

Wireless control and directional navigation of a roadheader in drilling process

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Abstract: Careful observations of the global mining industry development trends, in terms of the needs and expectations of mining machinery and equipment, led the Institute of Innovative Technologies EMAG to undertake work to introduce innovative solutions in the new diagnostics and control system for road headers. In this paper we will discuss new wireless control system and extensive diagnostics of the machine, based on the SKD-2M system, with an innovative solution for directional navigation of excavation axis of road header. Solution used in the SKD-2M with technologies for monitoring stroke fore and guiding roadheader, will increase the capacity of the machine utilization, by increasing the degree of automation and prediction parameters of drill machine corresponding to the momentary conditions of mining. System will also limit damage resulting from improper use, reduce energy consumption in mining process, improve safety and will affect positively the efficiency of roadways drill, which is important, in relation to the prospects of the application of the system to eastern markets.

Keywords: roadheader, control, wireless, drilling, diagnostic system

1. Introduction

MAKS-DBC control system implemented in 2007 by the Institute of Innovative Technologies EMAG gained recognition and has been applied in a number of longwall coalcutters, domestic and foreign. Constant technological development and the increasing emphasis on improvement in the health and safety of people, especially in areas with the highest risks and danger of accidents, which no doubt is the mining fore, were a prerequisite to work on a new control and diagnostics system for roadheader. Not all light and medium class roadheaders currently operated for the drilling of roadways have developed intelligent control systems and diagnostics. Despite constant development of machinery for mining, a significant amount of medium class roadheaders does not have a system monitoring and guiding the excavation machine, as well as providing full safety in the event of ejection of rocks and gases [1]. Use of the remote control combined with wireless methanometers with on-line measurement, and increase in the degree of automation combined with prediction of parameters of the machine corresponding to momentary conditions of mining, enables: increase in the capacity of machine utili-

zation, mitigation of damage resulting from improper use, reduction in the energy intensity of mining process and improvement in safety at a mining fore, thereby supporting the effectiveness of roadways drilling.

SKD-2M is a wireless control and diagnostics system with an innovative solution that enables directional navigation of excavation axis of roadheader. The concept of the SKD-2 [2] is based on a dispersed structure of mutually connected functional blocks (modules), each of them carrying the control and diagnostic functions. The designed system is the so-called open system, both in terms of hardware and software. High processing power of the system allows use of data processing algorithms for control and diagnostics of high numerical complexity. In order to extend functionality of the SKD-2 system, we cooperated with the “Zakład Montażu Urządzeń Elektronicznych” – Department of Assembly of Electronic Equipment, which is the manufacturer of “Monitoring System of road header’s cutting head – MINOS-2”. Integration of the SKD-2 and MINOS-2 systems led to the latest version of wireless control and diagnostic system SKD-2M, which provides laser positioning of the road header [3].

2. Description of functionality of the system

The SKD-2M system is intended for use in the roadheader working in the excavation of “a”, “b” and “c” methane explosion hazard. Basic functions performed by the SKD-2M include:

- local control using Operator’s Panel PAK-1;
- wireless control of machine using the Remote Control Panel RSO-CH;
- monitoring the performance of specific components of the machine by means of a number of sensors;
- monitoring the cutting head position relative to the roadheader or pavement;
- monitoring longitudinal and transverse position of the machine relatively to the ground;
- monitoring the position relatively to pavement axis;
- diagnostics of individual components of the machine;
- visualization of the state of the machine on the LCD;
- indication of the approach of the cutting head to the border of the stroke;
- faults detection and informing the user about their appearance;

- internal communication through fast and reliable CAN 2.0 interface, optional RS-485 with Modbus RTU protocol;
- visualization of the roadheader's state on the surface.



