Outlet facility to pass coal flow to armored face conveyor

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Abstract. The authors review the international experience in thick coal seam mining. Advantages and disadvantages of multi-slice and full-seam longwall mining technologies are compared. The low-efficiency multi-slice longwall mining is little used and is being replaced by the full-seam longwall top coal caving technology with undercut and with top coal disintegration under the physical effect of overburden pressure. In the recent decade, the longwall mining systems used in top coal caving have been given additional functions connected with control of coal extraction above and behind the powered roof support. The authors have examined the patent documentation and invention activity in the field of the LTCC methods and equipment in the top coal mining countries. This paper describes the revealed trends in engineering facilities capable to enhance efficiency of longwall top coal caving in mining of thick coal seams. Different type feeders are described, and recommendations on their application are given.

1. Introduction
Two technologies currently prevail in mining of thick coal seams: multi-slice longwall mining and full-height top coal caving with an undercut [1–9]. Multi-slicing features high coal losses and high risk of spontaneous fires. For these reasons and due to low efficiency, the fully mechanized longwall mining methods of coal slicing have fallen into disuse. The currently common method of longwall top coal caving with an undercut allows full height extraction of thick coal seams [10–12]. Physically, disintegration of top coal takes place under the action of the overburden pressure. In consequence of this, the complete longwall systems have been given auxiliary functions in terms of control over coal caving above and behind the face support [13, 14].

Coal lost in the caving zone can spontaneously inflame. When coal gets mixed with caved roof rocks, ash content of coal grows. The challenging objective of all known technologies of coal mining is complete extraction of coal at the preserved safety and efficiency of longwall face.

Efficiency of new technologies and machines for mining thick coal seams in many ways depends on the appropriate design of outlet facilities of powered roof support and on the method of coal flow outlet.

This paper aims to review the available scientific and technical literature and to define the current efficiency enhancement trends in the longwall top coal caving technology in thick coal seams.

2. Review of inventive activity
The authors have thoroughly reviewed the patent documentation from the top coal mining countries and the inventive activity in the field of methods and equipment for coal caving through powered roof support (figure 1).
3. Advances in the design of loose material dischargers (feeders)

The technology of controllable top coal caving involves special-design powered roof supports and equipment capable to control coal caving above or behind the support.

There are two variants of coal flow outlet in the LTCC technology: either on the front or rear armored face conveyor.

In the first case, the outlet window is arranged nearby the face. The length of the support unit is shorter, but preparation of top coal for caving is poor due to a short spacing between the face and the outlet window and it is required to subject even loose coal to preliminary loosening.

In the second case, the conditions are favorable for deformation and fracture of top coal. On the other hand, the design of the longwall system complicates and the size of the support unit is to be greatly increased.

The controllable LTCC method allows creating an increased joint flow of coal above the longwall mining system, much greater than in the other known methods. The throughput capacity of the outlet window in the support unit increases, completeness of coal discharge, including large coal, improves, and coal dilution is reduced. Furthermore, loading of AFC becomes adjustable, capabilities of the conveyor are utilized in full, and junctions of the longwall with temporary roadways are arranged in much simpler way.

Efficiency of the technology and equipment for mining thick coal seams depends on the appropriate design of the outlet windows of powered roof supports and on the method of coal discharge [15].

Extraction and haulage of coal are commonly carried out using continuous-type machines, feeders and conveyors which enable continuous flow mining.

The controllable longwall top coal caving and discharge needs adequate selection of the powered roof support design, location of outlet windows and method of coal discharge. The productivity and efficiency of controllable coal outflow can be improved by adding powered roof support with feeders to assist the discharge and loading of caved top coal to armored face conveyors.

The review of the scientific and technical literature revealed different type feeders with design features advantageous for engineering coal outlet facilities for the LTCC technology.

