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Electrohydraulic control systems for powered roof supports in hazardous conditions of mining tremors

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ABSTRACT

This paper presents an application of a powered roof support equipped with an electro-hydraulic control system to underground excavations with mining tremors hazard. The research included an analysis of mining and geological conditions of longwall 2, seam 506, section K in Wujek Mine, Ruch Śląsk and an assessment of a system providing protection from dynamic loads for a hydraulic leg of Glinik-12/23-POz powered roof support. The final results of the research include an optimization of a powered support's protection system designed to work in mining and geological conditions of longwall 2 located in seam 506 K. The optimization was based on tests of the hydraulic leg and the support system for hazardous conditions of mining tremors. The process included proper operation of relief valves, leg's valves (check control valve), bearing capacity of the leg and a cross-bar.

1. Introduction

Powered roof support is one of the basic machines of the whole longwall complex that determines the safety and efficiency level of the mining process. The roof support working in hazardous conditions of mining tremors should be adapted to absorb dynamic loads. In the next years Polish mining industry will try to design solutions that allow limiting the number of personnel responsible for the control of machinery in the longwall. Decreasing the number of failures of machinery and equipment connected to technological process of coal mining is equally important as increasing the safety level of staff during mining (Lu et al., 2011). Control system of the powered roof support takes place according to specific stages. In order to conduct its proper and safe operation the following aspects should be provided (Smużyński, 1993):

- maximum safety level of the staff,
- maximum time reduction of process individual stages by elimination of unnecessary breaks and, as a result, greater speed of sets readjustment,
- optimal adjustment of the roof support to difficult mining conditions,
- elimination of personnel errors by application of semi-automatic and automatic systems.

Basic presentation of the control system for roof supports is presented in Fig. 1.

Katowicki Holding Węglowy S.A. uses newer and more reliable machinery systems in order to increase efficiency of coal mining. The basic characteristic of coal mining is an increasing level of hazardous mining and geological conditions which are caused mainly by mining in lower levels. This

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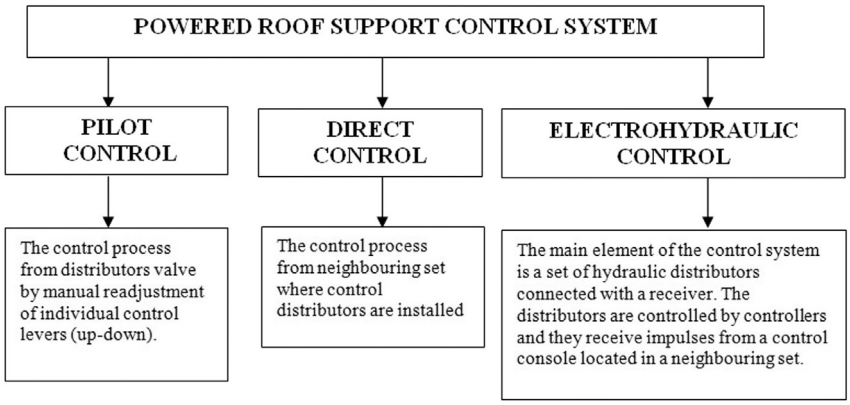

Fig. 1 – Powered roof support control system.

raises the level of mining tremors occurrences. Thus, the mines that are a part of KHW S.A. are trying to limit the number of necessary personnel working directly by operating machinery.

DOH-matic electrohydraulic control system for Glinik-12/23-POz powered roof support has been applied for the first time by KHW S.A. in KWK Murcki-Staszic – Boże Dary Mine. The control system was designed in cooperation with Elsta Company, Centre of Hydraulics DOH and University of Science and Technology in Krakow with executive work of Katowicki Holding Węglowy S.A.

The aim of the research project was to determine the capabilities of the longwall operation working in an automatic mode. The project involved a number of tests and research focused on data which would allow to design software for a powered roof support operation in a full automatic mode. Obtained data also proved the correctness of the method for roof support selection to work in given mining and geological conditions. Measurement data gathered in the system allow to conduct a number of analysis, such as pressure parameters monitoring in the under-piston compartments of hydraulic legs, operation of fast-release valves proving the proper selection of the roof support and hydraulic support in regard to given mining and geological conditions.

Such system allows using all functions required to control the powered roof support and enables to integrate it with other elements of the mining system. Moreover, the system includes full monitoring of the mining complex both, in underground excavations and at the dispatch office (Janik, Kuska, Świeczak, Wojtas, & Fitowski, 2011, 2012; Kasprusz, Mikuła, & Wojtas, 2013; Kozieł, Jasiulek, Stankiewicz, & Bartoszek, 2012; Krauze, 2007; Schaeffer, 2008).

