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MONITORING OF THE MINING POWERED ROOF SUPPORT GEOMETRY

Abstract: The paper presents the results of research on the geometry measurement system of a powered roof support using inclinometers that meet the requirements of the ATEX directive. Coal mining is most often carried out using a mechanized longwall system. The longwall system includes basic machines, such as a longwall shearer, a longwall conveyor, and a powered roof support that secures the roof of the excavation. The powered roof support consists of sections that are hydraulically or electro-hydraulically controlled and are equipped with pressure sensors in selected places of the hydraulic system and displacement sensors for selected actuators. One of the challenges associated with controlling and monitoring the parameters of the powered roof support section is the mapping of its geometry and mutual arrangement of individual components. KOMAG Institute of Mining Technology has designed and made a geometry monitoring system based on inclinometers that meet the requirements of the ATEX directive. System tests were carried out on a real object in laboratory conditions. As a result of the research, the influence of the structure of the powered roof support on the accuracy of geometry measurement and mapping was determined. The results of the tests will be used during the implementation of the system in real conditions.

Monitorowanie geometrii górniczej obudowy zmechanizowanej

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

Streszczenie: W artykule przedstawiono wyniki badań systemu pomiaru geometrii sekcji obudowy zmechanizowanej z wykorzystaniem inklinometrów spełniających wymagania dyrektywy ATEX. 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 elektrohydraulicznie i wyposażone są w czujniki ciśnienia w wybranych miejscach układu hydraulicznego oraz w czujniki przemieszczeń wybranych siłowników. Jednym z wyzwań związanych ze sterowaniem i monitorowaniem parametrów sekcji obudowy zmechanizowanej jest odwzorowanie jej geometrii i wzajemnego ułożenia poszczególnych podzespołów. W tym celu w Instytucie Techniki Górniczej KOMAG został zaprojektowany i wykonany system monitorowania geometrii, bazujący na inklinometrach spełniających wymagania dyrektywy ATEX. Badania systemu przeprowadzono na obiekcie rzeczywistym w warunkach laboratoryjnych. W wyniku przeprowadzonych badań określono wpływ konstrukcji sekcji obudowy zmechanizowanej na dokładność pomiaru i odwzorowania geometrii. Wyniki przeprowadzonych badań zostaną wykorzystane w trakcie implementacji systemu w warunkach rzeczywistych.

Introduction

The longwall system is one of the main highly advanced mining systems in the hard coal mining industry. Coal production in this system is realized by the mechanized longwall system consisting of the following three main machines: powered roof support, cutting machine, and armoured face conveyor. Protection of working people and the operating machines is the main function of the powered roof support [1–6]. Advancements in automation of the longwall systems rarely includes monitoring of the roof behaviour and the prediction of not controlled phenomena resulting from action of the rock mass on the powered roof support such as rock fall in the area of the longwall face.

At present, the systems for monitoring the parameters of the powered roof support are mainly the pressure sensors, but information collected from these systems is not enough for analysis of the roof condition.

In 2017, KOMAG Institute of Mining Technology started the realization of PRASS III (Productivity and safety of shield support) project [7]. The project is co-financed from the Research Fund for Coal and Steel (RFCS) as well as from the Ministry of Science and Higher Education. The project is realized by an international consortium consisting of the companies from Poland (Main Mining Institute, KOMAG Institute of Mining Technology, Jastrzębska Coal Company S.A., Becker Warkop Sp. z o. o.), from Germany (DMT GmbH & Co. KG), Great Britain (University from Exeter), and Spain (Geocontrol S.A.). Development of the measuring system dedicated to powered roof supports and the system for rock fall prediction is the main project objective. The interdisciplinary consortium is composed of an organization that designs and manufactures the powered roof supports, including The Institute of Mining Technology, engineering companies involved in the mining industry, the manufacturer of mining machines and electronics, and mining enterprises.

