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MONITORING THE OPERATIONAL PARAMETERS OF A POWER ROOF SUPPORT

Key words: coal mining industry, longwall system, powered roof support, automation, monitoring, pressure measurement, geometry measurements.

Abstract: Safety aspects of mining personnel as well as the safety of the coal mining processes are presented. A mechanised longwall system is commonly used in the coal mining industry. The system consists of the basic machinery, such as a shear loader, an armoured face conveyor, and a powered roof support, which protects the roof of workings. The powered roof support consists of hydraulically or electro-hydraulically controlled units, equipped with pressure sensors placed in different parts of the hydraulic system and displacement sensors for the selected actuators. Projects related to the automation of roof support operation and the monitoring of its parameters are currently being undertaken.

Analysis of available solutions concerning the controlling and monitoring of the roof support with special regard to pressure measurement in a prop and roof support geometry measurement is presented. Existing solutions are described and KOMAG development directions for parameter monitoring systems of roof support operation in terms of personnel and technical safety are indicated. The paper discusses work realised within the framework of PRASS III "Productivity and safety of shield support" project, co-financed by Research Fund for Coal and Steel (RFCS).

Monitorowanie parametrów pracy górniczej obudowy zmechanizowanej

Słowa kluczowe: górnictwo, kompleks ścianowy, obudowa zmechanizowana, automatyzacja, monitorowanie, pomiar ciśnienia, pomiar geometrii.

Streszczenie: W artykule przedstawiono aspekty bezpieczeństwa załogi górniczej oraz bezpieczeństwa technicznego procesu wydobywczego węgla kamiennego. Wydobycie węgla kamiennego realizowane jest najczęściej z wykorzystaniem ścianowego kompleksu zmechanizowanego. W skład kompleksu wchodzą maszyny podstawowe, takie jak kombajn ścianowy, przenośnik ścianowy oraz obudowa zmechanizowana, zabezpieczająca strop wyrobiska. Obudowa zmechanizowana składa się z sekcji, które są sterowane hydraulicznie lub elektro-hydraulicznie i wyposażone są czujniki ciśnienia w wybranych miejscach układu hydraulicznego oraz czujniki przemieszczeń wybranych siłowników. Obecnie podejmowane są prace związane z automatyzacją pracy obudowy oraz monitorowaniem jej parametrów.

W artykule przedstawiono analizę dostępnych rozwiązań z zakresu sterowania i monitorowania obudowy, ze szczególnym uwzględnieniem pomiaru ciśnienia w stojakach podporowych oraz pomiaru geometrii sekcji obudowy. Przedstawiono istniejące rozwiązania oraz wskazano na realizowane przez ITG KOMAG kierunki rozwoju systemów monitorowania parametrów pracy obudowy w kontekście bezpieczeństwa ludzi oraz bezpieczeństwa technicznego. Artykuł opisuje prace realizowane w ramach projektu PRASS III „Productivity and safety of shield support" współfinansowanego przez Europejski Fundusz Węgla i Stali.

Introduction

The longwall system is one of the main mining systems. In this system, mining operations are realized by a mechanized longwall complex consisting of three main machines: powered roof support, longwall shearer, and AFC. The protection of machines and the mining team working in the longwall panel is the main function of the powered roof support [1, 2, 3]. Advances in the automation of the longwall mechanized system does not include monitoring of the roof behaviour and the prediction of uncontrolled phenomena, such as roof caving or uncontrolled roof fall, resulting from cooperation of rock mass with the roof support. Currently installed systems monitoring the operational parameters of a powered roof support consist mainly of pressure sensors; however, data obtained from these systems are not useful for the analyses of the current condition of the roof. Roof caving within the longwall outline as well as uncontrolled behaviour of the roof out of the roof support poses a hazard to the workers life and health due to the technical condition of the machine.

In 2017, KOMAG started the realization of PRASS III (Productivity and safety of shield support) project. The project is co-founded from the Research Found for Coal and Steel (RFCS), and it is realized by the international consortium of the companies from Poland, Germany, Great Britain, and Spain. Development of the measuring system for powered roof supports and the system for roof fall prediction is the main project objective.

