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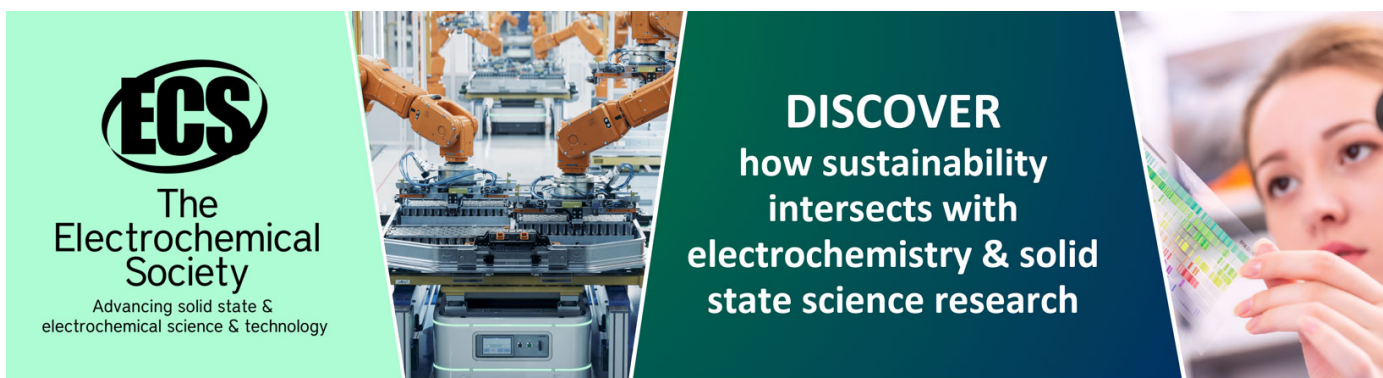
Functional schemes of automated and robotic control of equipment in longwall top coal caving

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Functional schemes of automated and robotic control of equipment in longwall top coal caving

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Abstract. The article proposes functional schemes of automated and robotic control of equipment in longwall top coal caving method (LTCC) with coal discharge to face conveyor. The application of the proposed schemes lessens the influence of the human factor, prevents coal dilution, eliminates conveyor overloading, decreases workload of shearer operator in face area and reduces the probability of making errors by operators.

1. Introduction

The effective operation of the longwall complex depends on the coordinated work of powered roof support, face conveyor and shearer. Therefore, as usual, integrated automation systems are used that provide electro-hydraulic control of the support from the control posts located on the support units and remote from the control panel installed on the drift, with reference to the conveyor and shearer position [1].

Thick coal seams development technology with controlled coal discharge to face conveyor involves applying support units with special devices. The features of such supports are the availability of an outlet window, a feeder, which are intended for withdrawal and discharged coal loading to face conveyor [2–4]. Для управления процессом выпуска угля задействованы следующие технические устройства:

- backstop, providing overlapping withdrawal flow gate (outlet window) of support unit;
- feeder initiating a motion process of drawing caved rock mass;
- feeder tray, providing the function of loading on the face conveyor with simultaneous operation of the feeder [1].

It is possible to implement a feeder and feeder tray in the form of a single device, depending on the type of feeder.

2. Methodology

Development of the functional schemes of control is the critical stage of engineering new mining equipment, especially when the equipment is meant for self-operation and is the basis for design of robotic mining complexes for manless mines.

Functional schemes of automated and robotic control of technical devices for top coal caving are worked out on the basis of the developed model of the mechanized top coal caving [1, 5]. Top coal caving process is decomposed into technological operations, and then system-functional approach in the form of IDEF0 methodology is applied [6, 7]. The model aimed at solving a problem of feeder,



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feeder tray and backstop control with taking into account changing parameters of the technological environment.

3. Results and discussion

3.1. Functional scheme of automated control

Functional scheme of automated control of technical devices for top coal caving is composed of necessary and sufficient elements, mechanical and hydraulic connections, data transmission lines as shown in Figure 1. The elements are arranged in three independent control circuits: slide valve position, feeder inclination and feeder mode of operation.

