

Kuzbass mineral raw material base available for applying the method of robot-based roof coal release

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Abstract. Coal reserves suitable, in prospect, for underground mining by means of robot-based system of roof coal release are situated in Bachatskey, Yerunakovskoy, Kemerovskoy, Leninskoy, Prokopyevsk-Kiselyevskoy and Tom'-Usinskoy geological-economic regions of Kuzbass, in the coal seams with the thickness of more than 5 meters and the depth of 600 meters and total about 3 billion tons.

1 Introduction

Coal production in Russia in 2020, according to the data of Central Control Administration of the Fuel and Energy Complex, made 401.37 million tones and more than half of this volume is produced in Kuznetsk coal basin (Kuzbass) [1].

Coal balance reserves in Kuzbass counted to the depth of 600 m from the surface (mountainous – 300 m) according to the sum of A+B+C1 categories total 52.45 billion tons [2]. In flat-lying seams with the thickness of more than 5 meters, there are about 9 billion tons and 30 per cent of them can be mined using underground method.

The most effective excavation of such seams is the excavation at full capacity with roof coal release on a face or a goaf conveyor (Longwall top coal caving method – LTCC). In such methods roof coal massive disintegration is made by a rock pressure [3-10].

In the global practice, complexes equipped with the additional goaf conveyor are used (China, Australia, Turkey, Bangladesh). “Caterpillar” Company and “CODCO” (China) provide the delivery of powered (shield) supports [11]. However, extra goaf conveyor complicates the complex, demanding significant enlarging of a support unit size and placing the load-transfer device on headgate, which in its turn, complicates its maintenance.

2 The technology of roof coal release onto the face conveyor

The Institute of Coal of The Federal Research Center of Coal and Coal Chemistry of Siberian Branch of the Russian Academy of Sciences is developing the method of powerful flat seams excavation using the system of “Longwall top coal caving method” (LTCC) with extracting coal out of the undermining layer of a seam and robot-based roof coal release on to the face conveyor. In the bases of the method the application of powered-support unit of

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supporting and shielding type (KUB) with discharge ports in the shields connected with a loading chute and a feeder is placed (Fig. 1) [12, 13]. The discharge port of the support unit is two times larger than the existing analogues and it allows increasing the rock mass flow, reducing the losses and decreasing the downtime of the stopes that takes place due to the oversized lumps. Not heavy weight of the support unit (17 tons) allows excavating soft floor seams. To compare, the weight of ZF 8000-22/35 (“CODCO”) support unit is 26 tones; the support unit base area is 1.5-2 times smaller than the overlap area and under the condition of soft clayey floors it can cause sticking of the support unit in the seam soil and decreasing the operating efficiency. KUB base area is not smaller than the overlap area and it allows excavating from thick deposits with soft clayey soil without decreasing the load on the stope.



Fig. 1. KUB powered (shield)-support unit.

The given method if compared with the layer development of a seam and roof coal release on to the goaf conveyor will allow:

- decreasing operational losses and ash content due to the controlled release of coal;
- providing the load on the stope up to 15.0 thousand tons per day (4.5 million tons per year);
- decreasing mounting/dismounting costs: complexes, means of transportation, electrical equipment, pipelines, maintenance etc.;
- decreasing coal mining energy consumption on 25-30 per cent;
- reducing the expenses on expensive and metal-consuming equipment of the stopes and on rock mass means of transportation in the limits of the mining extracted area.

The analysis of the mining and geological conditions of the Kuzbass deposits showed that the coal reserves suitable, in prospect, for this method are situated in Bachatskey, Yerunakovskoy, Kondomskoy, Leninskoy, Mrasskey, Prokopyevsk-Kiselyevskoy and Tom’-Usinskoy geological-economic regions (GER) (Table 1).

The idea of the method is in the following: the development of the extraction pillars starts from flank inclined shafts towards central inclined shafts. Preparation of the extraction areas is panel, with double entries and leaving unextractable strip abutments. Standard process chart is demonstrated in Fig. 2 and Fig. 3.

The characteristics of the extraction system and the conditions of its application are given in Table 2.

Table 1. Kuzbass potential coal seams suitable for LTCC method with robot-based roof coal release [14-16].