The article provides possibilities of the longwall complex automation, including DOH-matic electrohydraulic control system designed to work with the powered roof support in mining and geological conditions of longwall 2, seam 506 K in KWK Wujek – Ruch Śląsk Mine.

2. Basic functions of the system

The electrohydraulic control system for powered roof supports has a number of advantages and positive characteristics. The research showed that the longwall equipped with the electrohydraulic control system, when its operation process is correct, has a greater level of safety than the longwall without such system. Even if the capabilities of the automation of the system are not fully used, the system is a valuable tool supporting top productive results. Such control system, however, has to be set and configured in a way allowing a steady shift from manual control to fully automatic control (Liduchowski & Wojtas, 2004; Wen & Lian, 2011).

Safety of the mining exploitation is the basic requirement that must be met by the electrohydraulic control systems. It should be done by introducing function of emergency manual control for work of a given unit directly from the electrohydraulic set. Additionally, the system should be adjusted to work in extremely difficult environment and should be protected from mechanical damage (Jaszczuk & Krodkiewski, 2001).

DOH-matic electrohydraulic control system for powered roof support units consists of a number of devices. The range of responsibility of such devices is presented in Photos 1 and 2.

These units form a unite element responsible for:

- control system of solenoid valves in the main control valve of a given unit,
- gathering of control and measurement data required to diagnose the system and data used as input data for algorithms controlling a given unit,
- user's interface for a unit's operator during manual operation, support for the unit's operator during advanced control and providing an automatic mode of control system and control of a roof support unit.

The set includes the following devices (acc. to tasks) (Janik et al., 2011, 2012; Kasprusz et. al., 2013; Kozieł et al., 2012; Krauze, 2007; Schaeffer, 2008).

- MS-01 module mounted in solenoid valve module, responsible for safety control – the unit consists, in addition to main elements, of a system responsible for feedback diagnosis as controlled by the solenoid valve,
- LR-01/*/* device used as distributor/concentrator of data from/to the set of solenoid valves. Due to module character

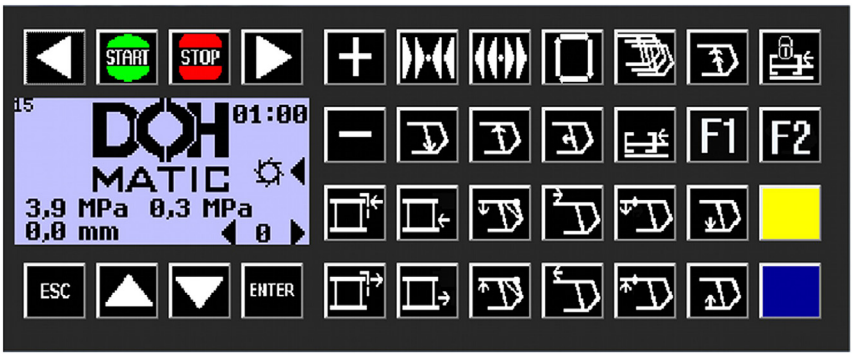

Fig. 2 – Front panel for SOZ-01/S device.

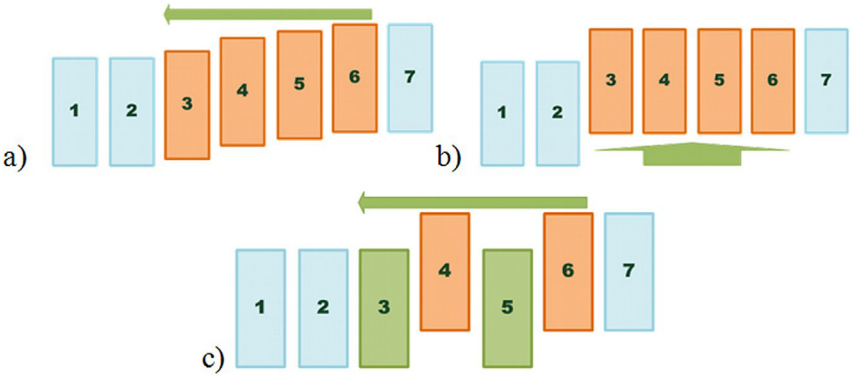

Fig. 3 – Collective control system: a) one by one, b) by a group, c) advanced by a group.