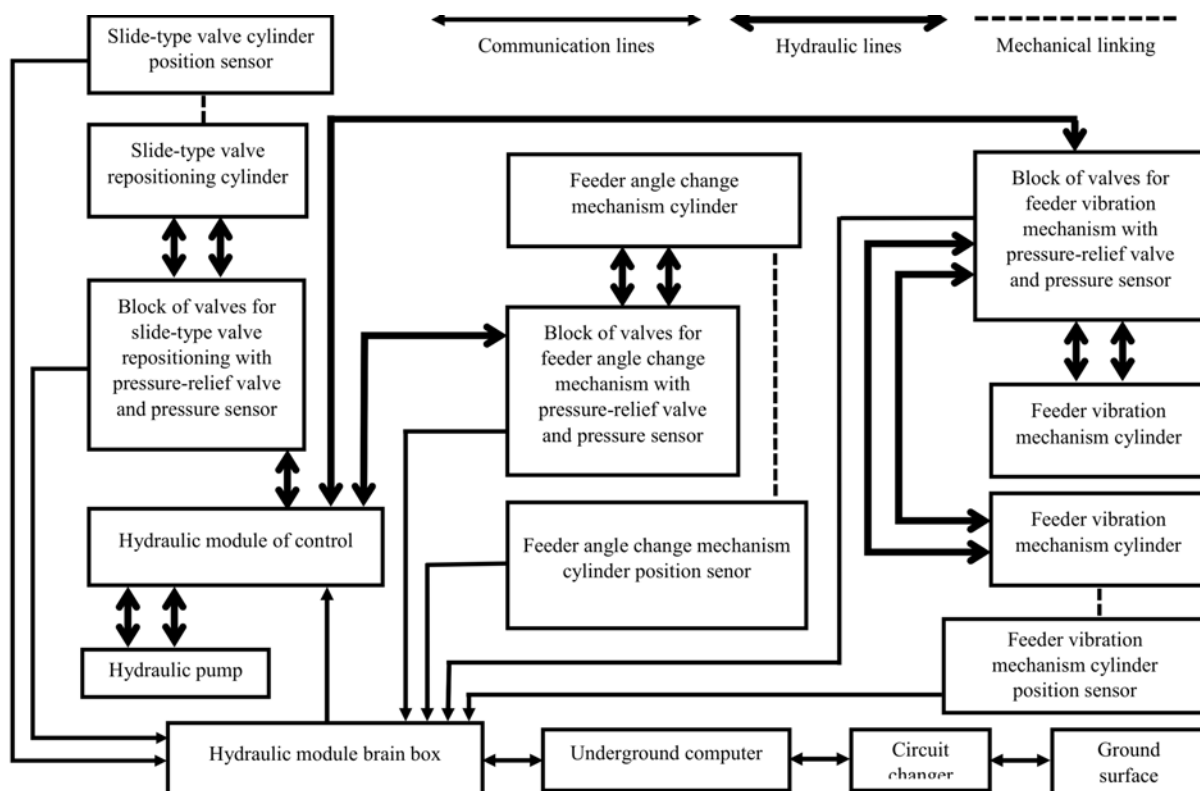


Figure 1. Functional scheme of automated control of technical devices for top coal caving.

As seen in Figure 1, all circuits ensure adjustability of parameters using the hydraulic module brain box arranged on the powered roof support unit. It is provided that double control of mining equipment from the single dispatch office and by underground computer.

Each circuit has independent system of valves to control oil flow to and from the hydraulic cylinder pressure-relief valve of the hydraulic system and oil pressure sensor in the hydraulic circuit. The blocks of valves are connected to the hydraulic block of the roof support control, which allows integrating auxiliary blocks in to common hydraulic system of the LTCC equipment. The data from the oil pressure sensors are sent to the hydraulic module brain box and then to the general control database on the underground computer and to the single dispatch office. Position of the cylinders is controlled by the position sensors which send data to the hydraulic module brain box, which allows an operator to know current condition of any technical device engaged in top coal caving and discharge.

In order to ensure back-and-froth motion of the feeder, the hydraulic cylinder position sensor is used by the control system as the position indicator of the feeder pan for the prompt change in the direction of movement. The signal of automatic change in the direction of movement of the cylinder is set by the underground computer. Since the position sensor continuously informs of the cylinder

position, the frequency of the to-and-fro movement is smoothed and physical shocks of the cylinder at the end points are eliminated.

3.2. Functional scheme of robotic control

Functional scheme of robotic control of technical devices for top coal caving is shown in Figure 2 and represents an extended version of the automatic control scheme. It is added with the computer vision and the human-machine interface based on the brain-computer interface.

According to robotic application scheme, the powered roof support is equipped with the computer vision, including lidar to determine discharge rock volume and ash content meters—ah meter and ultrasonic sensors. This set of equipment is to perform key robotic functions when the powered roof support is in self-operation mode. These functions are prevention of rock outlet through discharge opening, determination and overcoming of bridging or arching of coal flow above the powered roof support sections.