In the Polish mining industry, the powered roof support is rarely monitored in relation to other machines of the longwall system, but mining effectiveness and safety mainly depend on the roof support. The problems associated with the cooperation of rock mass with the powered roof support, i.e. proper protection of the roof, have a significant impact on safe mining operations in hard coal mines. Among others, the width of near-face path, the load-bearing parameters of the powered roof support (initial load-bearing capacity and working load-bearing capacity), the control system, and the cutting height affects roof stability [8].

In the world, many research projects on modelling the behaviour of the system made of the powered roof support and roof are realized. The modelling is carried out based on real data recorded during mining or by using the theoretical assumptions [8, 9]. Results of the modelling process univocally indicate that proper operation of the powered roof support is indispensable for effective and safe mining operations. Supporting the operator and prevention against possible mistakes of the operator is only possible when the main operational parameters of the powered roof support are monitored and trends of their changes are analysed in a real time.

1. Prass III Project's objective

Improvement of safety and mining effectiveness of the mechanized longwall systems by a development of a comprehensive monitoring system and by a control of power roof support operation (monitoring the operational parameters in a real time) as well as the system for prediction of hazards resulting from cooperation between the rock mass and the roof support is the main project objective. The detail objectives are as follows: the development and manufacture of a Shield Support Monitoring System (SSMS) which includes the following:

- The geometric features of the powered roof support, its load-bearing parameters, the distance of the roof support from the longwall face (near-face path) and the communication system;
- The development of the methods for proper roof maintenance;
- Deepening the knowledge on stresses distribution in the roof of longwall panel and on roof falls;
- The determination of relationship between the roof behaviour and occurrence of the events dangerous to human health and life as well as to the mine technical equipment;
- The correlation of historic measuring data with information about dangerous events associated with the longwall roof; and,
- The development of the system for the prediction of hazards resulting from cooperation between a powered roof support and rock mass (Longwall Mining Conditions Prediction System – LMCPS).

It was assumed that monitoring and analysis of powered roof support's operational parameters in real time using SSMS enables predicting the hazards associated with the fall of roof rock.

2. Shield support monitoring system – SSMS

The basic measurements necessary to monitor the Shield Support parameters enables the determination of its position in the space. To determine the position of each roof support component, it is necessary to measure the relative angles between the mobile section units and the geometrical dimensions. To take the necessary measurements, inclinometers can be used. The modular Shield Support Monitoring System should be made as intrinsically safe devices of type "ia" according to the ATEX directive [10] and the harmonized standards. Another requirement is to use wireless data transmission between the shield supports [11]. This solution eliminates the problems with wired connections, which are vulnerable to damage. SSMS will be dedicated for cooperation with the wireless communication system, where the wireless pressure sensors are the main nodes. The wireless communication system will be developed by Becker Warkop within the PRASS III project.

The initial analysis of wireless data transmission has shown that it is reasonable that all inclinometers on the shield support (the minimum number of inclinometers

per one shield support is 3 and maximum number is 6) are connected to one wireless communication module. Figure 1 presents a block diagram of the proposed system for monitoring the Shield Support.
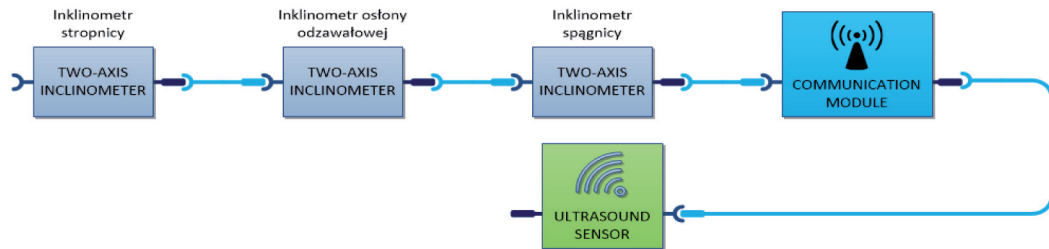
The ultrasound sensor shown in Fig.1 will be used for the measurement of the near-face path, which is the parameter indicating the distance of the canopy end to the longwall face. This sensor was not tested during the tests described in the further parts of the article.

