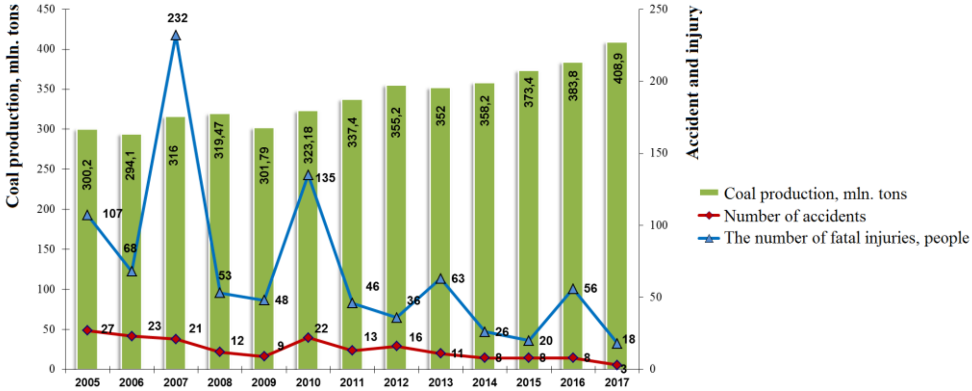


Figure 1. Dynamics of mining, fatal injuries and accidents in the coal industry in Russian mines [2].

Figure 2 shows a time-based rescue operation schedule in the event of an accident at a coal mine that occurred on October 23, 2003 at the Zapadnaya-Kapitalnaya mine, in which water broke through in the main skip shaft of the mine [3], as a result of which 46 workers were blocked underground mine.

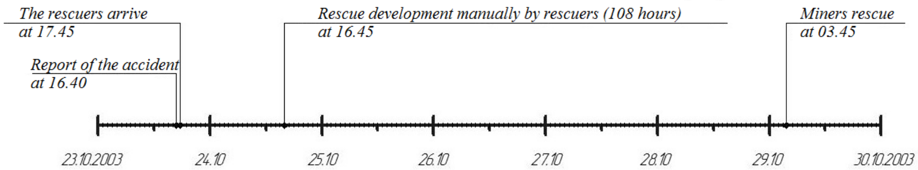


Figure 2. Time-based schedule of rescue operations at the Zapadnaya-Kapitalnaya mine.

In order to evacuate the blocked miners by the rescuers, it was decided to undergo a rescue tally of 60 m in length from the drift from the neighboring Komsomolskaya Pravda mine to the conveyor drift of the Zapadnaya-Capital mine. The crash was done manually, the fastening was carried out with wooden frames. The rescued workers were in a very serious condition, the slightest delay in the sinking, most likely, would not allow to save people. Therefore, in this case the presence of rescuers special equipment for high-speed penetration sboyka as a driving machine consisting of prefabricated units quickly facilitated type, would significantly reduce the time spent saved working in extreme conditions.

For mines, the creation of a rescue complex based on the following principles is relevant:
- the entire complex consists of quickly assembled units of lightweight type, the transportation and assembly of which is carried out by 1 or 2 rescuers;
- the speed of evacuation making by the rescue complex is higher than when carrying out the production by hand. The use of a rescue complex will significantly reduce traumatic situations for rescuers at risk.

2. Methods and means of rescue operations of mines

Carrying out high-speed workings of a small section is the main method of rescuing people from localized zones after accidents at mines. In addition to carrying out workings of a small section to evacuate the victims, the workings were also used to supply air and livelihoods to miners who got into the obstruction. In some cases, in addition to carrying out horizontal evacuation workings, it is advisable to conduct vertical wells from the surface. Further expansion of the vertical well allowed one to evacuate people from the dam area. This is proved by the experience of conducting such operations at the mine of San Jose, Chile [4, 5]. Patents are known for the design of rescue complexes and sets of equipment for performing such operations, however, they are not manufactured in industry, therefore a very urgent task is to create a rescue complex for high-speed penetration of workings of a small section consisting of quickly assembled lightweight assemblies that facilitate the transportation and assembly of the complex , which ultimately will increase the speed of rescue operations.