GER	Seams with the thickness of 5 m and more, m	Mining method	The potentials for the method
Bachatskey	Hard (powerful), Prokopyevsk I and II, Goreliy, Vnutrnniy II-III	Open-pit mining	final extraction of coal reserves in the mine take boundaries
Yerunakovskiy	91, 86-84, 82, 81-82, 81-80, 78, 73-71, 69, 68, 67, 60	Open-pit mining	final extraction of coal reserves in the mine take boundaries
Kemerovskiy	Kemerovskiy, Volkovskiy	Open-pit mining	final extraction of coal reserves in the mine take boundaries of “Kedrovskiy”, “Tchernigovets” and “Yuzhnaya” Mine transition into deep workings
Kondomskiy	3-3a, 6, 9	Open-pit mining and underground mining	final extraction of coal reserves in the mine take boundaries and at “Alardinskaya” Mine site
Mrasskey	III, IV-V	Underground mining	At “Sibitginskaya” Mine site
Leninskiy	Karakanskiy 9, 8, 7, 6, 5, 4, 3, 2, 1, Verkhniy, 1, 3, 4, 5, 9	Open-pit mining	final extraction of coal reserves in the mine take boundaries
Prokopyevsk-Kiselyevskiy	Vnutrnniy IV, Vnutrnniy III, Vnutrnniy II, Goreliy, Lugutinskiy, Mochshney, Bezymyanniy, Dvoinoi, Sadoviy	Open-pit mining	Opening of the open-pit mines under the condition of modernizing support units for steep pitch coal seams (the method patented in Russia, invention No. 2709903)
Tom’-Usinskiy	21, 19, III, IV-V, VIII-IX, XXX	Open-pit mining and underground mining	At Ol’zherasskaya”, “Raspadskay-Koksovaya” Mines and at the “Mine named after Lenin V.I”

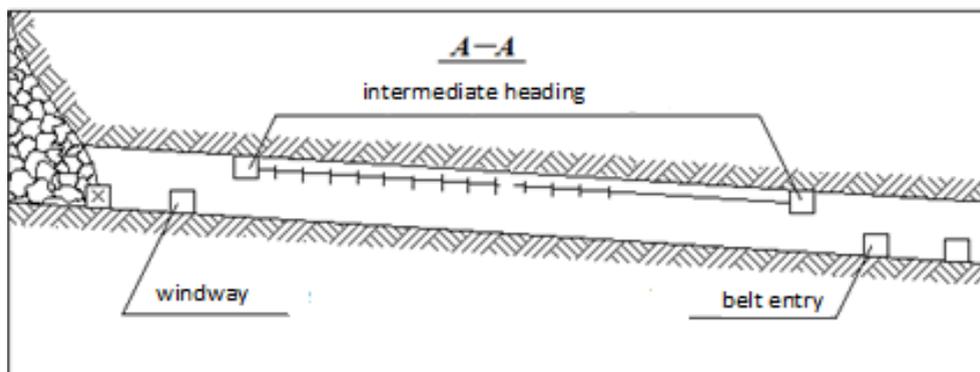


Fig.2. Preparing the roof coal massif to release chart (extraction pillar cross section).

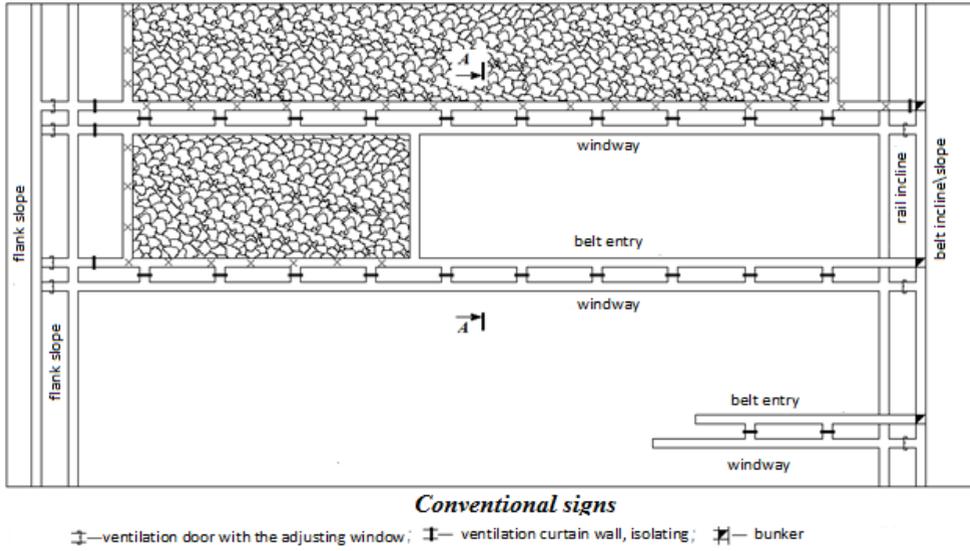


Fig.3. Standard chart of uncovering, development of flat coal seams using LTCC system with roof coal release and panel preparation of the extraction areas by double entries and leaving unextractable strip abutments.