Fig. 1. Block diagram of the modular Shield Support Monitoring System

2.1. Two-axis inclinometer

The new two-axis inclinometer, which meets the requirements of ATEX Directive and the application functional requirements, was developed in KOMAG. The module is equipped with intrinsically safe circuits supplying the module and data transmission systems in the MODBUS RTU format. The module is equipped with two connectors – one input and one output.

The assumption for the unification of the mechanical structure of inclinometers required the analysis of the method of their installation on the powered roof support. After several attempts, the option

with the unsymmetrical measuring range in the X axis was chosen. After the diagonal installation of the PCB (Fig. 2), the inclinometer acquired the following measuring ranges: Axis X – -60° to +120°; Axis Y – -90° to +90°.

After start-up and initial testing of one inclinometer, three more were made in order to prepare them for the functional tests. Inclinometers will be used to verify their arrangement on the powered roof support. The inclinometer enclosures were made using a 3D printer and attached to powered roof support by magnets. Figure 3 shows four inclinometers connected with each other and prepared for the functional tests.
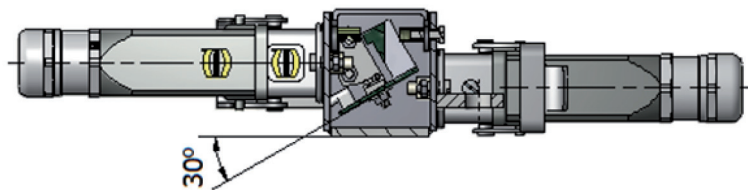

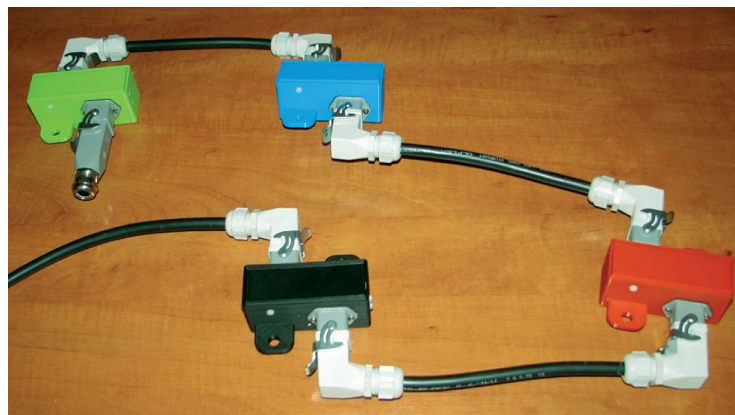**Fig. 2. Angular position of the printed circuit board**

Fig. 3. Four inclinometers connected with each other

Inclinometers are connected in series using the MOBUS RTU protocol. This solution simplifies electrical connections and the configuration of the measuring system. Each inclinometer has their own numbers, which allow one to unequivocally determine the place of their attachment.

3. Tests

KOMAG started the tests on SSMS-I inclinometers. The research project was carried out in two stages. At the first stage, a single inclinometer was tested. The tests were carried out on a calibration table (Fig. 4) available in KOMAG. The tests aimed at determining the correctness of the inclinometer's indications.
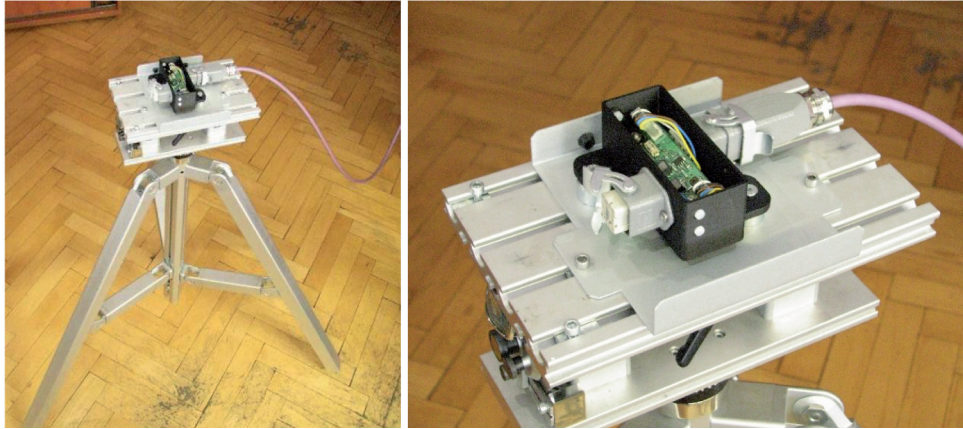