Fig. 1. Display screen – MINING

Rys. 1. Plansza z ekranem – URABIANIE

As already mentioned, the SKD-2M system has the structure of a distributed system. This solution provides an easy and inexpensive way to set up the system and

implement it in any type of light and medium class road header. In the operator's cabin, on the LCD, you can select the board "mining" (fig. 1), which displays the selected profile of excavation and the current position of the cutting head relative to the profile. Approach of the cutting head to the border of the stroke is indicated by change in graphics colour. The movement in the critical direction is stopped, which allows for precise and safe dredging. The benefits of this system are: voids minimization in the mining excavation, gunning with nearly constant thickness, but most of all the remote control [4].

3. Structure and working principle of the SKD-2M System

System structure has been shown in fig. 2. Basic functional blocks of the SKD-2M System include:

- operator's panel PAK-1, which consists of:
 - MOP-1 module,
 - BKP-i module,
- operator's devices RSO-CH, RSO-27, MOJ-1, PUS-10,
- visualization devices MLCD-1 or Pop-1,
- actuation devices BSHkm, BSP-i, EE-1,
- devices of MINOS-2 System,
- sensors and measuring transducers.

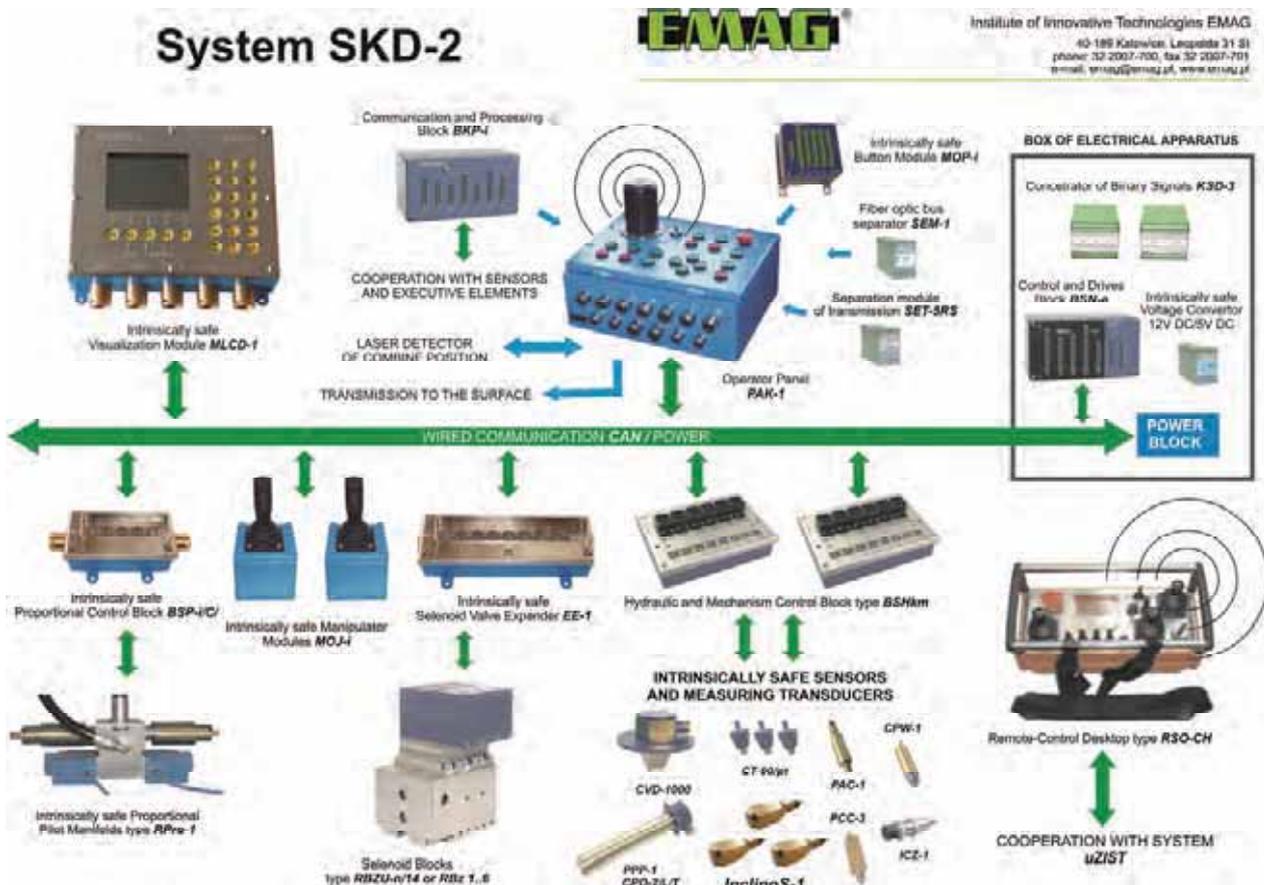


Fig. 2. SKD-2 system structure

Rys. 2. Struktura systemu SKD-2

3.1. Operator's panel PAK-1

The operator's panel PAK-1, shown in fig. 3, acts as a central controller of the roadheader, whose main task is to directly control the operation of the machine. Software modules support the following panel control buttons: drive the cutting head, dust collector, sprinkling, hydraulics, feeder, conveyor and driving. The panel controls indications of the system bus and the Bluetooth wireless connection. The device indicates malfunction by the audio signal.



Fig. 3. Operator's panel PAK-1

Rys. 3. Panel Kontrolno-Sterujący PAK-1

The panel consists of:

- communication and processing block – BKP-i,
- buttons module – MOP-1,
- control buttons,
- mode switch (local – wired or remote),
- emergency stop button,
- directional antenna with cover.

3.1.1. Communication and Processing Block BKP-i

Block of communication and data processing BKP (fig. 4) is the central unit designed for use in multi-module systems control and operation of machinery.

The device is equipped with a powerful microcontroller, memory chips and integrated I/O to ensure cooperation between other devices included in the combine control and diagnostics system.