Table 2. The characteristics of the extraction system and its application condition.

No.	Parameter	Measurement unit	Value
1.	Extraction depth	m	to 600
2.	Coal ignitability	-	Prone to ignition, Rather prone to ignition
3.	Strength of a coal seam	m	over 6
4.	Coal seam inclination	degree	0-18
5.	Extraction pillar length	m	1000-4500
6.	Face length	m	150-350
7.	The advancing direction of the stope	-	along the strike, under the angle to the strike line
8.	Extraction pillars development order	-	Downward, successive
9.	Pillar dimensions: – at installation chamber – at break-down chamber – for protecting main workings – for protecting extraction workings	m	15-80 15-80 15-30 10-30
10.	Cross slit distance	m	60-200

Table 3 demonstrates mining-geological characteristics of the seams suitable for development by mechanized complex with robot-based system of roof coal release

operating in Kuzbass mines [14-16]. Fractured coals; in dislocation zones their strength is from medium to hard (hardness coefficient according to P.P. Protodyakonov scale is $f - 1.0 \div 2.5$). Complex seam structure with the layers of aleurolite and argillite. Immediate roof rocks are of medium stability and stable, created by calley-stone or aleuralite with the hardness correspondingly from 2.66-22 m to 17 m. Bedrocks prone to swelling during soaking. Coals of the seams are dangerous on self-ignition.

Table 3. Mining-geological characteristics of the seams suitable for development by mechanized complex with robot-based system of roof coal release at operating Kuzbass mines.

	Mines				
	Allardinskaya	N.a. V.I. Lenin	Ol'zharasskaya-Novaya	Raspadskaya Koksovaya	Sibirginslaya
Coal seam	6	IV-V	21	III	IV-V
Coal rank	TS (Green coking)	KO (Coking lean)	GZhO (Gas fat lean)	K (coking)	OS (lean coking)
Inclination angle, degree	14	8-15	6-10	11-15	11-15
Medium thickness, m	8.73	9.94	7.5	10.44	10.05
Rock bumps hazard depth, m	150	150	220	200	150
Coal and gas outburst hazard depth (horizon), m	300	265	240	265	(+ 100)
natural gas content, m ³ /tons	11.0-14.9	to 15	to 15	to 19	to 18

Before starting a pillar mining, the extraction area is fully contoured by the development headings. The windway is meant for providing upcast ventilation shaft airflow, materials and equipment delivery, workers transportation and serves as an emergency exit for the workers of the stope.

Belt entry is meant for rock mass transportation, for delivering fresh air into the stope, for settling electric equipment and for exiting of the workers out of the face.

At a flank boundary of a pillar, starting from the belt entry towards the windway the installation chamber is cut out. There in the installation chamber, a mechanized complex is installed: a shearer loader, KUB support unit, armored face conveyor. At the coupling of the installation chamber with the belt entry the belt elevator and face-end supports are installed. A belt conveyor is assembled in the belt entry.

The stope advances from the extraction area flank to the center and the airstream is sent out of the belt entry into the stope and further on it goes into the windway.

The shearer loader extracts undermining layer at the bed floor with the thickness of 3.5 m. The remaining coal ply is artificially destructed and is released on the face conveyor. The roof coal is prepared by two by-levels for weakening the roof coal (see Fig. 2). The recommended scheme of stope orientation towards coal massif fracturing is given in Fig. 4.