Fig. 4.   Calibration of the SSMS-I inclinometer

The next stage of the research concerned the communication system between the inclinometers. These tests were carried out without the central unit and the wireless communication system. During the tests, inclinometers were connected directly to a PC, and the measurement results were recorded on specially developed test software.

The next stage of functional tests consists of equipping an exemplary test shield support in the shield support fatigue testing stand for the, which KOMAG has at its disposal.

A JZR 13/28 POZ shield support was tested (Fig. 5). Inclinometers were installed on the shield support using

Fig. 5.   JZR 13/28 POZ shield support

the magnetic catches. Four inclinometers were installed – on the base, on the canopy, on the gob shield and on the lemniscate link. Places of the inclinometers installation are presented in Fig. 6. Data from the inclinometers were recorded using the computer programme developed

specially for the tests. Sampling frequency was 500 ms.

Figure 7 presents the course of angle changes of shield support elements. The angle of base was not shown on the graph, because the shield support stood

Fig. 6.   Places of the inclinometers installation: a) canopy, b) base, c) lemniscate link, d) gob shield
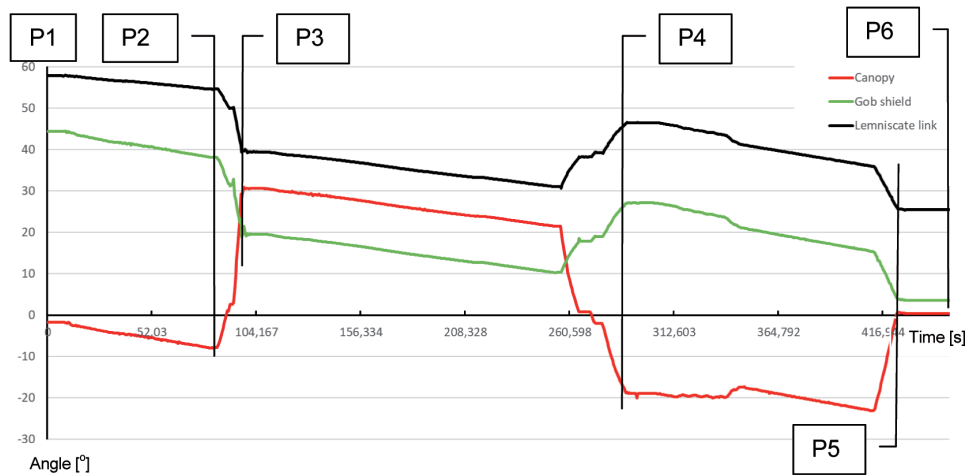

Fig. 7.   Data recording from inclinometers

on a stable ground and the angle did not change during the tests. Under real conditions, the housing can stand on unstable ground and the position of this element changes. Points P1 to P6 correspond to the items shown in Fig. 8. During the tests, the shield support geometry was changed from the maximum (P1) to the minimum position (P6). During the movement, extreme positions of the canopy were also achieved (P3 and P4).

