Development of technology for withdrawal of the powered roof support from a row and its relocation from the liquidated longwall system

K Mazurek1*, M Szygula1 and K Turczyński1

1KOMAG Institute of Mining Technology, Division of Powered Roof Supports, Pszczyńska 37, 44-101 Gliwice, Poland

*E-mail: kmazurek@komag.eu

Abstract. Directions in improvement of efficiency and safety of the used systems for relocation of powered roof supports from the liquidated longwall was indicated basing on a review of the current systems. Suggestion for the machines and devices used for mechanization of a powered roof support relocation from a row and its transportation in cross-cut entry is presented. The innovations consist in combination of two functions in one machine used for roof support reinstallation and its rotation as well as its safe and fast relocation to the main transportation roadway.

1. Introduction

Necessity of reducing the number of operating mining fronts due to economic reasons makes the process of re-equipping of liquidated longwall panels and equipping new ones very important for effective mine operation. Such a process has to be carried out in a short time in an effective and safe way. Relocation of powered roof support is one of difficult technological operation due to high weight of the roof support and its big size, which is almost the same as the size of transportation routes. Additionally, the local mining-and-geological conditions such as convergence of the workings, roof conditions or increased methane concentration make the process more difficult [1]. Complexity of the roof support withdrawal from a row and its transportation in a cross-cut entry, specificity of local mining-and-geological conditions as well as different supporting technical equipment cause that the process is realized in each mining plant in a different way.

Experience shows that transporting the roof support from the liquidated longwall to a new longwall location depends on the proper preparation of the roof support for loading and the selection of a suitable transportation system. Preparation of the roof support for loading consists in pulling it out (withdrawal) from a row in the liquidated mining longwall, rotating and positioning along the created transportation channel of the cross-cut entry and dragging it to the loading place in the transportation system. Due to the shape of the cross-cut entry and its equipping, proximity of the roof fall zone and big mass of the roof support, these activities are time consuming, complicated and dangerous.

Current technologies of the roof support withdrawal form a row and its transportation in the cross-cut entry are analysed in the aspect of their effectiveness and safety as well as the concept of the
innovative system for powered roof support withdrawal and its transportation in the cross-cut entry is presented.

2. Analysis of current technologies for powered roof support withdrawal from a line and its transportation in the cross-cut entry

To assess state of the art of the technology for withdrawal and transportation of powered roof support in the cross-cut entry, the following stages of the process were distinguished:

- withdrawal of the powered roof support from a row to the cross-cut entry,
- transportation of the powered roof support from the cross-cut entry to the main transportation roadway.

Using the practical experience of PGG S.A., JSW S.A mines as well as the independent mines the following variants are used for withdrawal of the roof support from a row:

With use of additional wooden sprag

Opposite the powered roof support, the wooden sprag, friction or hydraulic prop is installed at cross-cut entry front, which is additionally tied by a chain to the steel canopy located in a transportation area. The end of the beam of the roof support’s advancing system is connected with the sprag and after the roof support yielding it is dragged to the cross-cut entry with use of the advancing ram. Then a winch rope is attached to the beam of advancing ram and by using it, the roof support rotates in such a way that it is positioned parallelly to the cross-cut entry front. At the place of withdrawn roof support, the crib boxes are constructed (Figure 1).

![Figure 1. Powered roof support withdrawal with use of a wooden sprag.](image)

With use of insurance roof support

First roof support withdrawn from a row and positioned in the cross-cut entry parallelly to its front plays a role of insurance roof support called sometimes closing support [2]. Its task is to protect the roof in the area of withdrawal of next roof supports as well as to play a role of a sprag during roof
support withdrawal from a row. Withdrawn roof support, yielded to the height, which enables its movement under the insurance roof support, is dragged to the cross-cut entry using its advancing ram, and then it is positioned parallelly to the cross-cut entry front using the winch (Figure 2).

![Figure 2. Powered roof support withdrawal with use of an insurance roof support.](image)

Use of the insurance roof support for additional roof protection in the area of withdrawal of next roof supports as well as for separation from a roof fall zone of the liquidated cross-cut entry significantly improves the work safety. It also eliminates the necessity of setting and relocating the sprag for moving the roof support pulled out from a row.