3. Development of design and parameters of the rescue complex

3.1. The design of the rescue complex.

Figure 3 shows the possible layout of the complex with a medium-resistant roof. The tunneling machine 1 produces rock breaking by a shock executive body. At the same time, the roof above the combine is held by a mechanized walking support 2. The rock is transported, for example, by belt loaders 3. The ventilation of the output is carried out with the help of ventilation pipes 4 and a local ventilation fan. Fastening production made frame support 6, the installation of which is carried out by the lining placer 5. The design of the frame support 6 is protected by a patent, the main advantage of which is the speed of its deployment from the transport position to the working position and installation in the coupling [6].

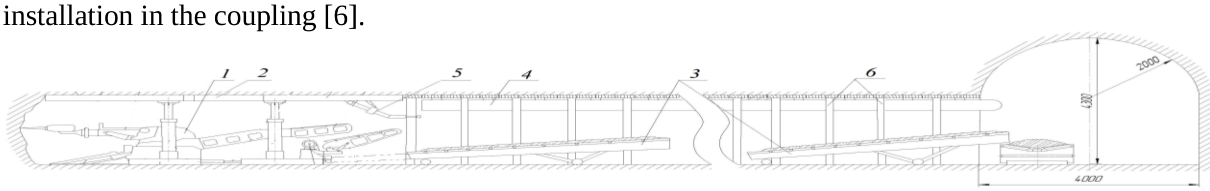


Figure 3. The layout of the rescue complex.

The driving unit of the rescue complex is equipped with interchangeable actuating devices: a crown with incisors for processing fragile and soft rocks (coal); percussion executive body for processing the face of increased strength. Also, if in the area of the complex there are damaged metal structures, additional executive bodies are used: hydraulic shears, a diamond circular saw, a breaker. The quick-changeability of the executive bodies ensures a high speed of work flow. The design of the rescue complex is patented.

3.2. Computer modelling.

To study the parameters of the complex, an imitation model of work has been developed using the following basic formulas:
- calculation of the processing time of the face:

$$T_{\text{formation}} = \frac{V}{Q_t} = \frac{S \cdot l}{Q_t}, \text{h}, \tag{1}$$

where V - the volume of the worked out space, m^3; S - cross sectional area ($S=3m^2$);l - the depth of the worked out space ($l=0.5m$); Q_t - technical productivity, m^3/ h;
- calculation of the cycle time of walking mechanized support:

$$T_{\text{cycleof walking}} = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 \tag{2}$$

where $t_1 - t_3$, $t_3 - t_6$ – the time required for lowering, moving, raising the head and end parts of the powered roof support ($T_{cycle\ of\ walking}=0.028\ h$);
- calculation of the rate of penetration of the i-th cycle:

$$\upsilon_i = \frac{L_C}{T_C}, m/h, \tag{3}$$

where: L_C - the length i-th cycle ($L_C=0.5\ m$);
- determination of the driving time of the 100 m long connection:

$$T_{driving} = \frac{L_{connection}}{\left(\dfrac{\sum\limits_{i=1}^{n=200} \upsilon_i}{n_{cycle}}\right)}, h, \tag{4}$$

where $L_{connection}$ - length of the connection ($L_{connection}$ =*100 m)*, υ_i - the rate of penetration of the i-th cycle, n_{cycle} - number of cycles (n_{cycle} =200).

For unstable roofing and increased hardness of rocks in the face, the calculation of cycle time:

$$T_C = T_{formation} + T_{cycleof\ walking} + T_{support} + T_{preparatory}, h, \tag{5}$$

where $T_{formation} + T_{cycleof\ walking} + T_{support} + T_{preparatory}$ – the time of formation of the face, the cycle of walking, the support of the connection, the preparatory operations (the sum of the time for pulling up the conveyor and increasing the ventilation pipe). If combined $T_{formation}$ and $T_{cycleof\ walking}$ used the longest time $T_{formation}$. Since there is no need for frequent fixing of a stable roof, the step of installing the arch support is 1m, thus l=L_C=*1* in the formulas (1, 3).