Fig. 4. Communication and processing block BKP-i

Rys. 4. Blok komunikacji i przetwarzania danych BKP-i

The priority tasks of the unit are: control of data transmission between modules connected to the CAN serial bus (optional RS-485), recording data on the local machine memory, and providing radio communications.

3.1.2. Buttons Module MOP-1

Buttons module MOP-1 (fig. 5) allows controlling the mining combine using switches and keyboard located in desktop on the machine. Additionally, it can control outputs (LEDs, lights control). The device transmits data using CAN or optional RS-485 interface.



Fig. 5. Buttons module MOP-1

Rys. 5. Moduł przycisków MOP-1

3.2. Remote-control panel RSO-CH

Remote-control panel RSO-CH, shown in fig. 6, is designed to radio control the mining combines. The device communicates wirelessly with the panel PAK-1 in the 2.4 GHz frequency band. The panel is equipped with three manipulators, which enable driving and moving the organ, and 8 switches with programmable functions. RSO-CH has an LCD screen, which displays parameters, condition of the machine, information and alarm.



Fig. 6. Remote-control panel of RSO-CH type

Rys. 6. Pulpit zdalnego sterowania typu RSO-CH

3.3. Display module MLCD-1

Display module MLCD-1 (fig. 7) has a colour LCD screen, 5.7 inch, which allows to present parameters of the combine and its components. Using the keypad we can set all control parameters. Information about each parameter is transferred by two-way CAN communication interface.



Fig. 7. Intrinsically safe display module MLCD-1
Rys. 7. Iskrobezpieczny Moduł Wyświetlacza MLCD-1

3.4. MINOS-2 System components

Hardware integration between the control system SKD-2 and the monitoring system of the combine cutting head MINOS-2 significantly expanded functional properties of the SKD-2M and improved the performance of making precise gap for a selected cover. This is possible by generating information about the cutting head approach to the border of a calculated cross section, as well as about its deviation from the vertical and horizontal direction and from the axis of excavation.

The MINOS-2 System consists of the following elements:

- sensors:
 - angular position of the boom on the y-axis (vertical) – CK-1,
 - angular position of the boom on the x-axis (horizontal) – CK-1,
 - the levelling – CN-1,
 - position of the combine – CPK-2,
- processing module MP-2.