1. Productivity and safety of shield support

In the Polish mining industry, powered roof supports are not monitored, unlike other machines of the longwall system, but the safety and efficiency of mining operations depend to a high degree on proper operation of roof supports. Longwall shearers are equipped with advanced control and diagnostics systems with thermovision [4] and vibro-diagnostics [5] systems. AFCs are equipped with adaptive control systems adjusting speed to the machine load as well as with automatic tensioning systems [6]. Examples of a powered roof support designed by ITG KOMAG and produced by HYDROMEL are presented in Fig. 1.

Fig. 1. HYDROMEL-16/34-POz and 16/35-POz powered roof support [3]

Aspects of the cooperation of powered roof support with the rock mass affecting roof stability have a significant impact on the effectiveness and safety of mining operations in hard coal mines. The distance of near-face path, hydraulic feeding, control method, as well as cutting height have an impact on roof stability [7].

There are different forms of roof stability loss in the cave-in longwall (Fig. 2) [8]. If, as a result of roof stability loss, there are no chances for bringing back the working's original functions within 8 hours, the case is defined as a roof fall [8].

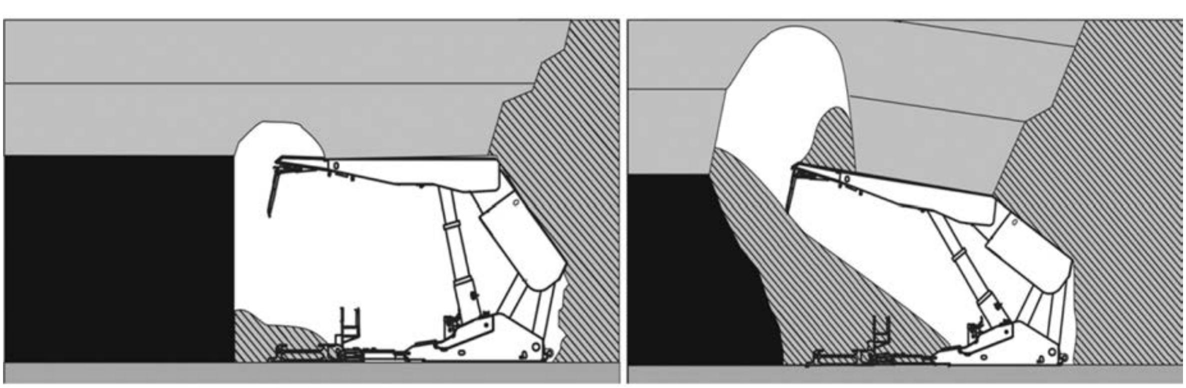

Fig. 2. Different forms of roof stability [8]

A review of branch literature indicates that the monitoring of main operational parameters of roof support in the aspect of its cooperation with rock mass and other machines of the longwall system is justified. The initial load-bearing capacity in relation to the pressure required during the roof support setting for load is one of key parameters conditioning proper operation of the roof support. The hydraulic leg is one of the main components of a powered roof support [9–11]. Its operational parameters determine the load-bearing capacity of the support. The leg is a double-acting cylinder, which a range of operations that covers pressing – bearing.

The initial load-bearing capacity affects the entire operational cycle of the powered roof support as well as the ability of transferring the loads. As mentioned in [12], on the basis of conducted investigation in two caving longwalls, the roof supports were not properly set to load in some regions of the longwall, and initial load-bearing capacity was not achieved. The tests were conducted with use of a wire measuring system, and the sensors were installed in under-piston areas of the hydraulic legs. The necessity of the improvement of measuring technology towards better reliability is one of conclusions drawn by the author. The presented results of work indicate problems with the system cabling.

In [13], the author indicated that improper setting to load causes the roof support to experience asymmetric load to the hydraulic legs in each roof support. This results from random setting the load of the neighboring roof support to the tested roof support.

The author of [14] also indicates the necessity of monitoring the pressure in roof support legs. The presented software enables the prediction of roof fall in the area of the longwall panel. The computer software accomplishes this on measuring the pressure in the legs.

