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ANALYSIS OF OPERATION OF POWERED LONGWALL SYSTEMS IN MINES OF SUEK-KUZBASS

The geological conditions and mining technology used in mines of SUEK-Kuzbass company are described. Mining machines and equipment included in the powered longwall mining systems are examined. The main criteria of any longwall system efficiency are output per face, productivity, life time and failure-free operation of mining machines. This study is focused on the downtime in longwalls and on the most significant factors connected with the mining equipment failures and complicated ground conditions including unstable roof, frequent roof rock falls, rockburst-hazard, high gas content, etc. It is found that 15% of downtime is taken by the mine safety measures to be implemented, and 56% of idling is due to the other production and technical reasons. Such events that intersection of faults, high methane release, unstable and very unstable roof with doming and rock falls, high water inflows and kicks, increased strata pressure, false floor and intensive roof rock fracturing entail long-term stoppage of work of the powered longwall systems, many non-productive operations and appreciable production loss. The productivity of the powered longwall systems in mines of SUEK-Kuzbass is analyzed with a view to estimating their operational stability in rational modes in fully mechanized longwalls. To this effect, the curves of output per face for 12 months and for a few years have been analyzed. An emphasis should be laid on the high nonuniformity in the values of output per face, i.e. there is considerable deviation of actual performance of the powered longwall systems from their specifications. The plotted density functions for output per face per mines within SUEK-Kuzbass are closely spaced, which points at the similar history of the processes. Despite the modern high-tech equipment, longwall mining has an erratic performance and capabilities of the powered longwall systems are used inefficiently. In order to refine the factors that condition the nonuniformity of output per face, it is planned to study the actual feed velocities of shearers and the real-time operation of a powered longwall system.

Key words: *coal, bed, underground mining, longwall system, shearer, powered roof support, conveyor, downtime, operating mode, stability, output per face, productivity*
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Introduction

SUEK-Kuzbass is an affiliate to the Siberian Coal Energy Company — SUEK. SUEK-Kuzbass comprises mines situated in the territory of the Kemerovo Region: Kirov, Ruban, Yalevsky, Komsomolets, Polysaevskaya, Talda-Zapad-1 and Talda-Zapad-2.

Table 1 gives a brief description of the mines within SUEK-Kuzbass as of 2016. Coal mining is carried out at a depth of 180–470 m. The thickness of coal beds varies from 1.7 to 4.5 m, dip angles range as 0–20°; gas flow rate in longwalls is from 5 to 122 m^3/min, and the length of longwalls is 186 to 300 m.

Some of SUEK-Kuzbass mines operate closely spaced coal beds under the impact of

Table 1. Structure of powered longwall shearing–loading systems in mines of SUEK-Kuzbass in 2016

Mine	Longwall/ Coal bed	Coal bed thickness, m	Length, m	Length, m	Mining depth, m	Longwall shearing–loading system			Output per face, t/day
						Powered roof support	Shearer	Conveyor	
Kirov Mine	2458/ Boldyrev	1.5–2.4 2,22	242	2750	350–470	Joy RS 2400/650×2	Joy 7LS-20	AFS-38×800/1500	10400
	2595/ Polenov	0.8–1.7 1.73	212	1800	300–436	Joy RS 2400/650×2	Joy 4LS-20	AFS 38×800/1500	5520
7th November Mine	1385/ Baikaim	4.5	286	1152	285	Tagor 24/50	Eickhoff SL-500	PF 4/1132	9580
Ruban Mine	1210/ Nadbaikaim	2.20–2.55 2.37	220	2270	200–310	MKYU 2SH-13/27	Eickhoff SL-300	PF 4/1132	8800
Polysaevskaya Mine	1749/ Breev	1.5–2.0 1.71	210	1030	430–470	FRS-Glinik-12/25	Eickhoff SL-300	FFC-9 Glinik	10000
Kotinskaya Mine	5202/ Bed 50	4.5	200	1980	340–310	DBT 2200/4800 DBT 2400/5000	Eickhoff SL-900	PF 6/1142	50000
Yalevsky Mine	5212/ Bed 62	4.5	250	1711	253	DBT 2550/5500 DBT 2400/5000	Eickhoff SL-500	PF 4/1132	25000
Talda-Zapad-1	66-05/ Bed 66	4.0	186	1630	200–320	DBT 2200/4800	Joy 7LS6C	PF 6/1142	25000
Komsomolets	1731/ Breev	2.0–2.3 2	213/175	1890	369–460	Glinik-15/32 Tagor-15/32	Eickhoff SL-300	PF 4/1032	9000

the increased strata pressure induced by overmining or undermining of contiguous beds [1, 2].