3.4.1. Angular position sensor CK-1

The angular position sensor CK-1, shown in fig. 8, allows converting of the swing arm angle relative to the combine into a digital value. By using two sensors working with the X-axis and Y-axis, the roadheader cutting head can be properly guided while performing the gap. The sensors are mounted on the turntable of a combine.



Fig. 8. The angular position sensor CK-1
Rys. 8. Czujnik kąta CK-1

Data from sensors are processed in the MP-2 module and transmitted to the visualization module MLCD-1 by

means of the communication interface RS-485. The data are presented on the LCD screen in the form of animated graphics of the combine cutting head performing a gap. When the combine approaches the limit of the calculated cross-sectional contour, the graphics changes its colour from green to yellow, and the control system locks moving the boom arm in the border crossing direction.

3.4.2. Levelling sensor CN-1

The levelling sensor CN-1 (fig. 9) is an electronic inclinometer. It determines the angle of combine deflection from the level, determined based on direction of the strength of Earth's gravity, and enables driving the machine by levelling point. Similar as in case of the angle sensor CK-1, data are presented in the form of an animated graphics on the MLCD-1 screen. The event of exceeding the pre-set value of levelling angle is indicated by a relevant message.



Fig. 9. The levelling sensor CN-1
Rys. 9. Czujnik niwelacji CN-1

3.4.3. Combine position sensor CPK-2

The combine position sensor CPK-2, shown in fig. 10, is the most important part of the system. It supports the operator's work by setting the combine position with respect to the side wall. The sensor contains a control system, a drive system and a laser rangefinder mounted on a turntable of the combine. The microprocessor determines the position of the machine axes relative to the excavation axis. This ensures accurate tunnelling in correct direction.



Fig. 10. Combine position sensor CPK-2
Rys. 10. Czujnik położenia kombajnu CPK-2

The information gathered from all described sensors allows drilling down the sidewalk along its axis – devia-

tion of the axis of excavation is in the range of 8 to 15 cm over a distance of 100 m.

The data from the combine position sensor CPK-2, after processing in MP-2 module, are presented in the form of animated graphics on the MLC-1 screen.

3.4.4. Processing module MP-2

The processing module MP-2 (fig. 11) connects all components of the MINOS-2 System and the microprocessor processes, according to the algorithm, the information provided by the sensors:

- angle of CK-1 for axes X and Y,
- levelling CN-1,
- combine position CPK-2.

The data prepared in the MP-2 module are transferred by means of the RS-485 communication interface with Modbus RTU protocol to the MLC-1 visualization module and displayed on LCD screen as animated graphics on three boards:

- MINING – image of the cutting head on the background of sidewalk cross-section,
- LEVELLING – side-view image of a combine, with information about pre-set and actual levelling,
- EXCAVATION AXIS – top-view image of a combine, with information about the machine position relative to the excavation axis.

3.4.5. Reflectors assembly

Proper operation of the combine laser requires use of three plates covered with reflective material. The plates are mounted on the support ribs of the tunnel housing. They are called “Reflectors”.

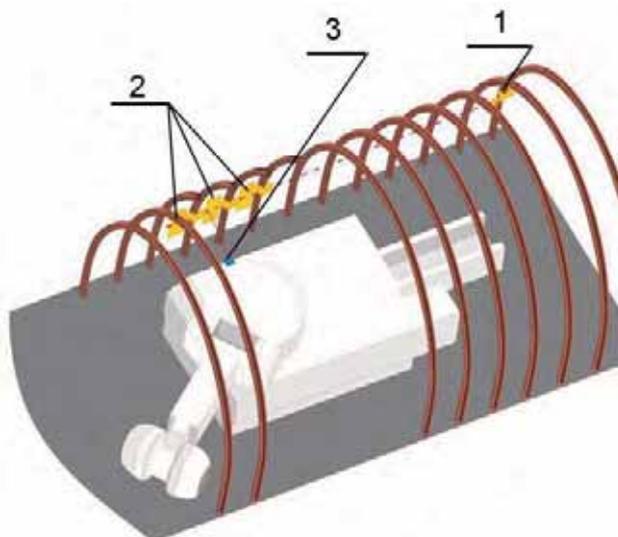


Fig. 11. Method of assembly of reflectors on ribs of the tunnel housing

Rys. 11. Sposób mocowania odbłyśników na łukach obudowy tunelu

Fig. 11 shows the mounting positions of the following elements:

1. laser pointer WL-1,
2. reflectors,
3. combine position sensor CPK-2.

Conditions for correct positioning of reflectors are:

- installation on the same side of a combine where the sensor CPK-2 is mounted,
- reflectors' reflective surfaces in one vertical plane, parallel to the line of the mining divisions – called „hours”,
- constant distance between the „hours” and the plane of reflectors.

4. Conclusion

The wireless control system SKD-2M with extensive diagnostics, with an innovative solution for directional navigation of road header, provides:

- local and wireless control of electrical and hydraulic functions of a roadheader,
- implementation of proportional control of roadheader's path and positioning of cutting head,
- diagnostics of individual machine components,
- monitoring of the cutting head position relative to the roadheader or pavement,
- monitoring of longitudinal and transverse position of the machine relative to the ground,
- monitoring of the position relative to pavement axis,
- visualization of the state of the machine on the LCD screen,
- monitoring readings from pressure sensors, temperature sensors, current, etc.
- early faults detection,
- keeping proper cutting head for cutting undisturbed soil,
- visualization of the roadheader's state on the surface.

Control and diagnostics system designed by ITI Emag allows reducing presence of people in most dangerous places during mining process and greatly increases work safety. The system permits continuous monitoring of operating parameters and their planned and structured analysis as well as possibility of excavation contour profiling, which brings tangible benefits like:

- increased performance of mining process,
- reduced energy intensity of mining process,
- increased utilization of capacity of the machine,
- increased drives life span caused by implementation of proper protections,
- reduced time of securing mining tunnels,
- improvement in mining safety.

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Bezprzewodowe sterowanie oraz kierunkowa nawigacja kombajnu w procesie drążenia wyrobisk korytarzowych

Streszczenie: Baczne obserwacje światowych trendów rozwoju branży wydobywczej, w aspekcie potrzeb i oczekiwań użytkowników maszyn i urządzeń górniczych, spowodowały, że Instytut Techniki Innowacyjnych EMAG podjął prace mające na celu wprowadzenie innowacyjnych rozwiązań w nowym systemie diagnostyki i sterowania maszyn przeznaczonych do drążenia wyrobisk korytarzowych. W artykule omówiono nowy układ bezprzewodowego sterowania i rozbudowanej diagnostyki maszyny, w oparciu o system SKD-2M, z innowacyjnym rozwiązaniem umożliwiającym kierunkową nawigację kombajnu chodnikowego w osi wyrobiska. Zastosowane w systemie SKD-2M rozwiązania z technologiami monitorowania obrysu przodka oraz prowadzeniem maszyny w wyrobisku, w odniesieniu do większości obecnych systemów, poprzez zwiększenie stopnia automatyzacji drążenia i predykcji parametrów pracy maszyny odpowiadających chwilowym warunkom urabiania, pozwoli na podniesienie stopnia wykorzystania potencjału technicznego maszyny. Nastąpi również ograniczenie zużycia maszyny wynikającego z niewłaściwej eksploatacji, zmniejszenie energochłonności procesu urabiania oraz podniesienie poziomu bezpieczeństwa w przodku chodnikowym. Wpłyne to korzystnie na efektywność drążenia wyrobisk korytarzowych, co ma istotne znaczenie, w związku z rysującą się perspektywą zastosowania systemu na rynkach wschodnich.

Słowa kluczowe: kombajn chodnikowy, sterowanie, bezprzewodowe, drążenie wyrobisk, system diagnostyczny

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