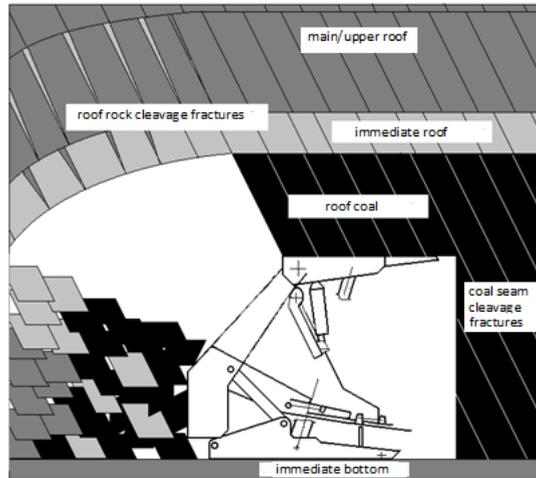


Fig.4. The recommended scheme of stope orientation towards coal massif fracturing.

In KUB support unit the discharge port is situated near the face. On the one hand, it allows lessening the area of the supported roof; on the other hand, it does not provide enough preparation of the coal massif to release under the influence of rock pressure forces.

In this connection, it is important to provide qualitative preparation of the roof coal massif to the release and this is what makes the given method effective.

For additional weakening of the upper layer (roof coal), one or two by-levels are meant to be done in a sub-roof part of a massif in the area between a belt entry and a windway. Moreover, the measures for weakening hard roof prone to caving are meant to be fulfilled. There are several options for weakening:

- advanced blasting (torpedoing) method;
- directional hydraulic fracturing method.

The need for preliminary weakening of roof and sub-roof patches of coal, final selection of the weakening method are recommended to be defined experimentally under supervising of specialists and qualified companies (Institute of coal FRC CCC SB RAS, VostNII).

3 The developing a coal seam with the thickness of 5-6 m

When developing a coal seam with the thickness of 5-6 m, the preparation of a roof coal massif can be done during advancing of the stope and the support unit without introducing additional operations into technological cycle (making compensative workings, drilling boreholes and wells) and additional devices (cleaver blades, seismic vibrators, high-pressure pumps etc.), only with the help of the existing mechanical equipment embedded into the complex.

A shearer-loader moving along the frame of the armored face conveyor breaks down coal in undermining layer with a thickness of 3.5 m and loads it on the face conveyor (Fig. 5). The operating space of the undermining layer is supported by KUB powered support unit.

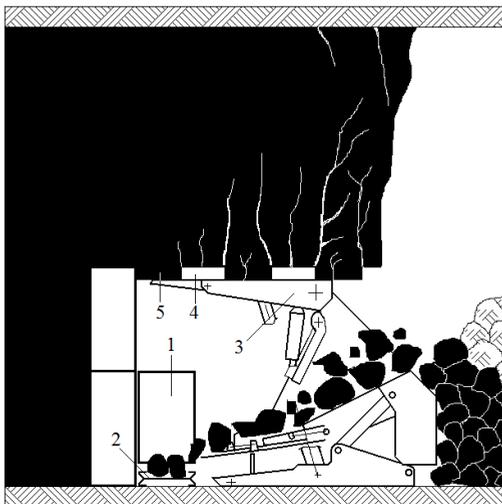


Fig.5. A stope cross-section (1 – shearer-loader; 2 – armored face conveyor; 3 – powered support unit of the supporting and shielding type; 4 – channels; 5 – coal pillars).

To increase the completeness of the roof coal destruction during the excavation of every second coal stripe in sub-mining layer the thickness of the layer is increased on 0.3-0.4 m by means of rising upper drum of the combined machine and dividing the roof coal massif into lengthwise portions by channels with the width equal to the drum web layer width (0.63 or 0.8). The support units are pushed apart not into the complete undermining layer roof but into the pillars between the channels.

Depending on coal physical properties the pillars taking up the load from the support unit canopy are partially destroyed and transfer the compressive force to the over-layer. The channels do not receive the thrust forces from the support unit but are pressured from the over-layer side, i.e. in opposite direction that spread the channel surfaces. Two third of the support unit shifting provide cracking of the roof coal massif and prepare it to the release thus, the better prepared part or the massif portion appears to be directly over the discharge port of the support unit.

4 The developing a coal seam with the thickness of 6-12 m

During the development of the coal seam with the thickness of 6-12 m before the combined machine starts its work from the operation space of the undermining layer through the inclined channels in the canopy of the support unit some inclined boreholes are drilled into the massif of the roof coal to the coal seam roof (Fig. 6).