**With use of devices intended for realization of powered roof support withdrawal and its positioning parallelly to the cross-cut entry**

UDW Ryś device developed and constructed in the Division for Powered Roof Supports in KOMAG [3], presented in Figure 3, is the device realizing the following functions: protection of the roadway’s roof in the powered roof support withdrawal area, moving the roof support to the transportation section, positioning the roof support parallelly to the cross-cut entry as well as loading the roof support on the transportation platform.

The device consists of two parts connected with each other by the advancing rams which are moved against each other on guides. The first part consists of a base, on which 3 hydraulic legs are installed, 2 on left and 1 on right side. The second part consists of a base, on which 2 hydraulic legs are installed, one on each side. The legs are supporting the roof by through canopies. The legs are stabilized in the working position by the hydraulic cylinders. Connection of both parts by guides and hydraulic cylinders enables self-advancing of the device along the cross-cut entry.
Figure 3. UDW Ryś device for withdrawal of powered roof supports.

In the Polish mining industry, also UWS–PUMA device of similar design, manufactured by Sigma with its own advancing system or without it, was also used, and a hydraulic loading ramp type HRZ-2 [2].

The following methods for transportation of powered roof supports from cross-cut entry, used by mines can be distinguished:

- transportation of roof support on the floor (optionally on a special plate) using a winch placed in an upper entry; rope winches which are used have one disadvantage consisting in reduction of pulling force along with the progress of the rope winding. This phenomenon has adverse effect on the process of pulling the powered roof support. During rope transportation there is a high probability of rope break. Factors conducive to this may include mining and geological conditions (transverse and longitudinal wall inclination), crew selection, day of the week, technical condition of the equipment used for transport, etc. A broken rope may behave in an unpredictable manner, which has often been the cause of serious accidents.

- transportation of roof support by suspended monorail; the use of suspended monorail for the transportation of powered roof supports from the longwall to the main transportation roadway requires the construction of the railway route in the transport area, which is a time-consuming process and requires employment of additional crew during its construction. The use of suspended monorail for transporting roof supports from the longwall requires a greater height of the transportation field, because the height of the transported roof support additionally increases the height of the railway route and transportation beams. Transport of the powered roof support directly from the liquidated longwall to the new location by means of a suspended monorail, despite the initial large amount of work, significantly reduces the time of the entire transportation process.

- transportation of roof support by floor-mounted railway; use of floor-mounted railway for transportation of powered roof support directly from the cross-cut entry requires building the railway route on the cross-cut entry floor is a time-consuming process and requires employment of additional crew during its construction,
however it can reduce time required for dislocation of roof supports between the longwalls.

- transportation of the powered roof support on a sliding platform pulled by a rope of the winch along the troughs of partially disassembled face conveyor or along the trucks installed in the cross-cut entry;
  such transportation method has the same disadvantages as those in the case of roof support transportation on the floor (optionally on a special plate) using a winch rope.
- transportation of roof support using the self-propelled machines [4] [5];
  such a method of transportation does not require additional transportation equipment. However, due to size and turning radius of such machines, transportation space of bigger dimensions than in the case of above mentioned roof support transportation systems is required. Besides, in the case soft floor the machine can immerse into the floor. Each subsequent pass causes more and more wheel-ruts and driving problems.
- transportation of roof support using the chain capstan;
  a withdrawn roof support is pulled out to the transportation sledge connected with a pulling chain using the pulling harness and it is dragged from a longwall to upper entry. The chain drive is installed in a special stable in the upper entry and the chain return end is bolted ahead of insurance roof support using the expansion stands and lashings. Compared with the rope, the chain used to transport the roof support breaks much less frequently, and in the case of breaking it does not cause whipping as much as a broken rope. Changing the location of the return end, requiring it to be pulled up and bolted again with shortening the chain is a time-consuming operation in this transportation method.

Characteristics of the features of currently used technologies for withdrawal of the roof support from a row in a liquidated longwall as well as its transportation in the cross-cut entry, enabled developing the concept of the devices and procedures that make the both operation more effective. The devices designed in KOMAG based on this concept, using the virtual prototyping [6], are presented in chapter 3.

3. A concept of the system for powered roof support withdrawal and transportation in the process of longwall panel liquidation
As a result of the analysis of the advantages and disadvantages of the technologies used so far, it was decided to use and combine the advantages of the UDW RYŚ device and the chain capstan. The device was designed based on the UDW RYŚ device, equipped with a fixation of the chain capstan return end and a special transportation plate. The system equipped with this device supports the process of withdrawal of a powered roof support from the moment of it’s yielding in a row of roof supports standing in the cross-cut entry until the transportation of the roof support begins, using the basic mean of transportation in the upper entry. The system is shown in Figure 4 as an example of its use in cross-cut entry prepared for longwall liquidation.