Loading facilities ensure productivity of armored face conveyor and efficiency of coal flow outlet. Conditionally, the loading facilities are grouped into units designed for forced coal flow, complex coal flow and gravity coal flow. In the forced coal flow units, coal is driven by feeders. Feeders ensure uniform coal flow throughout the area of the outlet window and provide wider range adjustability of their capacity.

The units for complex flow enable combination of gravity and forced movement of coal flow using a vibrating feeder and a vibrating guide chute.
Feeders are meant for the uniform and adjustable feed of granular materials of various size grades. Feeders may be designed as transfers, chutes, plunger rams, drums, screw feeders, disk feeders, vibrating feeders, etc.

Feeders can be classified with respect to the mode of motion and characteristics of a material being fed.

For the purposes of this review, feeders can be conditionally divided into two large groups:

- Conveyor-like feeders of smaller length and with lower capacity drives (belt, apron, screw, shaking and vibrating feeders);
- Conveyor-unlike feeders (drum, disk and chain bucket feeders).

The mining industry employs different types of feeders: apron, screw, shaking and belt feeders. As compared with the known types (apron, disk, shaking and belt feeders), vibrating feeders, owing to the specificity of interaction with the flow material, ensure persistent flow through the mouth of hoppers, prevents choking, and are beneficial in terms of energy consumption, reliability, abrasive wear and, often, specific content of metal. Vibrating feeders combine the process of transportation with screening and dewatering of loose material in a chute. The chute of a vibrating feeder has usually an adjustable tilt.

From scientific and technical literature, vibrating feeders can be made in the form of bowls, belts and rotators.

Vibrating feeders are the alternative to the pneumatic transport as they eliminate choking and sticking of materials of any particle size. As a rule, a vibrating feeder has a chute and is mounted on the load-bearing frame of a hopper on spring suspensions. Vibrating feeders can be equipped with one or two electromagnetic vibration exciters.

Hopper-type vibrating feeders can be equipped with super resonance oscillation systems with unbalanced-mass vibration generators which provide steady-state vibration and minimized wear of load-transport surfaces. In the capacity of vibration exciters, electromechanical motors–vibrators can be used, or unbalance vibration assemblies rotated by electric motors via elastic clutches and drive shafts. The engineering design of a vibration exciter depends on the dimension and weight of the feeder, its arrangement and mode of operation. The key assemblies of vibrating feeders and conveyors are the vibratory drive, load-bearing element, elastic system and the frame.

4. Feeder design and its junction with support unit

The facility meant for the controllable coal flow in the longwall top coal caving technology – feeder – is manufactured as a lipped chute arranged between hydraulic props in the opening of the shield. On the bottom of the chute, the slide of the feeder is placed as a weld assembly with its working surface made with wedge grooves to ensure minimized resistance to the flow toward the tail and maximized cohesion between the flow material and the surface when the feeder moves toward the front armored face conveyor. A zone of resistance is generated in coal flow above each groove. The feeder is fitted with a hydraulic cylinder so that the cylinder is connected to the chute and the cylinder rod – to the slide. To avoid jamming at the end of the feeder slide, under the connecting beam, there is a window made to allow outflow of chippings when the support unit is advanced. The front end of the feeder has a flap shield driven by the hydraulic cylinder and meant to ensure free passage of a shearer if necessary.

The feeder is to provide uniform coal flow throughout the whole area of the outlet window in the shield of a support unit. Furthermore, capacity of the feeder should be adjustable in a wide range. One AFC can be serviced by a group of simultaneously operating feeders. The number of feeders in the group is governed by the technical capability of AFC. Considering the same operation conditions of the grouped feeders, their weighted mean capacities should be adjusted to a wanted value to ensure full load of AFC.

The weld structure chute serves as the undercarriage of the transporter. The chute bottom is connected to the support unit pivotally on the shield side and by means of the hydraulic cylinder on the face side. Owing to this, the tilt of the feeder relative to the seam floor can be varied. The bottom of
the chute also serves as the support and guide for the feeder slide which ensures coal flow toward the front armored face conveyor. To avoid jamming at the end of the feeder slide, a window is made under the connecting beam to allow outflow of chippings when the support unit is advanced. The side shields of the chute are intended to eliminate side clearances when the longwall width is changed, and to prevent ingress of coal under the support.

