THE NEW ASPECTS DRILLING AND BOLTING IN MINING INDUSTRY

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Abstract: Present market prices of copper and the forecast of thease development let us make investment decisions which guarantee that the exploitation in the conditions of deep deposits will be profitable. Experience shows that the technological processes of deposit mining will be carried out in more difficult mining-geological conditions. It concerns processes connected with the exploitation of these deposits and the protection of roofs in the workings, in particular. The paper is presenting a solution of a modern roof bolter which has been designed by AGH Cracow and Mine Master, Wilkow, and which should ensure safe and efficient work in polish regions during the exploitation of copper ores.

Key words: roof bolter, working system, layers, simulation, drilling-bolting processes

1. INTRODUCTION

Currently the exploitation of copper ores is carried out in three Mining Plants: O/ZG "Lubin", O/ZG "Rudna" and O/ZG "Polkowice-Sieroszowice". In each of the selected mining areas, the quantity of output of ores is and will be different for each of these mines in the future years. An analysis of the state of deposits leads to a necessity to modify current types, models and structures of workings within allocated mining areas of active mines. A modification of structures for deposit availability should be aimed at creating additional underground transport arteries, linking existing transport ways, which would lead to flexibility and easiness in transferring ores to the main drawing shafts in the current mining plants.

The exploitation of deposits of copper ores in the Legnicko-Glogowski Copper Region is getting close to the boundaries of "Rudna" and "Sieroszowice" mining regions. After the year 2000 all three mines of KGHM faced new challenges and they

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now practically respond to it. A currently available and tentatively studied deposit lies in thin deposits of 1.0-2.0 m or even thinner at greater and greater depths. Current exploitation levels are already placed over 1000 m below the surface. Concept and technical preparations have been started, aimed at entering a deposit at a depth of 1500 m. It is a perspective of just a few years and it is supposed to enable exploitation of copper ores and accompanying minerals for the future 40-60 years.

So, a natural direction of development of exploitation carried out by KGHM Polska Miedz S.A. is to exploit deposits of copper ores lying below 1200 m in the mining area of “Glogow Gleboki-Przemyslowy”. The deposit in this area is a continuation of the deposit lying in the existing mining regions; it lies up to 1400 m and is characterized by mining-geological conditions which are similar to those in the KGHM Polska Miedz S.A.’s mines. Study and design works show that the most efficient investment solution as for availability and management of Glogow Gleboki-Przemyslowy deposit is a model of a combined mine, basing on the infrastructure of the existing mines of Polkowice-Sieroszowice and Rudna. This model ensures a reasonable management of the deposit and an optimal use of the production potential, as well as a use of basic shaft objects, arterial routes and ventilation roads. Figure 1 presents size and shape of mining regions allocated to Mining Plants and regions that perspective in LGOM (Legnicko-Glogowski Copper Region). The mining region of Glogow Gleboki-Przemyslowy is marked with a red line, whereas the perspective areas of “Bytom Odrzanski”, “Glogow” and “Retkow” with a green line (red line: mining region of Glogow Gleboki-Przemyslowy; green line: perspective areas of “Bytom Odrzanski”, “Glogow” and “Retkow).

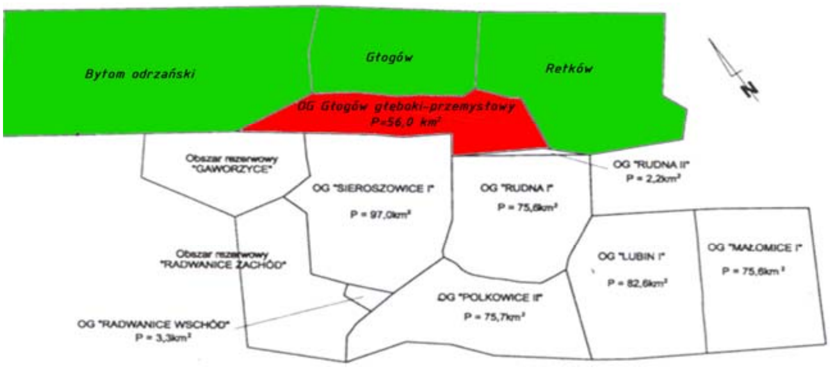


Fig. 1. Current and perspective mining regions in the area of LGOM (as of 2006)

According to a current geological recognition, in the considered area there are deposits of resources of over 300 million tons of ores including almost 7 million tons of pure copper and over 24000 tons of pure silver. Present market prices of these metals and the forecast of their development let us make investment decisions which guarantee that the exploitation in the conditions of deep deposits will be profitable. Experience shows that the technological processes of deposit mining will be similar to the current ones, yet they will be carried out in more difficult mining-geological conditions. It concerns processes connected with the exploitation of these deposits and the protection of roofs in the workings, in particular. We are presenting below a solution of a modern roof bolter which has been designed by AGH Cracow and Mine Master, Wilkow, and which should ensure safe and efficient work in this region during the exploitation of copper ores.