The developed system consists of a device for roof support withdrawal and loading (A), of a chain capstan (B) as well as transportation plate (C).
Figure 4. System for powered roof support withdrawal and transportation in the process of longwall panel liquidation.

Device for roof support withdrawal and loading on the transportation plate is a self-advancing unit consisting of the advancing member I (A1) and the advancing member II (A2). Both members are connected using the set of advancing rams (A7) as well as metal guiding sheets (A8) enabling mutual movement of the members keeping linearity of their movement. The set of advancing rams enables positioning the device in a such position, which makes installation of the next roof supports in a row in the cross-cut entry possible. The canopy (A3) is installed on the advancing member I supported by two hydraulic legs and the canopy (A4) is supported by one hydraulic leg. Hydraulic legs of the canopies are stabilized vertically using additional tilt (stabilising) cylinders. The advancing member I has a cant in a front part and a fender facilitating entering the roof support to the device transportation compartment. In the rear part of the advancing member I, permanently attached metal guiding sheets (A8) are used when the device is advancing. A set of two manoeuvring cylinders (A5) used to pull the powered roof support out of the row is placed on the side of the transportation section of the device. These cylinders are connected in an articulating and rotating way, which makes it possible to maneuver them in every direction. Two canopies (A4) are installed on the advancing member II, each is supported by a hydraulic leg. The canopy’s hydraulic legs are also vertically stabilized by tilt (stabilising) cylinders. The advancing member II has a cant in the rear part to facilitate sliding the roof support off the device onto the transportation plate (C1). In the front part of the advancing member II there are guides through which the metal guiding sheets pass (A8). Next to the hydraulic legs, from the side of the transportation compartment, there is a set of two manoeuvring cylinders (A6) used to pull up, correct the position and support the transportation plate (C1). These cylinders are connected in an articulating and rotating way, which makes it possible to manoeuvre them in every direction. The advancing member II is equipped with a detachable chain catch (A9), which is used to pull up the roof support inside the transportation compartment of the device. The return end of a chain puller (B4) is connected to the rear part of the advancing member II via bolt connections (S). Canopies, cants and fenders of advancing members I and II define ends of the transportation compartment for the roof support. The withdrawn roof support is pulled into the transportation compartment, moved and pulled out onto the transportation plate. The canopies (A3 and A4) are equipped with articulating and rotating catches for installing additional manoeuvring cylinders, which will be fixed to transportation catches on the canopy or the gob shield of the withdrawn roof support via chains. They will additionally stabilize the position of the roof support while pulling (especially on inclination) and facilitate the rotation of the roof support during entering it into the transportation compartment of the device. The device for roof support withdrawal and loading onto the transportation plate of the roof support can be
made in the left or right version depending on the location of the roof supports being withdrawn in the cross-cut entry.

**Chain puller** (B) consists of a drive end (B1), a return end (B4) and the main transportation chain (B6). The drive end (B1) consists of a body installed on a plate, in the centre of which a chain driving drum, positioned vertically and driven by a propulsion unit (B3) is placed. The drive unit includes a reduction gear, a clutch with a brake and an electric motor. The drive end is bolted using the hydraulic legs. The chain puller’s return end (B4) is connected to the device withdrawing the roof support (A) by pins (S). The return end consists of a body installed on a plate, in the centre of which a return passive chain drum, also positioned vertically and additionally stabilized using 2 bolting legs, is placed. The main transport chain (B6) is a typical mining chain used in flight-bar conveyors. The bottom part of the chain moving at the floor is the driving part of the puller and the transportation plate (C1) is attached to it. The upper part of the chain is passive. The chain is made of easy-to-dismantle sections (quick connecting links) which is associated with the need to shorten it as more powered roof supports are withdrawn.

The complete transportation plate (C) consists of a main plate (C1) and detachable fastening chains, long one (C2) and short one (C3). The transportation plate (C1) is built in the form of a metal sheet vessel, open at the back. This is necessary to pull out the roof support. In the front part, the plate has a cant to facilitate its movement, and from below it is equipped with skids to facilitate dragging along the floor. Also in the front part, the plate is equipped with a series of catches, to which a long fastening chain (C2) is attached. These catches allow the transportation plate to be parallel to the main chain and to move it linearly when pulled with the roof support along the longwall cross-cut. The transportation plate (C1) in the front part, inside, is equipped with a handle for hooking the advancing system beam of the roof support when it is pulled onto the plate and the socket for installation of an additional bolting leg. The transportation plate is equipped with side covers protecting the transported roof support against contact with the passive line of the main transportation chain (B6).