The simulation was performed according to the following algorithm (Figure 4).

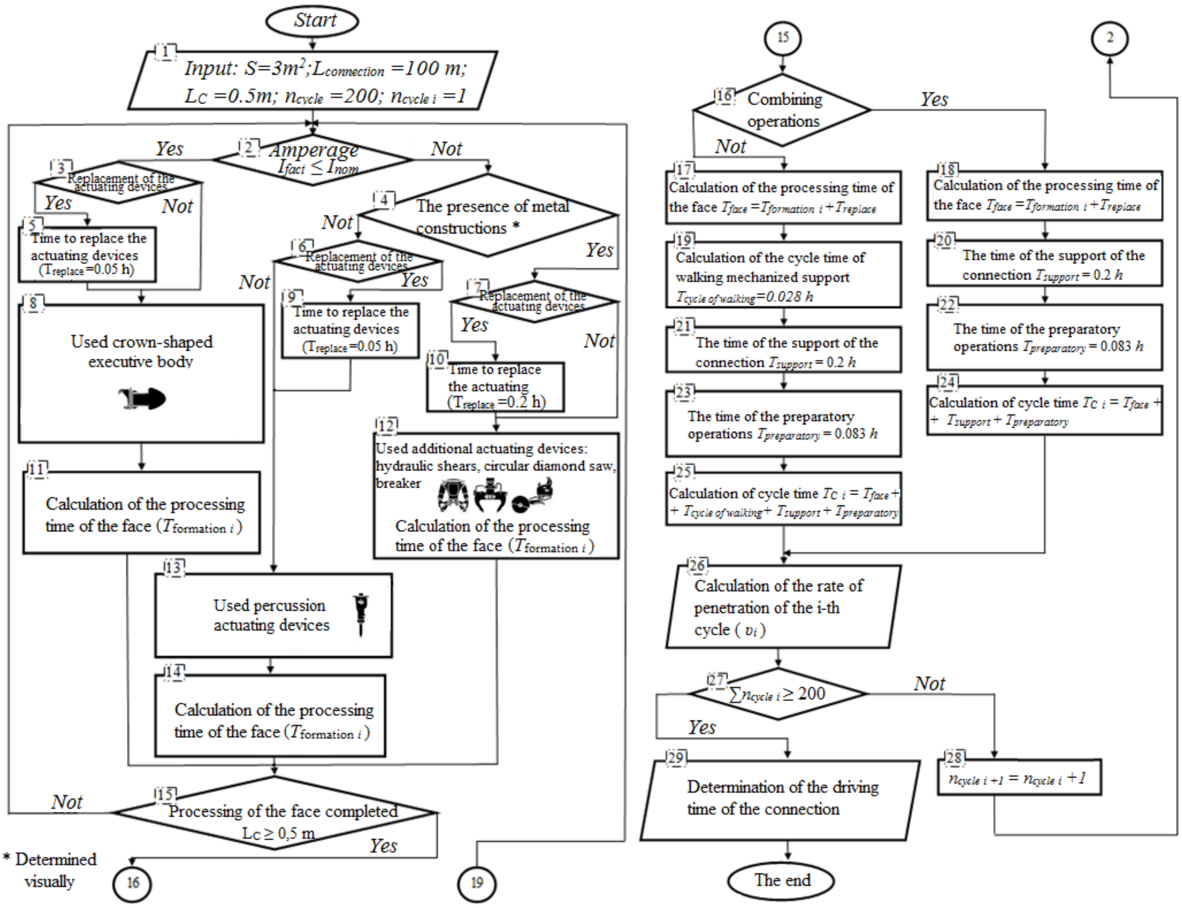


Figure 4. The flowchart of the rescue algorithm.