2. SYSTEMS OF EXPLOITATION OF DEPOSITS OF THICKNESS UP TO 3.5 M AND A SUGGESTED TECHNOLOGY OF ROOF PROTECTION

A choice of a system of deposit exploitation in ore mines depends on many factors. One of the most important factors is to adapt the exploitation port to the changeable parameters of deposits, especially thickness, which is closely connected with an application of appropriate mining machinery. An appropriately selected system should also ensure maximum work safety (crump hazard) and an achievement of the highest efficiency of production with the slightest exploitation losses. Experience has helped to work out and introduce room and pillar systems with a continuous liquidation of workings. In these systems a deposit is exploited in an area simultaneously, using a system of many chambers having a width of 5-7 m. The chambers are driven parallely (the so called stripes) and perpendicularly to the front line. Between pillars, other pillars are erected and their dimensions are adapted to the local mining-geological conditions. Behind the front line, there are a few rows of pillars and stripes.

On the basis of an analysis of mining-geological conditions of Glogow Gleboki deposit and the exploitation systems used in the Legnicko-Glogowski Copper Region, two pillar systems have been accepted for region of Glogow Gleboki-Przemyslowy: one with susceptibility of the deposit and additional protection of the roof, whereas the other with a deflection of the roof and an operating closing pillar. The first system, shown in fig. 2, is aimed at exploiting deposits of a bed type with the following characteristics:

- deposit thickness to 7 m,
- dip to 8°,
- roof rocks enabling application of bolt support.

It requires contouring the area of exploitation with workings driven in at least a bifilar system, which need to be connected with active workings in the mine. If the thickness of the deposit exceeds 5 meters, workings are driven in the deposit bed below the roof.

In the other system which is aimed at deposits of similar conditions, it is not necessary to contour the deposit fully by means of preparatory workings. A launch of exploitation is conditioned by a small range of preparatory works only, i.e., bundles of workings from which an exploitation front will be launched. If the thickness of deposit exceeds 4.5 m, workings are driven in the deposit bed below the roof. Contour workings must be connected with active workings in a mine.

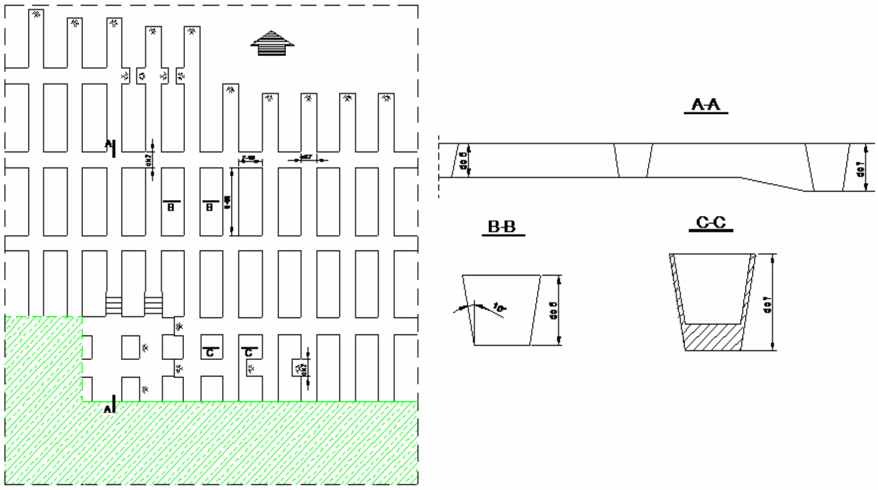
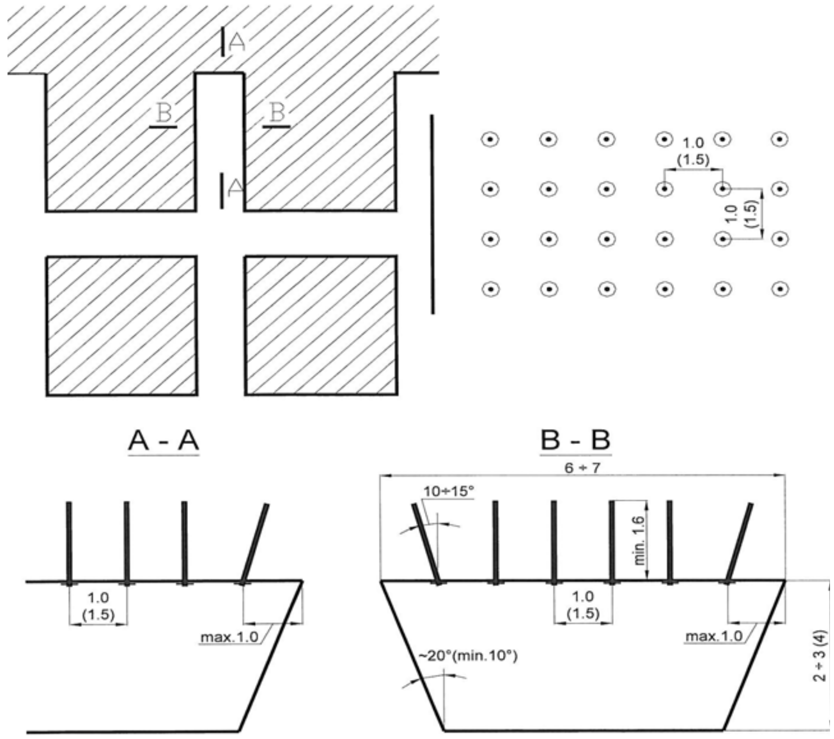