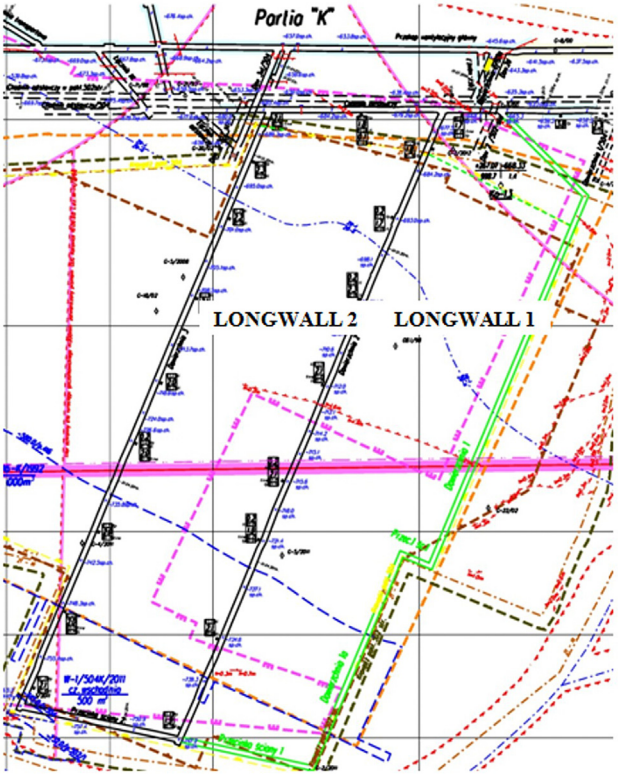

Fig. 4 – Mining conditions draft at 506 K seam with tectonics.

of the valve controlling the system, the device is available in versions that allow operation of 5–12 solenoid valves – it is possible to control up to 24 control functions,

- BP-01/*/* device responsible for gathering data from sensor located on roof support units. The device is available in version varied by number of data input, from 4 up to 8, and the location of communication connector,
- SOZ-01/S device – a controller for powered roof support. This element enables the user working in manual mode to use the control interface. The SOZ-01 controller has two functions – HMI panel (Human-Machine Interface) and a controller that controls a support unit. The panel is illustrated in Fig. 2,
- a location and pressure sensor.

Devices located in the unit are presented in Photos 1 and 2. They both form a complete set of the electrohydraulic control system. The selected task division has several advantages, such as: main valve as a separate device, lack of long, external cables connections between solenoid valves and a control elements, construction united with a solenoid valve that minimizes damages in this aspect, and a possibility of customizable positioning of devices responsible for data acquisition depending on the location of sensors on the powered roof support unit (Janik et al., 2011, 2012; Kasprusz et al., 2013; Kozieł et al., 2012; Krauze, 2007; Schaeffer, 2008).

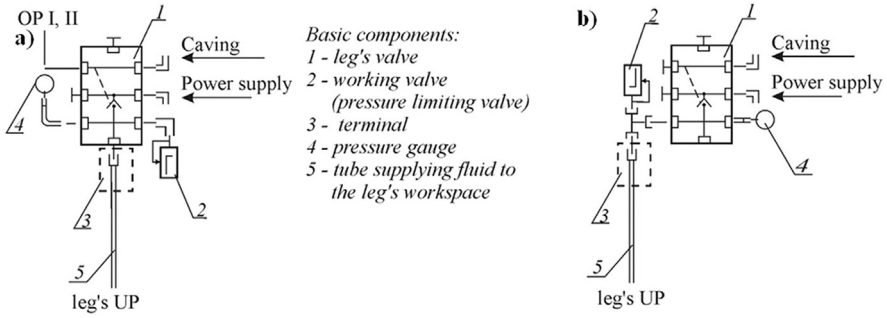

Fig. 5 – Leg control system in Glinik 12/23-POz roof support: a) for longwall 816 o KWK Murcki – Staszic b) for hazardous conditions of mining tremors – longwall 2, seam 506 K in KWK Wujek – Ruch Śląsk.