The majority of mines use the method of longwall mining with a single face. The key advantage of this method is spatial concentration of production, which allows considerable cut-down in cost of mining [3]. On the other hand, there is a drawback as mine performance depends generally on efficiency of a single face.

Recently SUEK-Kuzbass mines enjoy a substantial increase in production output per face, which is the result of the purposive transition to the modern highly productive powered longwall systems [4]. However, the actual output of the powered longwall systems appears to be lower than the rated technical capabilities.

Problem formulation

The mines operate shearers of foreign manufacture (Table 1). The employed shearers are made by companies Eickhoff (SL-300, SL-500, SL-900) and Joy (4LS20, 7LS20, 7LS6C). All these shearing–loading machines have a modular structure with two spaced apart cutting drums with independent drives, with east–west mounting of the primary motor with revolving gears and dual-drive electrical rack feed. Effective capacity of the machines ranges from cutting drum power to 830 kW to the total installed power to 2136 kW. The cutting width is to 0.82–1 m, the feed rate is to 36 m/min in idle mode and to 24 m/min in actual cutting.

It is worthy of pointing at the general properties of the advanced foreign shearers, namely, relatively high installed power, reliability and availability of the systems for control and diagnosis of operating modes and technical state.

The models of scraper conveyors of foreign manufacture in use are: Joy AFS-38×800/1500, DBT PF 4/1132, DBT PF 6/1142 and FFC-9 Glinik**.** The conveying chains have the link coupling breaking load from 1500 to 400 kN and the velocity from 1 to 2 m/s. The tonnage capacity of the conveyors totals from 5 to 20 Mt.

As seen in Table 1, the powered longwall systems in most mines are composed of the equipment produced by different manufacturers. One longwall uses the powered roof support model MKYU-2SH-13/27 of the domestic manufacture, the other longwalls operate foreign powered roof supports: Joy 2400/650×2 (America); DBT 2200/4800, DBT 2400/5000, DBT 2550/5500 (Germany); Tagor 15/32, Tagor 24/50, FRS-Glinik-12/25, Glinik-15/32 (Poland).

All of the powered roof supports in use in SUEK-Kuzbass mines are of the aggregated, supporting–shielding, single-line and twin-leg type (**Table 2**). The structural formula of a powered support is: SS×A×BS×1.75×[2+0]×4 units (SS — supporting–shielding, A — aggregated, BS — advanced behind advancing shearer). The setting step of the units is 1.75 m, advancing is from 0.8 to 1 m, resistance varies between 7600 and 9340 kN. Specific resistance is from 650–960 kN/m^2 in Joy, Glinik and MKYU support sections, and is to 1025–1075 kN/m^2 in Tagor and DBT units, which is sufficient for the mining depth down to 500 m in the conditions of Kuzbass. The advancing effort of the powered support units changes from 557 to 726 kN. The factor of extension of hydraulic legs is more than 2 for all models. The hydraulic system pressure is 32 MPa.

The technical appraisal shows that the domestic-manufacture systems have the same engineering capabilities as the supports produced by the leading foreign companies but come short of the manufacturing quality, control level, design, reliability and life duration.

The longwalls equipped with the Poland powered roof supports show the same average output per face per day as the faces with the domestic-manufacture systems, which is 2 times lower than the daily production capacity of faces operating the powered supports of American (Joy) and German (DBT) production [5].

The price of Joy and DBT supports is much higher than the price of the Russian systems due to the higher quality and reliability of the former. Specialists emphasize that the

Table 2. Technical details of powered roof support models

Description	Powered support model							
	Joy RS-2400/650×2	MKYU.2SH-13/27	Tagor-24/50	Glinik 15-32	Glinik 12-25	Tagor-15/32-Poz	DBT 2200/4800	DBT 2550/5500
Height of unit (min-max), mm	1200–2400	1300–2700	2400–5000	1500–3200	1200–2500	1500–3200	2200–4800	2550–5500
Permissible dip angles of coal beds along/across the strike, deg	35/12	15/±10	12 (±20)/ to 6	± 15/ to15	±10/±10	±15/ to 15	25/7	25/7
Setting step, m	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Advancing step, m	1	1	0.8	0.8	1.0	0.8	0.8–1.0	0.8–1.0
Resistance of unit, kN	7600	9340	8618	8264	6582	8550	6436	8534
Working pressure, MPa	32/43	32	32/38	32	32	32/42	32/46	32/46
Advancing effort of unit, kN	No data	643	643	643	726	643	658	557
Specific resistance, kN/m^2	650	960	1075	1043	848	1025	1015	1054
Extension coefficient	2.50	2.08	2.08	2.13	2.08	2.13	2.18	2.16
Wight, kg	16400	23500	31366	25800	16890	24500	29800	29650

powered supports from Poland and America have life durations, respectively, equal and 1.5–2 times higher than the powered support systems manufactured in Russia.