Fig. 2. Diagram of exploitation by the room and pillar system with susceptibility of deposit and additional roof protection

For preparatory, first driving and exploitation workings, on the basis of an analysis of applied roof protection methods in the mines of the Legnicko-Glogowski Copper Region, a bolting technology was suggested for the exploitation of copper ores in the Glogow Gleboki deposit. Roof conditions that were accepted were similar to those occurring at the depth of over 1000 m in Polkowice-Sieroszowice mine. Thickness of the extracted deposit ranged from 2.5-5 m. The dimensions of the chamber for the accepted room and pillar system were as follows: width 6-7 m, height 2-3 m, length 8-12 m. Whereas, because of the climatic conditions existing at those depths, it was assumed that the height of dog headings cutting the deposit would be 4 m. The basic bolting net was 1×1 and the alternative one was 1.5×1.5. Bolts were installed in rows, 6 pieces in each. The minimal depth of bolt holes was 1.6 m and their diameter, depending on the kind of installed bolt, 25.4 or 38 mm. Figure 3 shows a diagram of a network of workings for the assumed conditions along with the suggested bolting net and longitudinal and cross sections of a dog heading. Below, we are presenting the order of installing particular bolts for the presented bolting net and a 4-meter-high working.

For installing the first bolt, a roof bolter is placed and stabilized in the axis of working. This placement of the machine is sufficient for bolting the whole row of bolts (6 pieces). If we want to mount bolts in one line, in accordance with the 1×1 bolting net, we need to lift the jib by 45 degrees. The first bolt should be installed near the axis of a working with the jib being pulled out, as it is shown in fig. 4. Then, we determine the position of neighboring and outermost side wall bolts, which are installed no further than 1 m from the side wall and at the angle of 10 degrees. Because all of the bolts must be installed in a line, creating the so called ‘bolting net’, we must pull out the jib maximally and regulate the position of a bolt by the angle at which the jib is lifted and turned.



Depth of bolt holes: 1.6 m
Diameter of bolt holes: 25.4 and 38 mm

Fig. 3. Diagram of a working network along with a suggested bolting net and longitudinal and cross sections of a dog heading