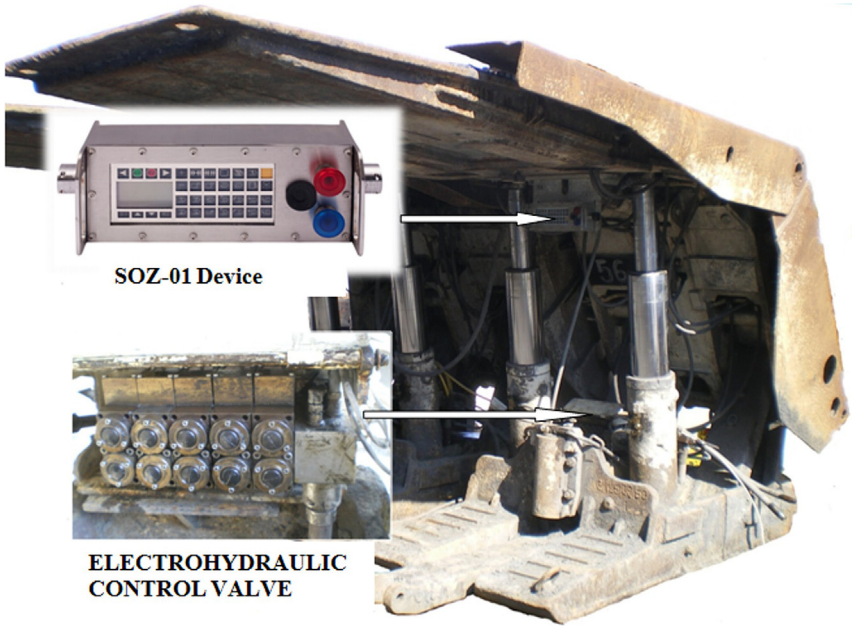

Photo 1 – DOH-matic control system set for Glinik-12/23-POz powered roof support unit.

Photo 2 – The device designed to control and gather data a) LR-01/10/CH b) BP-01/4/T.

3. Doh-matic automatics of unit operation

Presented technical scheme of the control devices for the powered roof support is the basic element of the electrohydraulic control system. According to that assumption, advanced software built into the unit helped to determine a wide range of capabilities regarding the support of operators working with powered roof supports in manual

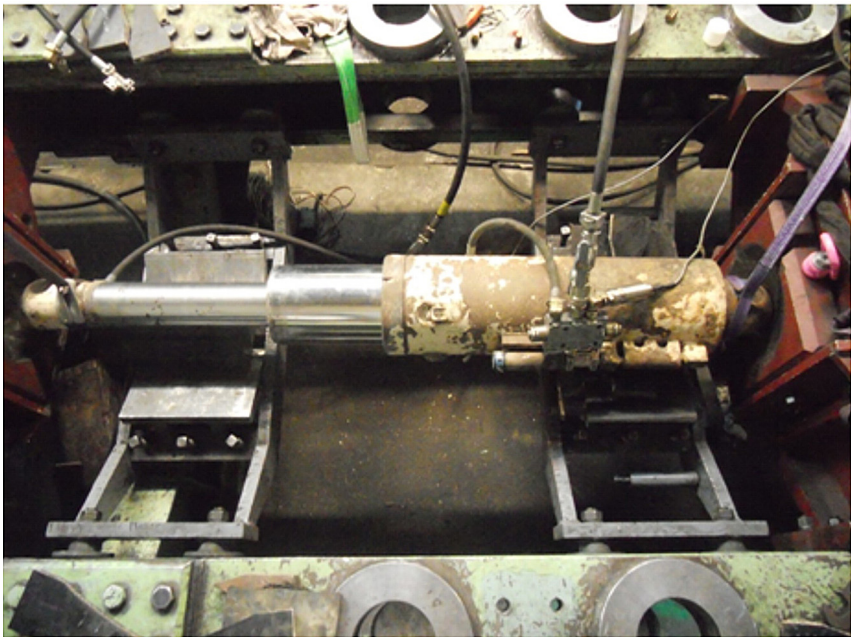

Photo 3 – Hydraulic leg Ø0.21/0.16 m installed in Glinik 12/23-POz roof support – static research test bench (GIG's Report, September, 2014).

mode, as well as during automatic operation using control system supported by individual functions of the roof support. Various requirements of the users cause that the device's front interface can be adjusted in such a way that it facilitates the work and the use of control system for a specific roof support type (Janik et al., 2011, 2012; Kasprusz et al., 2013; Kozieł et al., 2012; Krauze, 2007; Schaeffer, 2008).