In the world, many research projects associated with modelling the behaviour of powered roof supports and roofs are realized. The modelling is conducted on the basis of real data recorded during the cutting process or on the basis of theoretical assumptions [7, 15]. The results of modelling work clearly indicate that proper operation of a powered roof support is critical regarding coal mining effectiveness and safe operation. It also indicates that supporting the operator and the elimination of human error is only possible through monitoring the main operational parameters of the roof support and by analyses of time trends and changes of measured parameters.

2. Systems for measuring the operational parameters of roof support

There are measuring systems enabling the measurements of the roof support selected parameters on the market. The systems have different functionalities. They differ in technical solutions in the scope of the data transfer method and the feeding systems. Analysis of the existing solutions indicates that wire and wireless systems for measuring the pressure in legs are available. Pressure measurements are used in the control of roof support load-bearing capacity as well as the verification of selecting the proper roof support to the current mining conditions [16]. In the scope of measurements of roof support geometry, the wire systems are available.

2.1. Measurement of pressure in roof support legs

The control system installed in the legs determines the method of pressure measurements. In the case of electrohydraulic control, the wire pressure sensors connected to the control system are used. Information about the pressure is transferred to the dispatcher room through the control communication system, and it can be further processed. Such functionality is secured by DOH-matic systems of the DOH Hydraulic Centre [17], Tiefenbach systems [18], as well as the RS20S Faceboss system made by JOY [19]. In Poland electrohydraulic control is rarely used, due to high price of the system. Hydraulic control is an option; however, in this case, there is no communication infrastructure. Wireless pressure measuring systems with battery powered sensors are used in such a situation. EH-PressCater pressure monitoring systems made by Elgór Hansen [20] as well as the FAMAC RSPC II system made by FAMUR (Fig. 3) [21] enable wireless data transfer between the pressure sensors. Wireless sensor networks are equipped with self-organizing algorithms, which enable network reconfiguration in the case of changes in machine arrangements or failure in selected nodes [22].

Fig. 3. FAMAC RSPC II pressure monitoring systems made by FAMUR [21]

The X-MAN system developed by ITE EMAG [23] (Fig. 4) enables measuring pressure in the legs of powered roof supports. The bottom part of the system is of anti-explosion and intrinsically safe manufacture. The sensors are cable powered, and data transmission