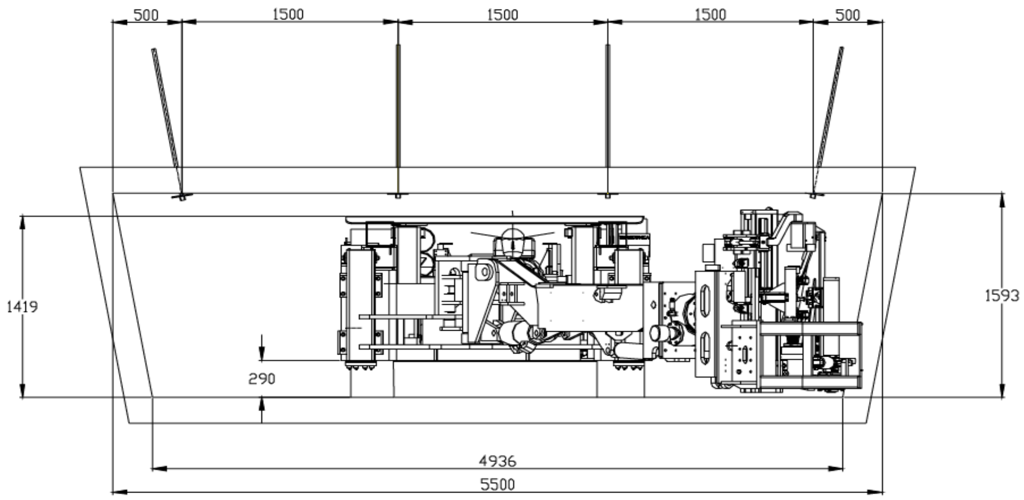


Fig. 4. Diagram of installing an exemplary bolt

With the presently used solutions of roof bolters in the Legnicko-Glogowski Copper Region, applying the above presented technology is difficult or even impossible. Thus, it was necessary to work out a structure of a roof bolter with an automatic drilling-bolting turret, which enables to carry out such works safely and efficiently.

3. ASSUMPTIONS AND GUIDELINES FOR THE NEW SOLUTION OF A ROOF BOLTER

An analysis of work and parameters of roof bolters operating in the KGHM Mining Plants and the suggested technology of bolting for exploitation conditions in the region of Glogow Gleboki were the basis for a technical development of a new solution of a roof bolter with an automatic bolting turret. These assumptions are the basis for a preliminary design of a self-propelled roof bolter with an automatic turret for medium and high deposits.

For a self-propelled roof bolter with an automatic bolting turret, the following assumptions (connected with geometric, structural, kinematic, organizational and technical parameters) were made:

- Transport height of the whole machine cannot exceed 1.8 m,
- Maximum width of the whole machine cannot exceed 2.4 m,
- Length of the machine shouldn't exceed 11500 mm,
- Weight of the machine shouldn't exceed 18000 kg,
- Speed of the machine: gear I - 4 km/ h , gear II - 10 km/h,
- Ability to go up a hill – longitudinal slope 12°, cross slope 4°,
- Ability to go along mining workings of minimal width 4.5m, intersecting at an angle of 90°,
- Machine must be operated by one operator,
- Protective construction of the driver's cabin must meet strength requirements against hits from the roof (energy 60 kJ) in accordance with requirements for constructions protecting the driver, standard: PN/G-59001,
- the driver's cabin must be air-conditioned and equipped with a system that cools down the air while that machine is moving and during the operation of the electric engine,
- Application of a hydrodynamic power transmission system with a combustion system in accordance with the COM III standard, and the driving axles must be equipped with internal dynamic brakes, an emergency brake and a parking brake,
- Construction of the whole machine and all the elements and subassemblies used while constructing the machine should meet all the standards so that the producer would obtain a certificate of conformity, WE type, issued by the independent Certification Institution,

- There should be an ergonomic post with an isolated desk for bolting during the operation of the electric engine and a different post for driving it when the combustion engine is in operation.

Taking into account the bolting technology and the requirements for the operation mode of the automatic bolting turret, the following technical assumptions (which the working system, i.e., jib and drilling –bolting turret should meet) were made:

- Possibility of installing expansion and glue-in bolts in workings whose height ranges from 2.5 do 4.0 m,
- Diameter of the drilled holes Ø38mm,
- Length of bolts being installed in a working 1.6 m and 1.8 m,
- Application of a hydraulic rotary driller (with a system of suction removal of drill cuttings through the drilling rod and the driller) for drilling holes in rocks whose thickness ranges from 80-120 MPa,
- Height of the bolting turret during transport shouldn't exceed 2100 mm,
- The bolt magazine in the turret must be capable of holding up to 6 bolts,
- Working system should be capable of installing one row of bolts according to the bolting diagram in fig. 3,
- Operation of the bolting turret is automatic, but there must be a possibility of manual operation from the driver's cabin,
- Assumed duration of a complete cycle of installment of an expansion bolt (1.6 m) can't exceed 3 minutes and a glue-in bolt 3.5 minutes.

Taking into account the above presented requirements that should be met during the preliminary design of a new solution of a roof bolter on a wheel chassis, the following assumptions were suggested. Three basic subassemblies were distinguished:

- Chassis with power transmission system, turning system and brake system,
- Bodywork with an air-conditioned driver's cabin and with a hydraulic working system and electric system,
- Complete working system consisting of a telescopic extension arm, a drilling-bolting automatic turret and a system of suction removal of drill cuttings.

4. PRELIMINARY DESIGN OF A NEW STRUCTURAL SOLUTION OF A ROOF BOLTER

On the basis of the accepted assumptions and guidelines, a preliminary design of a self-propelled roof bolter was made. It had an automatic bolting turret and an air-conditioned driver's cabin. While creating the design, design engineers used experience that had been acquired while designing similar constructions of self-propelled vehicles and they tried to adapt as many ready and reliable elements and subassemblies as possible.