The simulation results are presented in Figure 5, from which it can be seen that the use of the rescue complex will significantly increase the speed of evacuation development, compared with the manual labor of mine rescuers. Even in difficult geological conditions, when the rock composition of the face changes and there is a need for frequent changes of the executive body, the rate of penetration of the rescue complex is at least 2 times higher than the speed of evacuation sledging by rescuers after a uniform slaughter (f = 2) using minimum technical equipping.

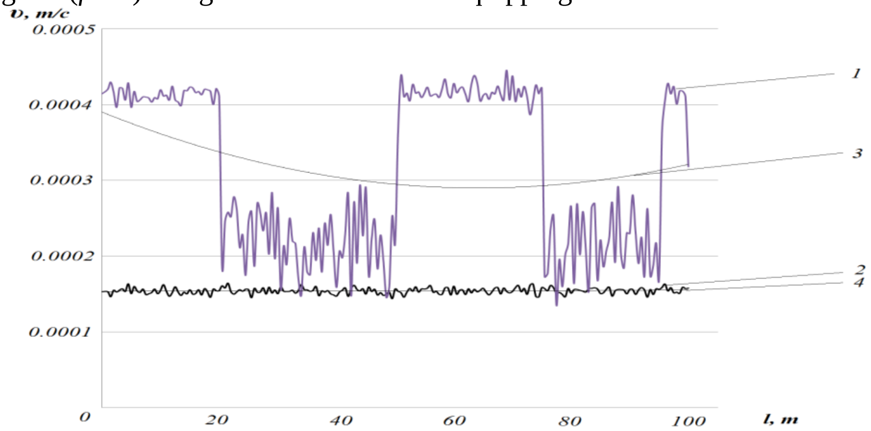


Figure 5. The graph of the rate of rescue development and its length when sinking through non-uniform slaughter: 1 – using a rescue complex with interchangeable actuating devices (crown, impact); 2 – using manual labor of mine rescuers with minimal technical equipment (carrying out rescue development by a division of the Rostov region at the Zapadnaya-Kapitalnaya mine); 3.4 – the average rate of penetration of the rescue mine when using the rescue complex and manual labor of rescuers.

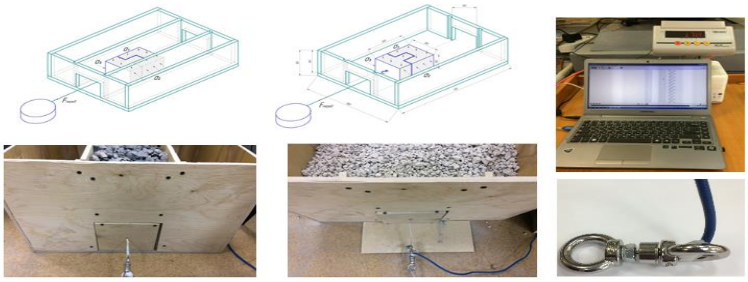
3.3. Justification of the parameters of the rescue complex.

In order to calculate and select the parameters of the units of the complex, it is necessary to establish the power and geometric parameters of the hydraulic cylinders as the main element of the rescue complex. To determine the main parameters of the hydraulic cylinder, the following relationship is used:

$$F = f_f \cdot k \cdot G = k_{res} \cdot G, \tag{6}$$

where f_f - friction coefficient; k_{res}- the coefficient of resistance to movement; G - weight of the lining model, N.

Figure 6 shows a laboratory bench for determining the actual friction coefficient.



a b c

Figure 6. The flowchart of the rescue algorithm Laboratory bench to determine the actual value of the friction coefficient (kres): a – using limiting partitions; b – without the use of limiting partitions; c – measuring equipment.

Figure 7 shows a plot of the displacement force versus the weight of a loaded lining model, the values of which are obtained as a result of laboratory research.