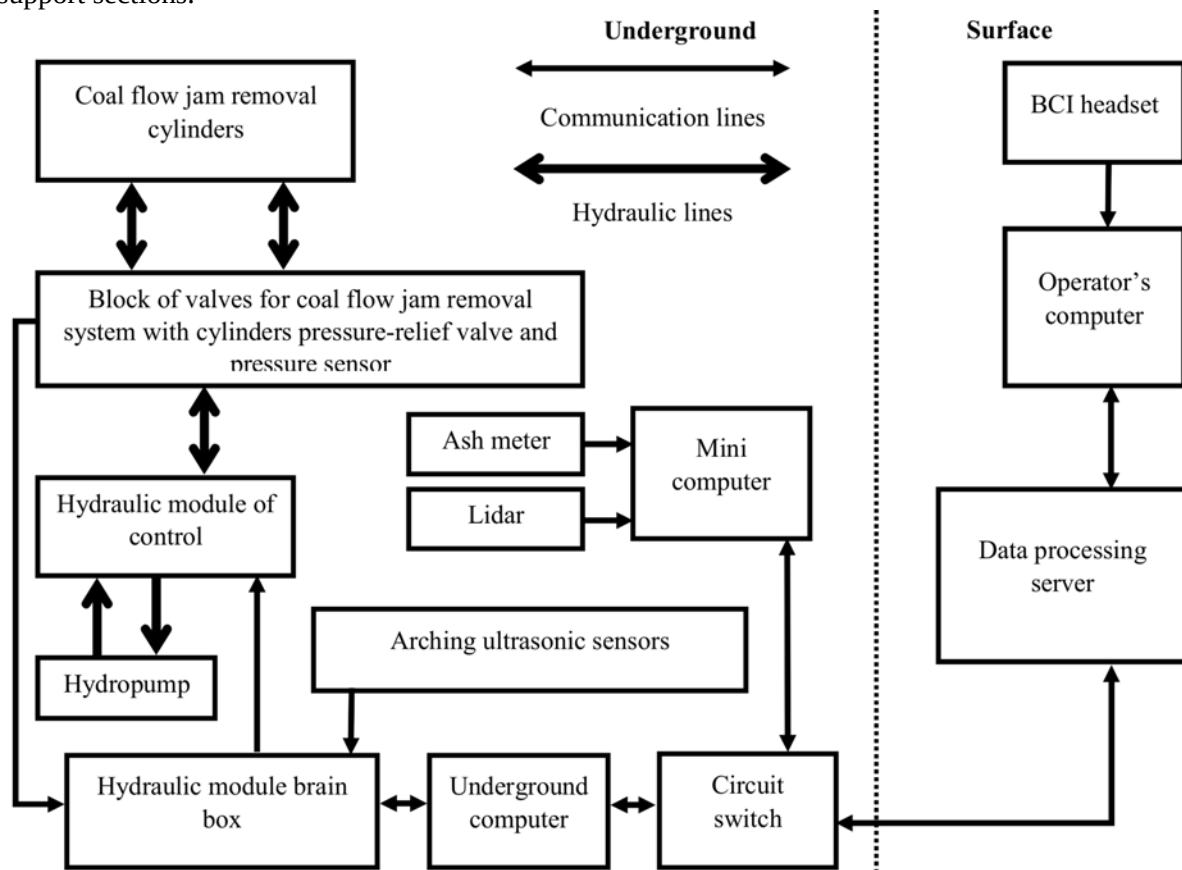


Figure 2. Functional scheme of robotic control of technical devices for top coal caving.

Aimed to prevent rock outlet in the discharge opening during or after coal discharge, discharge rock compositions is inspected by two ash meters arranged one above the other. The first ash meter is in charge of the flow upward from the the inlet opening, and the second ash meter surveys the inlet opening zone. The data are transferred to a minicomputer mounted on the powered roof support section and, then, to the data processing server on ground surface. In case that considerable concentration of ricks is recorded in the zone of the first ash meter, the system switches to ready condition to stop rock flow to the feeder pan. Namely, the velocity of coal flow on the feeder to the conveyor is changed by adjusting the feeder pan inclination. As son as the second ash meter recorded higher rock concentration too, the data processing serves generates the command to shut the inlet

opening by the sliding-type valve and to stop and system of the feeder pan excursions after its total unloading. Load of the pan is in this case recorded by the lidar.

Bridging of coal, which prevents rock flow to the feeder pan, is detected by the ultrasonic sensors. The ultrasonic range-finding sensors oriented at angle upward detect voids in the flow. The sensors operate continuously and trace distances from the protection enclosure to the objects in the work zone. The sensors are directly connected with the hydraulic module brain box and transfer data to the underground computer and surface data processing server. The mechanism of bridging removal is developed automatically or with an operator involved. The measures of bridging removal are the change in discharge mode in the other sections of the powered roof support, or employment of special mechanic devices to re-initiate the discharge.

Cessation of coal flow through the discharge opening due to blocking or arching is the off-normal situation which was simulated on the scaled longwall model [8, 9] and will be additionally investigated in benchmark trials of the feeder [10]. If the slide-type valve is closed, the fact of blocking of the discharge flow is determined by the filling of the feeder pan. The main filling control element is the lidar. If the lidar data show clear decrease in the coal flow through the discharge opening, the command is generated to actuate special mechanical facilities for unblocking of the opening. The efficiency of the undertaken measures is estimated by the data of lidar, as well.

3.3. Human-machine interface integration

Robotic self-operation equipment executes many operations controlled by an operator (dispatcher). This imposes considerable requirements on the physical health of the operator, as well as on the level and focus of his attention. The authors believe that BCI application will enable continuous monitoring of physical fitness of operators, levels of weariness and attention [5, 11]. Furthermore, during the preliminary research, it has been revealed that BCI perceives facial gestures and gaze direction of operators. This makes it possible to add gestures to the standard manipulators of the control system by connecting them with specific commands in the interface of the LTCC equipment parameters.

4. Conclusions

The proposed schemes of automated and robotic control of technical devices for top coal caving allow:

- reducing the influence of the human factor in managing the process of top coal caving;
- preventing coal dilution;
- preventing conveyor overloading;
- decreasing workload of shearer operator in face area;
- reducing the probability of errors made by operators, or loss of visual contact with the parameters of the control object.

Acknowledgements

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