4. **The principles of operation of the devices included in the system for withdrawing and transportation of powered roof supports in the process of the longwall panel liquidation**

In the initial state (Figure 5), the device for withdrawing and loading the roof support onto the transportation plate is positioned at the length of the last roof support to be removed from a row. The hydraulic legs are extended, the transportation plate is pulled to the device. Advancing segments of the device are pulled together to a minimum distance. The set of cylinders for roof supports withdrawal is ready for operation. The auxiliary cylinders are installed on a large canopy (supported by two legs). The roof support to be pulled out is yielded. The beam of the roof support advancing system is retracted (cylinder of the advancing system is extended to its maximum length). First, the advancing system of the pulled out roof support is connected with the device’s set of cylinders. The cylinders are extended to the maximum length. Using these cylinders, the roof support is pulled out of a row in a few steps by shortening the chains. The withdrawn roof support must be moved to the wedge edge of the device’s overrun segment to the length of the guiding fender (Figure 6).
Figure 5. Pulling out the roof support from a row in the cross-cut entry.

Figure 6. Pulling the roof support to the device transportation compartment.

Then, after disassembling the chains and roof support pulling out cylinders, the advancing system is connected with a special catch of the device sliding segment. The auxiliary cylinder on the canopy of the overrun segment supported by two legs is connected with the transportation catch on a gob shield by a chain (Figure 7). This cylinder enables rotation of the roof support in a direction of the device transportation tunnel. The roof support is rotated resting on the guiding fender, correcting at the same time its position with use the beam of its advancing system. Few times retraction of the cylinder with a chain shortening at the same time enables positioning the powered roof support in a front of the device transportation tunnel.
Figure 7. Pulling the powered roof support to the device transportation compartment.

The next step is to pull the roof support into the transportation compartment of the device. After unfastening the cylinder with the chain connecting the beam of the roof support advancing system with the eye of the sliding segment of the device and connecting the section beam with the chain with the eye in the transport plate, it is possible to pull the roof support into the transportation compartment of the device, using its advancing system (Figure 8). At the same time, the cylinders connecting the canopies of the device with the components of the roof support enable correcting its position and protecting it against tipping over.

Figure 8. Pulling the powered roof support to the device transportation compartment using the transportation plate.

After shortening several times the chain connecting the beam of the advancing system of the roof support with the transportation plate holder, the roof support can be pulled onto the transportation plate using its advancing system (Figure 9).
Figure 9. Powered roof support pulled onto the transportation plate.

In this position, the roof support is pulled along with the transportation plate to the tail gate, from where it can be transported by other means. The roof support with the transportation plate is pulled along the wall cross-cut entry by a chain puller, whose return end is connected to the basic device (Figure 10). The pulling process takes place according to the diagram shown in Figure 4.

Figure 10. Chain puller.
The integration of the chain puller return end with the device for withdrawal and loading the roof support onto the transportation plate solved the basic problem when using this type of pulling machine in the process of liquidation of longwall equipment, i.e. repeated moving and anchoring of the return end. In the new solution, the anchoring force is transmitted to the return end by the device itself. The return end is also moved by the device advancing system. In the previous applications of the chain puller, the return end was pulled up using an additional sprag, cylinder and chain. Often, even 6 bolting legs did not provide a sufficient anchoring force and it was necessary to use additional chain lashings.

5. Conclusions

Based on the systems used for moving the powered roof support from the liquidated longwall panels, a new device was developed combining the advantages of the different existing solutions and enabling the easier movement of the powered roof supports in the liquidated longwalls in all its phases. The presented set of devices creates a system of work mechanization, which previously required much greater workload and more time. In the new, innovative solution, all cylinders used for moving the roof supports are ready for use at any time and there is no need to prepare the anchoring points for them at any stage of roof support movement. The work related to loading the roof support onto the transportation plate is also supported. The device also protects the roof of the longwall cross-cut entry in the area of subsequent withdrawal of roof supports, definitely improving the work safety. The device is self-advancing, what eliminates the need to use other means for its movement. A dedicated chain puller integrated with the device also improves safety due to the elimination of previously used rope winches.

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