The conducted tests confirmed the correct operation of the SSMS system, which were designed in accordance with the requirements of the ATEX directive. The next step will be to make the prototype and install it in real conditions. The tests of the influence of clearances in structural nodes on the accuracy of the measurement system will also be carried out.
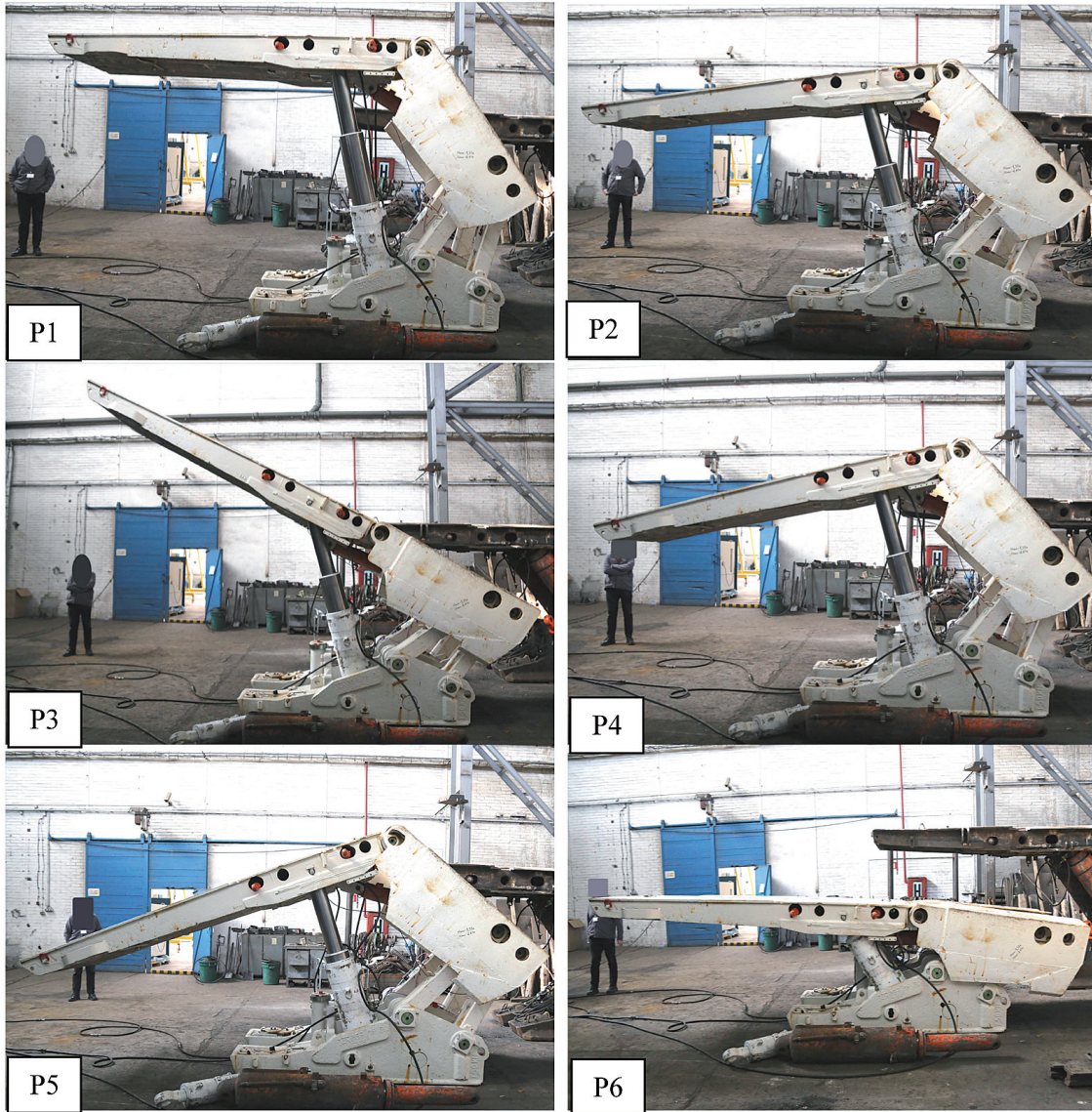
Fig. 8.   Position of shield support during the tests

Summary

It was assumed that monitoring and analysis of powered roof support's operational parameters in real time using SSMS enables predicting the hazards associated with the fall of roof rock. The KOMAG Institute of Mining Technology has designed and made a geometry monitoring system based on inclinometers that meet the requirements of the ATEX directive. System tests were carried out on a real object in laboratory conditions. The conducted tests confirmed the correct operation of the SSMS system. The next step will be to make the prototype and install it in real mining conditions. The tests of the influence of clearances in structural nodes on the accuracy of the measurement system will also be carried out.

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