Aimed to test the coal outlet process, the Laboratory of Mining Machine Engineering of the Institute of Coal at the Federal Research Center for Coal and Coal Chemistry of the Siberian Branch of the Russian Academy of Sciences [16] has designed and manufactured an installation at a scale of 1:4 (length 1025 mm, width 675 mm, height 1125 mm) which ensures adjustable flow of loose material, its removal and prevention of its cascading (figure 2).

![Figure 2. General view of laboratory installation: 1 – base; 2 – housing; 3 – enforcement ribs; 4 – loading bin; 5 – feeder; 6 – flip gate; 7 – hydraulic cylinder.](image)

The housing of the installation (its walls) is made of metal 3 mm thick, the bracket joints are steel, and the side wall (observation wall) is made of organic glass 5 mm thick. The hydraulic cylinders ensure the required force and stroke length of the vibrating feeder. The underside of the feeder is accessible for installation of sensors and strain meters to measure actual loads during outlet of loose material. This free zone extends either side of the central axis to 1/3 width of the underside along its whole length. The semiautomatic control, which has been designed [17], and the automatic control, which is under development [18], can promote integration of the outlet facility into the future control system of the complete longwall system.

5. Regulatory framework for functional chart of automated feeder control
Efficient operation of a feeder is governed by its design and also by the functionality of its control, and by its integratability in the overall electrohydraulic circuit of the powered roof support unit. The earlier attempts to try to engineer complete longwall systems for top coal caving with coal discharge to armored face conveyors featured operation complexity and high content of manual labor [19]. The current advancement of microprocessor technology and programming support allow many operations, previously manual, to be computerized. For instance, the systems of computer vision with auxiliary optical projection module with marker tracking are adaptable to the control over rock flow volume and jamming; a large-power intelligent controller integrated in the longwall operation brain box installed on a powered roof support unit can adjust position of the slide gate in the outlet window in the support unit using the data from the computer vision system.
Sophisticated engineering of the feeder control system including microcontroller, microcomputer, video cameras and rock flow composition sensors calls for a regulatory framework for the automation flow chart and software component algorithm. The algorithm of the software component can be developed using State Standard GOST 19.701-90 Flow Charts of Algorithms, Programs, Data and Systems. Definitions and Rules. At the same time, State Standards GOST 21.404-85 Process Flow Automation and GOST 21.408-93 Process Flow Automation Paperwork Regulations are incapable to assist in adequate description of all elements of the computer vision control of coal composition and their interaction. The relevant research succeeded in finding a fresher standard in USA—ANCI/ISA-5.1-2009 Instrumentation Symbols and Identification which is harmonizable with Russian GOST 21.404-85 but fits better the up-to-dateness and contains modern definitions. The application of the American standard is legally acceptable by the procedural rules effective in Russia in R&D activities. When there is no similar or analogous standards in Russia (and no certification of the test subject is supposed), it is allowed to use foreign standards and components.

4. Conclusions
The review of the inventions in the longwall top coal caving technology for sloping, steeply dipping and steep coal seams has revealed six principal technical and economic indicators of facilities perfection of which was the target or objective of the reviewed inventions.

Currently researchers engage themselves with the studies aimed to enhance the service life and capacity of feeders for trouble-free transport of free-flowing materials. The analysis of the data from the foreign and Russian normative references shows that wearing ability of feeder components exposed to impact loading is the most effectively increased using coatings made of alloys of chromium, iron, nickel, tungsten carbide, oxides, borides and diamonds.

Quality of coal flow depends on designs of feeders and outlet windows within the configuration of powered roof supports. This paper exemplifies feeder design solutions technologically suitable and capable to improve the process of coal discharge.

Acknowledgements
This study has been supported by the Russian Foundation for Basic Research, project No. 19-35-90075/19.

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