Technical devices of powered roof support for the top coal caving as automation objects

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Abstract. In the paper technical devices for the top coal caving as automation objects in the composition of the longwall mining complex (LTCC) are considered. The proposed concept for automation of the top coal caving process allows caving efficiency to be ensured, coal dilution to be prevented, conveyor overloading to be prevented, the shearer service personnel to be unloaded, the influence of the “human factor” to be reduced.

1. Introduction

The effective operation of the longwall complex depends on the coordinated work of the powered roof support, the front armored face conveyor (AFC) and the 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 section and remote from the central control panel installed on the drift, with reference to the conveyor and shearer position.

Technology development of thick coal seams with controlled top coal caving involves the use of crepe sections with devices of adjustable coal withdrawal on the front AFC. The distinctive features of such supports are the availability of an outlet window, a feeder, which are intended for withdrawal and discharged coal loading on the front AFC [1, 2]. The feeder evenly releases the rock mass over the whole area of the outlet window. Its performance is adjustable in a wide range. It is possible to simultaneously operate a group of feeders on the front AFC. The number of feeders working in the group is determined by its productivity. If we assume that the feeders operate under the same conditions, their weighted average productivity can be adjusted to the required value of the full load of the conveyor when the feeder group operates [2].

Depending on the functions performed, the technical devices providing caved coal drawing on the front AFC are:

- backstop, providing overlapping withdrawal flow gate (outlet window) powered support section;
- feeder initiating the process of motion caved rock mass drawing;
- feeder tray, providing the function of loading on the front AFC with simultaneous operation of the feeder.

It is possible to implement a feeder and feeder tray in the form of a single device, depending on the type of feeder.
Technical devices providing caved coal drawing are separate devices and at the same time are assembly units of a single powered support unit and functionally should be considered as an integral part of the longwall complex. For this reason, the development of the principles of automated control of the technical means of caved coal drawing on the front AFC, even at the initial level, should be considered as the development of a control subsystem, eventually integrated into the used longwall complex control system.

2. Methods of research
To substantiate underground automated geotechnologies with elements of robotization, without the constant presence of people in the faces, a system-functional approach in the form of IDEF0 methodology [3, 4] was applied. To this end, the top coal caving process is decomposed into technological operations and an IDEF0 model of the process of mechanized top coal caving (figure 1) is developed, displaying its organization without using automation tools.

![Figure 1. IDEF0-model of the mechanized top coal caving.](image)

As we are visually modeled in figure 1, with mechanized caving, all technological operations are closed on the mineworker: he tracks the course of the coal-face work, the longwall shearer position and the roof support position, starts and stops the runner at the discharging time. When automation of the caving process, these functional tasks are transferred to the control system.

As a result of the analytical review of the existing control systems of longwall complexes, it was concluded that the automation of technical systems in the development of coal seams longwall complexes developed at a high level and is built, usually based on electrohydraulic control systems; The available technical solutions for the automation of technical devices for LTCC from thick seams to the rear conveyor [5, 6] are integrated through the provided free (reserve) control channels of the hydraulic cylinders powered support unit based on the produced automated electrohydraulic control systems.

The analysis of dissertations on the specialty “Robots, mechatronics and robotic systems” over the last 5 years has led to the conclusion that the trend of development of Russian robotics is aimed at the development of adaptive control systems for robots and mechatronic systems in nondeterministic conditions. Namely, to create sets of mechatronic and robotic systems aimed at solving a single task of control taking into account a changing external environment and target performance and reliability criteria due to the intellectualization of control systems.

If we consider technical devices for top coal caving withdrawal as objects of automation and robotics, then the mine conditions are quite deterministic in terms of technological and operational
environment and possible operating modes. It does not require the constant adaptation of technical devices to the work environment. Allows the task of adaptive automation exclusively within the technological function to be considered, which is the determination of the moment of the beginning of top coal withdrawal (discharging) and the beginning of the appearance of rock fraction (fragments) in the withdrawal flow gate of the n-th support unit to ensure effective implementation of undulated areal extraction of coal.

3. Results and discussion

Undulated areal extraction involves the simultaneous opening and loading of coal from the group powered support units. Its effectiveness depends on the number and sequence of simultaneously open / closed release windows support units, whose work should be linked to the loading and position of the front AFC, as well as the position of the longwall shearer.

The duration of top coal caving withdrawal is proposed to be determined in real time at the time the rock fraction is exceeded in the discharging mass. For this, it is necessary to identify the different physical properties of coal and rock, which can be fixed during their discharging in the flow:

1. Different loose density of coal (200 kg/m$^3$) and enclosing rocks (over 300 kg/m$^3$). It is possible to distinguish between coal and rock by using the weight of rock mass established before the flow gate;

2. The ash content of coal affects its ability to reflect and pass through itself ionizing radiation and X-rays. Apparatus using this pattern, ash gauges, allows using its irradiation of a coal stream to detect its ash content by X-ray or gamma rays [7], which allows to stop coal withdrawal in time when the rock hits the flow gate of the powered support unit.

To ensure caving efficiency in the determination of ash content, it is proposed to install not one sensor, but several, higher than the first one. This will allow controlling the approach of a large rock mass and closing the flow gate until it falls onto the conveyor. Also, a system of several ash gauges will reduce the likelihood of premature closing of the outlet window and stopping the feeder when a single rock fragment passes through the working zone of the ash dump (figure 2).

![Figure 2. IDEF0-model of the automated top coal caving.](image)

Thus, the control system for technical devices for top coal caving should provide the solution of the following tasks:
• timely opening / closing the outlet window n-th powered support unit to ensure the operation of the complex in a given mode (Undulated areal extraction);
• adaptive control of the backstop and feeder, depending on the composition of the withdrawn rock mass, congestion and the position of the conveyor.

Based on this, the concept of automated top coal caving with robotic elements, presented on the IDEF0 model in figure 2.

4. Conclusions
The proposed concept for automation of the top coal caving process makes it possible:
• ensure caving efficiency of top coal;
• prevent coal dilution when installing the coal-rock sensor above the outlet powered support unit to ensure that the backstop can be closed in advance;
• dosing output depending on the position and loading of the conveyor, shearer position;
• prevent conveyor overloading;
• unload the shearer service personnel, who are directly in the face;
• reduce the influence of the “human factor” in managing the process of top coal caving.

On the basis of the IDEF0 model obtained, to conduct a detailed study of the structural and functional schemes of the adaptive system with the robotization element aimed at solving the problem of controlling technical devices for top coal caving taking into account the changing parameters of the technological environment.

Acknowledgements
The project was financially supported by the Ministry of Education and Science of the Russian Federation within the Federal target program ‘Research and development of priority directions of scientific-technological complex development of Russia for 2014-2020’ (agreement No. 14.604.21.0173 from 26.09.2017, unique ID RFMEF160417X0173).

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