The comparison of the powered support models based on the unit cost of coal production calculated as a ratio of the powered support price to its guaranteed overhaul life [6] shows that, given the higher price and longer life, Joy and DBT powered supports offer nearly the same unit cost per production of 1 t of coal as the powered supports manufactured at Yurga Machine Works in Russia. The unit costs of coal production with Poland powered supports are approximately the same as with the Russian systems.

The powered supports of Russian manufacture are developed towards the increased resistance and higher quality to reach a guaranteed life of 30 thousand production cycles [7], which, in the aggregate with the 2–3 times lower price, elevates their competitive ability in the Russian market as compared with the import analogs.

Analysis and method

The basic criteria of the longwall machinery performance are assumed as the output per face, life and failure-free operation of mining machines. The failure-free operation of mining machines has a direct influence on the actual output per longwall face.

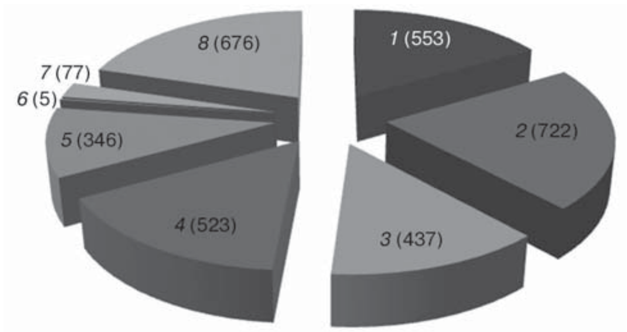

Fig. 1. Failure time of mining machines in SUEK-Kuzbass mines in 2015:
1 **— shearer–loader;** ***2*** **— face conveyor;** ***3*** **— powered roof support;** ***4*****–extraction area transport;** ***5*** **— main transport;** ***6*** **— fixed equipment;** ***7*** **— electrical facilities;** ***8*** **— other facilities**

The analysis of ineffective time in SUEK-Kuzbass mines over the period of 7 years shows that the longest failure time of mining machines is in Polysaevskaya Mine — 1470 h (2010) and in Kotinskaya Mine — 1093 (2011). These mines feature the longest downtime during the whole specified period of time. The maximum idle time of 708 h is observed in Kirov Mine in 2015. The ineffective time in Talda-Zapad-1 and Talda-Zapad-2 is the shortest and under 400 h/yr though there is a tendency toward the increase in the downtime. The mines of Ruban, 7th November, Yalevsky and Komsomolets show a clear tendency toward the decrease in the ineffective time with the maximum downtime of 500–650 h/yr.

Thus, the shortest downtime due to failure of mining machines is characteristic to Talda-Zapad-1, Talda-Zapad-2, Ruban and Yalevsky Mines. These mines use DBT longwall systems having the long life and high reliability of operation. The increase in the ineffective time in the other mines can be connected with the worked out life of the longwalling machines in use.

Fig. 1 shows the distribution of downtime per groups of mechanical/electrical equipment employed in SUEK-Kuzbass mines in 2015.

It follows from the diagram in Fig. 1 that the overall ineffective time is 3339 h. Out of this time, 17% is failure of shearers–loaders, 22% — face conveyor; 13% — powered roof support, 16% — transport in extraction area, 10% — main transport, 2% — electrical equipment and 20% — other facilities.

Fig. 2 illustrates the idle time due to mining machinery failure per mines within SUEK-Kuzbass in 2015. The shortest downtime of 136, 203, 258 and 279 h is observed in Komsomolets, 7th November Mine, Yalevsky and Ruban Mines, respectively. Kotinskaya and Kirov Mines show the longest idle time of 625 and 708 h, respectively, in 2015.

Based on the statistics on operation of powered longwall systems in mines of SUEK-Kuzbass (**Table 3**), it is found that the main causes of dead time in longwalls are not the machinery failure but the ground conditions, safety protection operations and other production-and-technical reasons.

The overall downtime due to failure of mining machines is not higher than 12%; in the meanwhile 11% of the ineffective time in longwalls is connected with the impact of ground conditions (unstable roof, high rockburst hazard, increased methane release etc.) and 15% of breaks is connected with