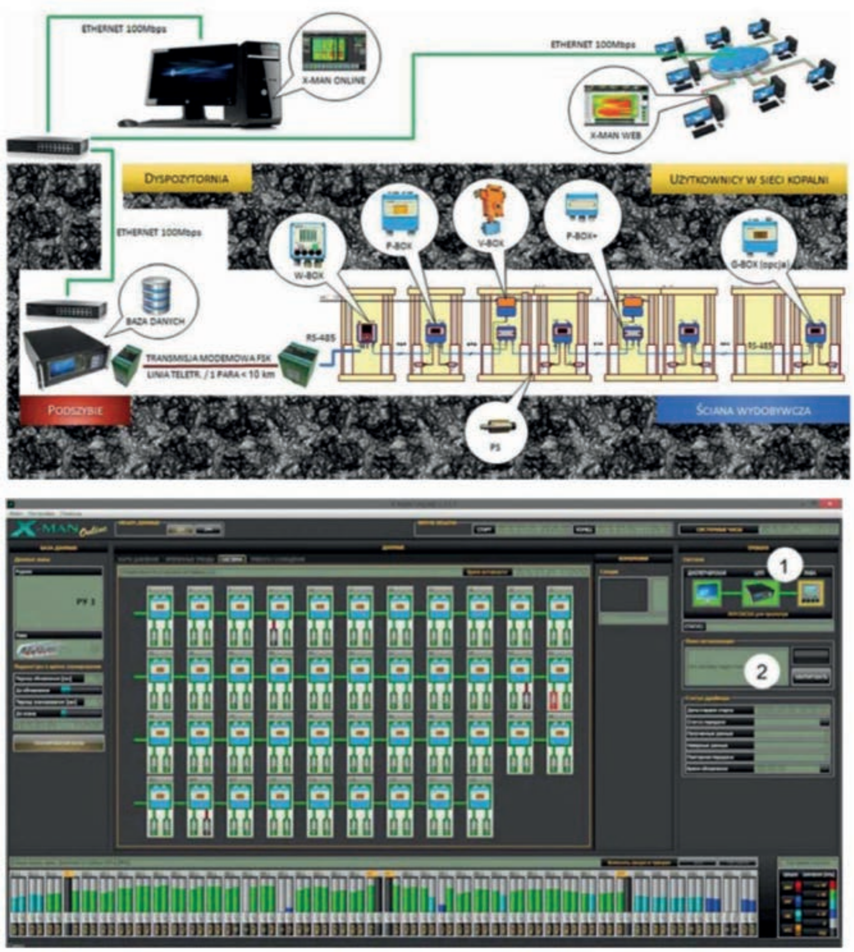

Fig. 4. System X-MAN: Block diagram and the window of visualisation system [23]

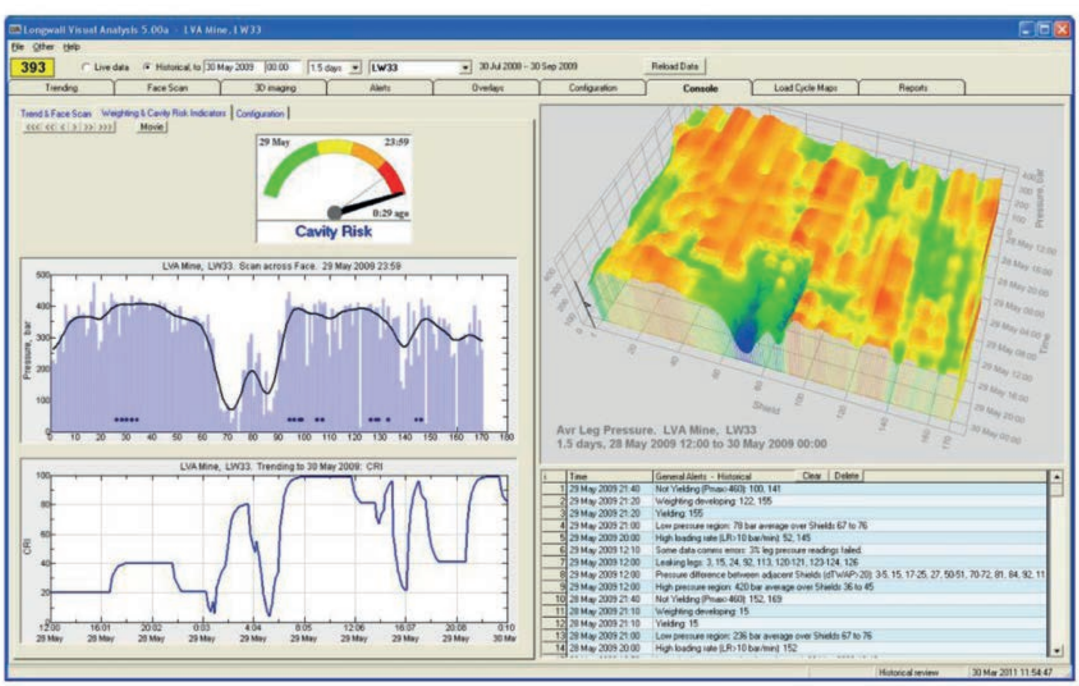

Fig. 5. LVA software [14]

is also realized by cable transfer. The system enables the transmission of data to the surface as well as local visualization using optical signallers. The system is dedicated for static pressure measurements in legs in under-piston areas. The system was implemented in a Belarus potash mine.

LVA software presented in [14] is used for the calculation of Cavity Risk Index (CRI) on the basis of information about the pressure in the legs of the powered roof support. The index indicates the likelihood of roof fall danger in the longwall panel. In [24], the methods for pressure analysis in the legs of a powered roof support are presented. In the analyses, the authors considered pressure in legs and roof falls during mining operations in the longwall panel. The analyses were made with use of LVA software (Fig. 5).