The preliminary design of the self-propelled roof bolter on a wheel chassis with an automatic bolting turret was worked out as a module construction. It consists of a chassis, bodywork, and a working system. In accordance with the accepted assumptions and guidelines, the designers planned an application of dry rotary drilling with the system of suction removal of drill cuttings through the drilling rod and the driller. The inner suction removal of drill cuttings keeps the area around the operator clean. This system draws contaminations through the rod and the driller for preliminary cleaning. The final filter stops the smallest elements of contamination. It requires applying a reliable solution of a rotary boring head, Fletcher, with the system of suction removal of drill cuttings. It consists of a hydraulic rotary driller, Fletcher, and a vacuum pump, Roots, which is driven hydraulically so as to remove drill cuttings. This solution of the head is supposed to drill holes ø 25 – 38 mm in diameter and to enable installing glue-in 1.8-meter-long bolts. Thus, the bolting turret should be characterized by a feed stroke of at least 1900 mm.

The turret along with the jib is supposed to be able to install 6 bolts in one row (every 1.5 m, at a distance of 0.5 m from the sidewall) from one position, without moving it. The bolt magazine in the turret must be capable of holding at least 8 bolts. Whereas the jib should be able to lift the turret by – 5° / + 21° in relation to the level of the floor and to turn it by 35° to the left and 35° to the right. In addition, the jib should have a capability to extend forwards up to 1000 mm. So as to ensure hole drilling and bolt installing in accordance with the approved technology, the bolting turret should also be capable of inclination to the left and right by 90° so as to ensure sidewall bolting, and by 10° to the front and back so as to ensure an appropriate inclination of the axis of the bolt holes. So as to obtain the above presented work parameters, it was suggested that the already reliable elements from the automatic drilling-bolting turret Fletcher should be used in the design process of a new solution of a working system. Whereas the structural solution of the jib was worked out as a new one, on the basis of experience that had been acquired while constructing similar solutions in other machines of this type.

During the preliminary design, the design engineers used advanced software packages such as ProEngineer and AutoDesk Inventor. These packages allow us to create spatial models of the designed complexes and machinery and combine them into one piece. At the same time they allow us to make flat drawings and determine overall dimensions of machines and subassemblies and their weight.

A preliminary design of a working system in a spatial version that was worked out with the use of the above mentioned packages is presented in fig. 5. A simulation let the designers claim that the assumed parameters of the jib's operation would be possible to be met, in terms of the value of extension, lifting and turning.

Next, the design engineers created a preliminary design of the chassis and the bodywork of a new solution of a roof bolter for medium layers. It was assumed in accordance with the approved guidelines and assumptions that the construction of the chassis would be jointed and would be divided into two subassemblies, i.e., a tractor and a working platform. The elements of the bodywork will be mounted on these subassemblies, creating an integral whole. In accordance with the approved assumptions and guidelines, the minimal height of the vehicle while it moves is 1.72 m. The operator's post will be placed in a closed air-conditioned cabin placed on the front frame, on the working platform. The chassis will be equipped with a power transmission system Power Shift (axle, torque converter, gearbox made by Clark) enabling four-wheel drive. The transmission system will be powered by a diesel engine BF4M 2012C made by Deutz. The transmission system will be operated from the operator's control desk by mean of the Orbitrol system with a steering wheel. The chassis will be equipped with principal multi-plate wet brakes that are operated hydraulically per all four wheels and emergency and parking brakes – spring ones, released hydraulically with a system of emergency unblocking. On the tractor there will also be elements of the hydraulic system such as a hydraulic multi-piston pump Oilgear (25 Mpa), oil tank and an electric engine (36 KW). Additionally, the tractor will be equipped with a reel of the supply cable, SMC type, capacity 80 m. The chassis must be equipped with 4 pieces of hydraulic floor outriggers, so as to ensure stability of the machine during operation. So as to obtain the above mentioned parameters of operation of the chassis and bodywork assembly, it was suggested that the already reliable solutions, subassemblies and elements used while constructing similar solutions in other machines of this type should be used in the design process. The preliminary designs of the tractor and the working platform were created separately.

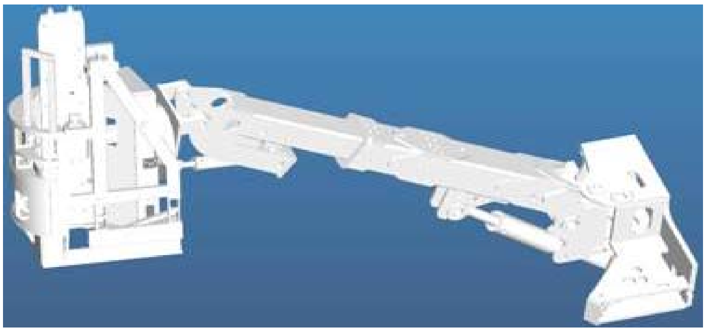


Fig. 5. Spatial model of the preliminary design of a working system of a new solution of a roof bolter for medium layers

Figure 6 shows the preliminary design of the tractor in a spatial version that was based on the above mentioned assumptions and guidelines, whereas figure 7 shows the design of the working system in a spatial version.