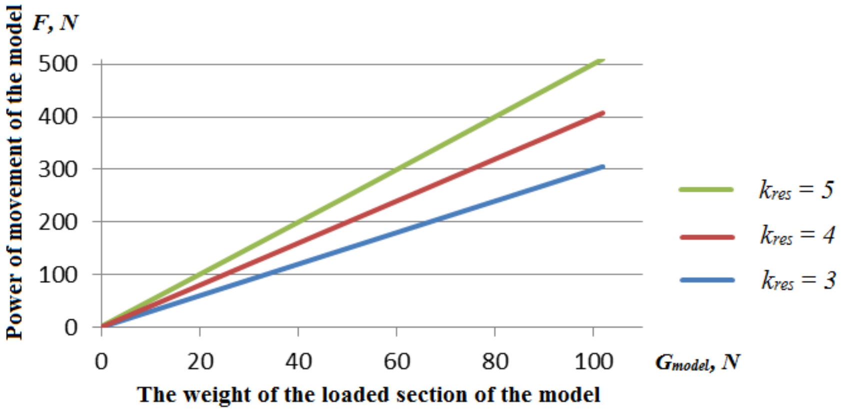


Figure 7. The graph of the advancing force of the weight of the loaded model of lining.

From Figure 7 it follows that for limestones, k_{res}=3-5. Using the coefficient of proportionality (k_p), obtained with the mass ratio of the lining sections of the complex (G) and the model (G_{model}) $k_p = G/G_{model}$ = 4000, the force needed to move the loaded part of the section can be determined.

The determination of the diameters of the pistons of hydraulic cylinders and the required pressure in the hydraulic system is determined by the obtained values of the force F. Figure 8 shows the nomogram for determining the power and geometric parameters of hydraulic cylinders.

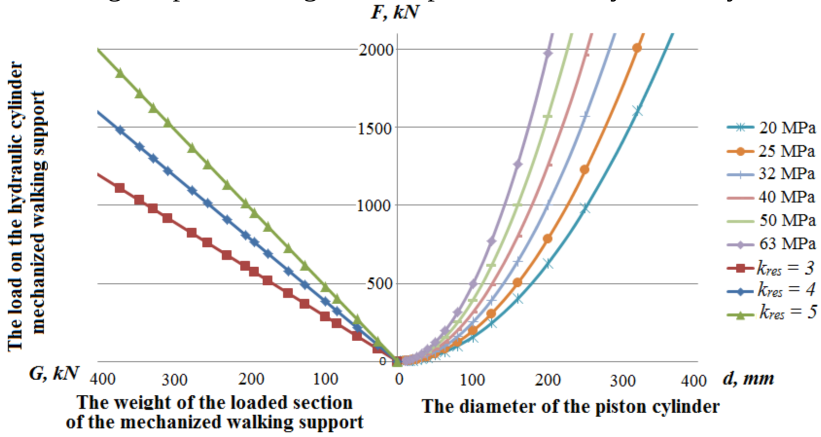


Figure 8. The nomogram of determining the parameters of the hydraulic cylinder advancing walking support, depending on the force of the weight of the section, taking into account the different number of rocks on the perimeter (with different coefficients of motion resistance k_{res}) [7-9].

So, for example, with a weight force of a section equal to 100 kN and k_{res}=5, to ensure movement of the support section, the hydraulic jack must develop a force equal to 500 kN (taking into account the friction forces on the lateral rocks and the additional load on the floor from the weight of the rock). The support section is moved by two hydraulic jacks, therefore the force of one must be taken 250 kN; with a working pressure of the oil station of 20 MPa, the diameter of the pistons of the shifters of the slide is 125 mm.

4. Conclusion

The developed complex for rescue operations (evacuation tunneling) at coal mines, at enterprises engaged in underground construction for various purposes, allows working at a speed of at least 18 m / day for rocks with a coefficient of strength f = 6. This is no less than twice as efficient as with manual penetration of a rescue ship. The developed simulation model makes it possible to determine the timing of the workings of the rescue complex for arrays of any complexity, which allows predicting the implementation of rescue work and selecting the necessary components of the complex for its high-quality work. Equipping the mine-rescue units with such complex will reduce the time for rescue work, which in some cases will lead to the rescue of workers who would suffer if they were rescued manually.

Acknowledgments
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