2.2. Measurements of powered roof support geometry

Measurements of the powered roof support geometry were taken for the purpose of research work with the use of instruments that did not meet the requirements of ATEX Directive [25] as well as for the purpose of the automation of longwall system operation. Inclinometers are used (among others) for measurements of face front shield inclination, and they are part of the system for the elimination of collision between the longwall shearer and the roof support. Measurements of roof support geometry were taken by manufacturers with use of inclinometers, but they did not reveal the functionality of such a measuring system.

3. Concept of the measuring system

At present, progress in the field of the automation of longwall systems does not include monitoring of roof behaviour and preventing disadvantageous phenomena associated with roof behaviour, such as roof falls to the longwall face or the lack of roof fall beyond the shield support. The development of the Shield Support Monitoring System (SSMS), which will enable monitoring of the roof condition in real time, by monitoring the parameters of shield support, as well as development of Longwall Mining Conditions Prediction System (LMCPS) for the prediction of roof falls hazards and the generation of information about indispensable corrective measures, is the PRASS III project objective [26].

3.1. Shield Support Monitoring System (SSMS)

The Shield Support Monitoring System (SSMS) will consist of geometrical parameters of the shield support, hydraulic pressure parameters, tip to face distance, and a new wireless communication system. SSMS will enable monitoring and recording the roof support operational parameters in real time, and it will be the basis to develop the Longwall Mining Conditions Prediction System (LMCPS). Regarding the monitoring of geometrical parameters of powered roof supports, SSMS will include a set of sensors enabling the determination of the absolute position of each component of a powered roof support. All devices of the SSMS have to meet the requirements of the ATEX Directive.

The new underground communication system meets the agreed requirements regarding band width and flexible configuration, which is indispensable for the collection of a large amount of data. From conducted analysis, wireless transmission appears to be the most appropriate method for data transmission in underground conditions of mechanized systems.

3.2. Longwall Mining Conditions Prediction System (LMCPS)

It is assumed that, by monitoring both shield support behaviour (leg pressures, geometry and tip to face distance) and geotechnical conditions in a longwall in real time, warnings can be given several hours in advance for significant improper shield support behaviour and the formation of roof instabilities, such as roof cavities/falls or shield closure. This advance warning allows miners to take preventive action (such as improvement of roof strata stability by injections or improvement of the shield support behaviour by increasing or decreasing leg pressure, the change of shield geometry, etc.), which in turn can reduce longwall downtime and hazards.

The system called Longwall Mining Conditions Prediction System (LMCPS) will utilize data from the shield support monitoring system and inform shield support operators and geotechnical engineers about any deterioration in longwall performance. It is intended that LMCPS will give an easily readable interpretation of results in the form of graphs and alerts/comments displayed on the PC computers.

Conclusions

Review of available solutions regarding the measurements of operational parameters of powered roof supports, especially pressure measurements in hydraulic legs and the geometry of the roof support, has been presented. However, the systems available on the market do not ensure full functionality required for the development of computer programmes for the prediction of roof caving in difficult mining and geological conditions. The presented review of the solutions provided a basis for the determination of guidelines for the development of the Shield Support Monitoring System (SSMS).

The suggested measuring system should include measurements of pressure in the legs, the measurement of roof support geometry, and the measurement of near-face path. The system should be of modular design and should be powered by batteries. Data exchange will be realized wirelessly.

The literature analyses indicates that it is necessary to develop the measuring system which will cooperate with the control system. The measuring system will be the basis for the development of the system for the prediction of roof fall.

On the basis of the presented concept, the measuring and communication system as well as the system for data collection and analyses will be developed. Implementation of the system in mines will improve work safety, technical safety, and will enable increasing the mining output by proper cooperation of roof support with rock mass.

The presented scope of work is realized within the PRASS III (Productivity and safety of shield support) project.

PRASS III project

The presented scope of work is realized within the PRASS III (Productivity and safety of shield support) project. The project is realized by an interdisciplinary and international consortium consisting of the following organizations: Instytut Techniki Górniczej KOMAG (coordinator), Becker Warkop Ltd. Company, Główny Instytut Górnictwa GIG, Jastrzębska Spółka Węglowa S.A., DMT GmbH & Co. KG, and Geocontrol, University of Exeter.

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