Using the preliminary designs of the tractor and the working platform, designers created a drawing of the chassis and the bodywork of the new solution of a roof bolter for medium layers, which is presented in fig. 8. This drawing also shows the basic overall dimensions.

On the basis of the drawings and spatial models of a working platform, tractor and a working platform, the designers worked out a preliminary design of a new solution of a roof bolter for medium layers. It is shown in fig. 9, whereas figure 10 shows an aerial view with the basic overall dimensions.

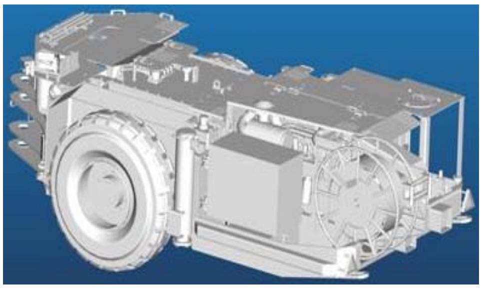


Fig. 6. Spatial model of a preliminary design of a tractor of a new solution of a roof bolter for medium layers. A view from the back, left hand side

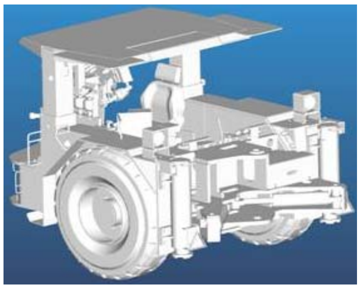


Fig. 7. Spatial model of a preliminary design of a working platform of a new solution of a roof bolter for medium layers. A view from the front of the driver's cabin

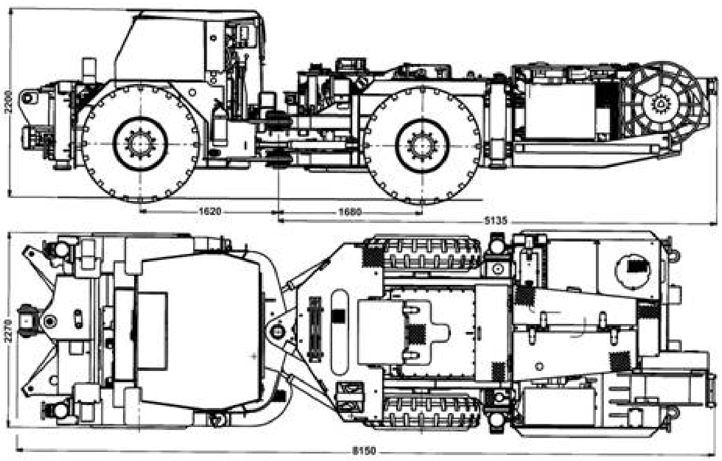


Fig. 8. Preliminary design of a chassis and bodywork a new solution of a roof bolter for medium layers, overall dimensions

Fig. 9. Spatial model of a preliminary design of a new solution of a roof bolter for medium layers –side view

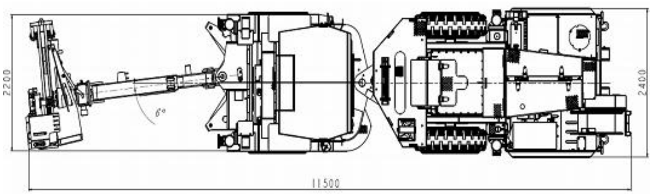


Fig. 10. Model of the designed solution of a roof bolter with the values of its maximum width and length, with the jib and the turret being turned by 6°

Similarly to the design process of a bolting turret with a jib, the design engineers also used the experience of Mine Master and Fletcher while working out the system for supplying and steering the turret. On the basis of an analysis, the engineers decided that the hydraulic system for transmission, steering the jib and the bolting turret with the drilling head will be powered from a two-section, multi-piston pump, working in a load-sensing system, which ensures energy-saving and precise supply for the hydraulic system.

For a precise control of the jib movements, the engineers used a proportional (5), sectional valve made by Hawe, installed near the operator's control desk. For a control of the drilling head, head feed, centralizer movements, arm of the feeder and the floor support, the engineers used a 6-section proportional valve made by Hawe. A control of the directional valve is electric and mechanical, which enables a quick diagnosis of the hydraulic system and the service reaction.