Parallel to drilling the boreholes the initiating elements are prepared. As an initiating element an elastic vessel in the form of cylinder with the diameter close but not larger than the borehole diameter can be taken. Under the mining condition a water stemming is used (it is a plastic chute with a hydraulic lock). The cavity of the water stemming through the hydraulic lock is filled by liquid, non-explosive, expanding mixture (NEM), for example, with water solution NEM-1 with well-known solidifying period of the mixture.

At the end of the drilling, near the face or along its length, depending on the coal strength, the initiating element (one or several) is placed and the borehole is sealed.

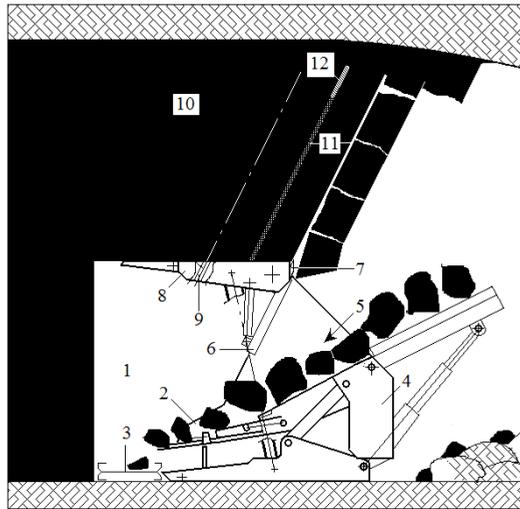


Fig. 6. The scheme for initiating an artificial crack in the roof coal and arranging coal release on the face conveyor (1 – operating space; 2 – support unit; 3 – face conveyor; 4 – caving shield; 5 – discharge port; 6 – rotating cover; 7 – dynamic cleaver; 8 – canopy; 9 – inclined channels; 10 – roof coal massif; 11 – inclined hole; 12 – initiating element).

The shearer-loader extracts the coal shear in the undermining layer. As the combined machine advances further, the powered support units are moved along the stope. The inclined holes are drilled (the distance between the hole row is not bigger than the distance between the neighbouring holes in a row) and equipped with the initiating elements. In addition, it is done during two or three cycles of coal extraction in undermining layer.

Within this time, NEM starts solidifying increasing in volume and influencing on the walls of the boreholes. In a roof coal massif in the area of placing the initiating element the cracks that propagate in the direction of the boreholes to the nearest free face – mined out space start appearing, weakening the massif.

When the support unit with its discharging port reaches the weakened massif the dynamic cleaver starts influencing on a roof coal, separating it and the separated part of the massif goes to the face conveyor through the discharging port.

5 Conclusions

The analysis of the mining and geological conditions of the Kuzbass deposits showed that the coal reserves suitable, in prospect, for underground mining of coal by mechanized complexes with robot-based system of roof coal release are situated in Bachatskey, Yerunakovskoy, Kemerovskoy, Leninskoy, Prokopyevsk-Kiselyevskoy and Tom'-Usinskoy geological-economic regions (GER). Balance reserves in the seams with the thickness over 5 m to the depth of 600m for underground mining makes 3 billion tons.

At present, there are five operating mines in Kuzbass (Allardinskaya (seam 6), the mine named after V.I. Lenin (seam IV-V), Ol'zherasskaya-Novaya (seam 21), Rspadskaya Koksovaya (seam III), Sibirginskaya (seam IV-V)) where mechanized complexes with robot-based system of roof coal release on the bases of KYB support unit which is worked out at the Institute of Coal of FRC CCC SB RAS (Kemerovo) can be used.

The method will allow providing high productivity of the extraction area; decreasing in about 2 times the drifting volumes of the extraction galleries towards the layering system;

simplifying the construction and lessening the metal consumption of the complex comparing to CODCO ZF 8000/22/35 complexes which includes additional goaf conveyor.

The mining of the extraction pillars is recommended to be done starting from flank inclined shafts towards central inclined shafts by the Longwall top coal caving method with roof coal release. Preparation of the extraction areas is panel, with double entries and with the leaving of unextractable strip abutments.

During final extraction of reserves within the boundaries of the mine take, the method “with roof coal release” will be on demand during the transition to the underground mining.

The need for preliminary weakening of roof and sub-roof patches of coal, final selection of the weakening method are recommended to be defined experimentally under supervising of specialists and qualified companies (Institute of coal FRC CCC SB RAS, VostNII).

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