The devices included in the DOH-matic electrohydraulic control system for powered roof supports enable:

- Manual control – direct control of units located in safe (customizable) distance from the release controller. The functions of the unit may be adjusted to be turned on by a switch button, turned on permanently or turned off permanently. Such configuration makes it possible to conduct most of the requirements present in the current mining method, i.e. permanent function of pushing the conveyor forward towards the shearer for seams with greater hardness.
- Supported control – control supported by data from sensors. Devices are equipped with sensors inputs which are connected by the use of configuration with current functions allowing the conduct of a given task, e.g. unit construction using a pressure sensor that ends the task when the unit reaches initial yielding capacity. Furthermore, there is a possibility to use sequential control software. An additional switch can be supported by a new defined group of tasks. The group can be defined automatically on the basis of sensors data i.e. complete unit adjustment. An example of configuration for such task is presented in Fig. 3.
- Coordinated control process. The devices facilitate amongst others: unit control one by one (Fig. 3a), i.e. to carry out given function on a set of units one by one with a support of sensors – the ending operation of one of the units starts the operation of the other unit; control system simultaneously of units in a group (Fig. 3b) that are responsible for the same task; control system in a group with restrictions e.g. alternate control where the functions are firstly carried out on even-numbered units and then on odd-numbered units (Fig. 3c).

4. Mining and geological conditions of 2/506 K longwall

The mining area outline of longwall 2, seam 506, K section is determined by: Cross heading 2, Rise gallery 2, Rise gallery 3 and end line of the longwall (Fig. 4).

Coal seam 506 in the area on longwall 2 is characterised by seam thickness of 1.35 m–2.45 m, depth of 950 to about 1030 m and inclination at about 7°.

In accordance with the description of mining and geological conditions, the roof contains of alternate layers of clump, sand shale and sandstone. Caving gobs created as a result of mining conducted in seal 504 are located 3.0–14.7 m from the roof, longwall 2. The floor contains deposits of clump. Mining works are conducted up to 160 m over the area of longwall 3 in the following seams:

- 504 – deposited in a distance of 3.0–14.7 m, caving operated at height of about 2.6 m.
- 502 floor layer – deposited in a distance of about 17.0 m, caving operated at height of about 3.0 m.
- 502 roof layer – deposited in a distance of approx. 20.0 m, caving operated at height of about 3.0 m.
- 416 – deposited in a distance of 140 m, caving operated at height of approx. 2.6 m.

So far no mining workings have been conducted in the distance of 60 m beneath the seam 506.

5. Analysis of hydraulic system in electrohydraulic control process, DOH-matic – Glinik 12/23 roof support

The roof support was acquired from KWK Murcki-Staszic where it was exploited in longwall 816 in safety conditions (lack of mining tremors hazard). The selection of the hydraulics for the powered roof support for specific mining and geological conditions is conducted individually for each longwall. It is significant to provide a protection for a hydraulic leg of a powered roof support because the leg is an element of a support system determining its safe operation.

Adaptation of Glinik-12/23-POz powered roof support designed to work in longwall 2, seam 506 K located in hazardous conditions of mining tremors in Śląsk Mine required yielding capacity assessment, in regard to Act 440 Paragraph 2 of Regulation of the Minister of Economy on Health and Safety (Walentek et al., 2014).

The assessment was used during tests carried out in the Central Mining Institute. Fig. 5 presents the tested hydraulic system. The tests included inter alia: flow requirements in the unit protecting the leg in the powered roof support and working capacity of the roof support (GIG's Report, September, 2014) (Photo 3).

6. Conclusion

DOH-matic system designed to control Glinik-12/23-POz powered roof support in mining and geological conditions of longwall 2, seam 506 K in KWK Wujek – Ruch Śląsk Mine, allowed to increase daily production and to eliminate the number of personnel from the mining area during regular exploitation. Such system perfectly fits the safety policy of Katowicki Holding Węglowy S.A. in relation to safety levels of personnel.

The control system discussed in this paper has all functions necessary in the mining process. It is integral with the whole powered longwall unit. All operations can be fully monitored in the underground excavations as well as at a dispatch office. The system provides advanced knowledge about operated longwall, used equipment, pressure magistrate diagnosis and enables detection of hazardous phenomena occurring during longwall mining.

This article presents actions taken by KWK Wujek aiming at adjusting Glinik-12/23-POz powered roof support to more hazardous conditions than estimated. After analysing the leg's hydraulic system, changes have been applied in order to protect the roof support from damage. The research determined required flow rate in the unit protecting the leg in the powered roof support and calculated working capacity of the roof support. Furthermore, the research team tested the valves limiting pressure under piston, leg's valves (check control valve), and load capacity of the leg and support of the roof-bar. These elements have been assessed in relation to their proper operation. Proposed control system has been tested in laboratory conditions and the assumptions and requirements that must be met during the selection of powered roof support for hazardous conditions of mining tremors were assessed as proper.

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