For a control of the directional valves of the jib, the rotation and the feed, the engineers used two biaxial hydraulically and electrically controlled joysticks, which were ergonomically installed in the driver's cabin on the control desk. The position of the joysticks which are used for controlling the jib, rotations and the feed is shown in fig. 11. Within the design of the control system of the automatic turret for deposits of medium thickness and on the basis of an analysis of products of the JHF Fletcher Company, the designers selected control components which are fully protected from mechanical damage resulting from falls in the mine face.

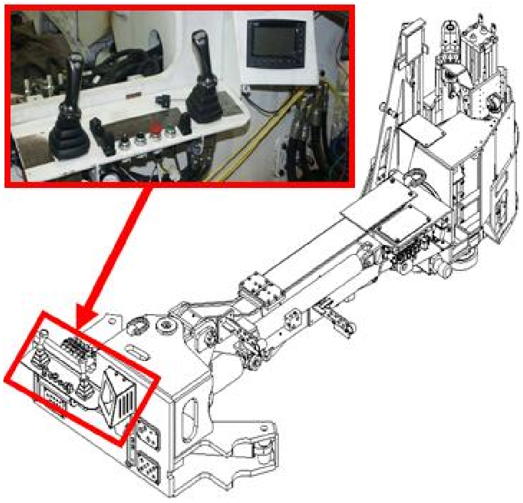


Fig. 11. Position of joysticks for controlling the jib, rotations and the feed on the control desk in the operator's cabin

The electronic control components include three separately connected computer modules, i.e., superior module, which has a display, monitoring the whole cycle of automatic bolting and allowing the operator to carry out the whole cycle manually by means of appropriate buttons, and two subordinate modules to which all controls from the directional valves and electrical bunches from all sensors on the turret are connected. The signals are then converted and displayed on the screen in the superior unit.

It was assumed that the control system would carry out a fully automatic cycle of bolting. An automatic cycle of bolting is based on drilling a hole and installing a mechanical bolt or a glue-in one without the operator's intervention, however, the insertion of the glue substances is carried out from the operator's cabin. If the course of the cycle is correct, the operator just controls the course of bolting. The automatic cycle of bolting is carried out by taking a sequence of steps. Taking a step is based on achieving a specified objective by a given component. The specified objective can be time, position or pressure, controlled by the automatic system of control. All of the steps are grouped into over 20 states, which must be carried out if we want to complete the automatic cycle of bolting. The automatic cycle of bolting is carried out step by step, and each subsequent step can be started once the previous one is completed. While a cycle is being carried out, the present state and its short description are displayed on the screen. If there is a problem that hinders a cycle during a particular state, we can compare the description of the current state with the course of the cycle so as to quickly find the cause of failure. During the automatic cycle of bolting, we can see a screen of this process. The screen displays information that is important for the operator – it shows the operation of the turret and current operation parameters. It also shows the depth and drilling durations as well as the levels of measurement signals from the sensors. The screen also informs the operator about each event occurring while bolting. The colour of the icons changes during the automatic cycle of drilling and it doesn't change during the manual control.

During the design phase, there were numerous simulations and analyses whose aim was to check if the main subassemblies worked correctly. In addition, there was a strength analysis and possible collision spots while driving and bolting were determined. At first, there was an analysis of strength of the construction of the telescopic jib which is exposed to dynamic and static pressures. The analysis was carried out by the finite-element method, and in terms of dynamics it included a case in which the machine ran over a 75 mm-high obstacle at a maximum speed of 12 km/h. There was also a static analysis of strength for a case which was based on determination of the effort of a construction which was weighed down by the maximum force of feed. Both during the dynamic and static simulations of operation of the jib in a transport position, in a pulled-out position with a feed force of 20Kn which was perpendicular to the axis of the jib and in a pulled-out position with the jib being lifted by 40° with a feed force of 20Kn at the angle of 40° in relation to the jib axis, the engineers found no cases of exceeding the limit of plasticity of the elements of the jib for its assumed material, i.e., steel S355J2G3. For defined conditions of load, the construction of the jib meets the requirements concerning immediate strength in terms of dynamics and statics.

Using the design of the vehicle for automatic bolting, the design of the bolting turret along with the jib as well as the control system, engineers carried out spatial simulations of the machine operation. They were worked out for the following positions of the roof bolter:

- simulation of kinematics of the working system with an automatic turret in the mine face during the complete cycle of installation of bolts,
- simulation of rides of the machine in underground dog headings,
- simulation of field of vision of the operator from an air-conditioned cabin during rides and during operation in the mine face,
- simulation of layout of the operator's control desk for the drilling process – bolting in terms of ergonomics of the operator's work.

The simulation of the kinematics of the working system with the automatic turret in the mine face during a complete cycle of bolt installation was carried out for the most unfavorable position of the machine, in a 4000 mm-high working whose width below the roof was 7000 mm. There were no difficulties while installing any bolt in a row, especially while installing bolts near the sidewall. The result of this simulation is shown in fig. 12.

A simulation of the machine's rides in underground 2500 mm-high dog headings for a case with an elevated roof of the operator's cabin also showed no cases of collisions. The machine is capable of going through almost every dog heading that would be exploited in 'Glogow Gleboki'. The turning system lets the machine turn at an angle of 90° in the case of 3800 mm-wide workings. The result of this simulation is presented in fig. 13. Whereas after a simulation of the field of vision from the operator's cabin during rides and during operation in the mine face, it was found that the operator has a good vision in each case of drilling and bolting. The operator has also an opportunity to follow the process of bolt installment, which gives him a full control of the bolting process.

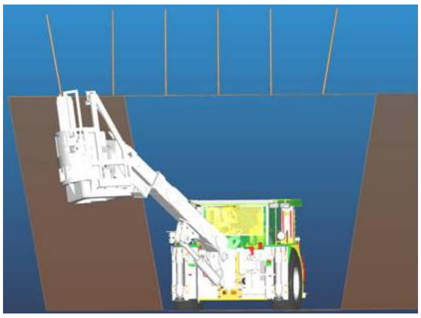


Fig. 12. Result of a simulation of an installation of bolts near the right sidewall

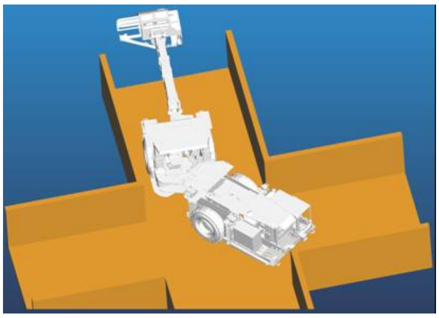


Fig. 13. Simulation of a ride in dog headings intersecting at an angle of 90º without a need to cut off the corners

The result of the simulation of the field of comfort in the operator's cabin during the drilling and bolting processes as well as during rides also turned out to be positive, i.e., the operator has a good visibility and an easy access to all the elements of the control system. The result of this simulation during the operator's work is presented in fig. 14.

Fig 14. Result of a simulation of the operator's access to the control desk during the drilling-bolting processes in terms of ergonomics of the operator's work during operation in the mine face

4. CONCLUSIONS

As a result of approved guidelines and assumptions and a created preliminary design of a self-propelled roof bolter on a wheel chassis with an automatic turret for medium layers, the design engineers achieved a structural solution of a machine which will be characterized by the following structural and technical parameters:

1.	Total mass of the machine	18000 kg
2.	Transport height	1800 mm
3.	Total length of the machine equipped with a bolting turret	11400 mm
4.	Width of workings in which the machine can ride	4500 mm
5.	Width of the machine	2200 mm
6.	Turning radius of the machine: inner	3500 mm,
	outer	5900 mm
7.	Drive axel base	3100 mm
8.	Inclination angle of self aligning axle	10°
9.	Approach angle of the tractor	12°
10.	Approach angle of the front platform	24°
11.	Ground clearance	325 mm
12.	Turning angle of chassis	42°
13.	Turning angle of the jib during a ride	15°
14.	Turning angle of the jib during operation	42°
15.	Mass of the jib	2500 kg
16.	Mass of the automatic turret	2000 kg
17.	Height of the turret being pulled back	2082 mm
18.	Capacity of the bolt magazine	8 pieces

We can estimate that the new solution of a self-propelled roof bolter should help to achieve the following organizational and kinematic parameters:

1. Possibility to install 6 bolts in one row every 1.5 m, distance from the sidewall 0,5m,
2. Diameter of drilled holes Ø38 mm
3. Drilling speed no lower than 1 m/min,
4. Duration of a complete cycle of installment of an expansion 1.6m-long bolt no longer than 3 minutes,
5. Duration of a complete cycle of installment of a glue-in 1.6m-long bolt no longer than 3.4 minutes,
6. Transport speed: maximum 13 km/h, 1st gear 4 km/h, 2nd gear 10 km/h

REFERENCES

[1]. A review of the research project ‘*Inicjatywa Technologiczna I’ No 13003. ‘Unikalna zautomatyzowana maszyna wiercąco-kotwiąca do eksploatacji rud miedzi w rejonie “Głogów Głęboki*’. Kraków 2009, (unpublished)