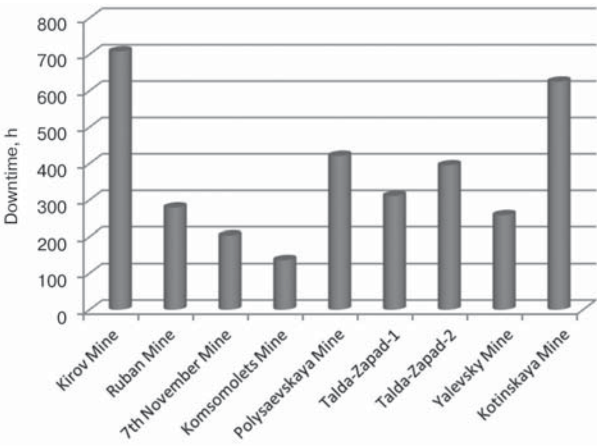

Fig. 2. Mining machinery failure downtime per mines in 2015

Table 3. Details of downtime in longwalls of SUEK-Kuzbass mines in 2015

Causes	Downtime	
	hours	percentage
Geology	2348	11
Gas conditions	512	2
Safety maintenance	3178	15
Failure of shearer	552	3
Failure of face conveyor	772	3
Failure of powered roof support	436	2
Failure of extraction area transport	522	2
Failure of main transport	345	2
Failure of other facilities	676	3
Other	12108	56

the mine safety maintenance. The other production-and-technical factors take up 56% of idle hours.

Such events as faulting [8], rock bursts and extensive methane release [9], unstable and very unstable roof [10, 11], high fracturing of roof [12], formation of domes and rock falls, high water inflows and kicks [13] and the increased strata pressure zones [14–16] entail long breaks in operation of the Incorporate Metallurgical Company OMK [17], extend the content of non-productive work and greatly decrease production output [18].

The downtime results in the production loss and unsteady operation of powered longwall systems. For instance, the total loss in production in 2015 is 8.7 Mt out of which 1.5 Mt of the loss is due to failure of mining machines.

The rate of stable operation of a fully mechanized longwall is evaluated in terms of actual output per face per month over the period of 7 years in the mines of SUEK-Kuzbass. **Fig. 3** shows the curves of the longwall performance per SUEK-Kuzbass mines in 2015. The behavior of the curves is reflective of high dynamics of the production process.

The probability density functions plotted for the values of relative output per longwall for five mines of SUEK-Kuzbass are closely spaced (**Fig. 4**); it is possible to say about their coincidence with minor differences in the modal value 0.3–0.36, and the disagreement in the probability profile 0.15 is within the tolerance of the error. The normal distribution law is clearly traced.

It follows from Figs. 3 and 4 that the operation of a longwall is subjected to the multi-factor influence and the influential factors exhibit the probabilistic behavior.

The above-discussed causes of downtime due to equipment failure, complicated ground conditions etc. offer no univocal explanation of instability of longwall performance. According to Figs. 2–4, the influences of the downtime on the productivity and its variability mismatch. Thus, there are other factors that exert considerable impact on the production output in longwalls, and these factors are to be identified and assessed.

The similar random behavior is typical of outputs per faces in SUEK-Kuzbass mines over the whole period from 2009 to

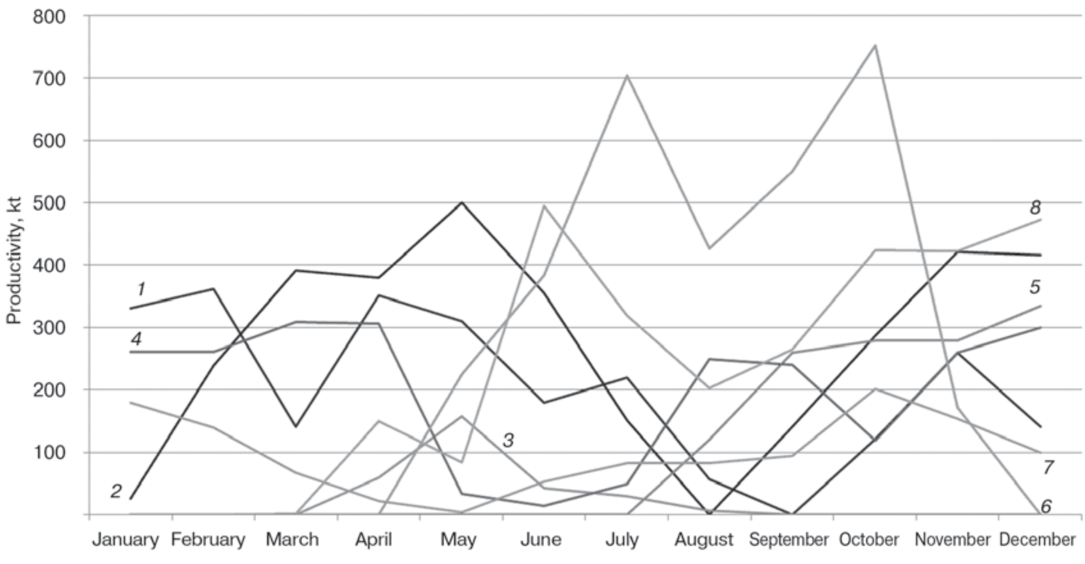

Fig. 3. Output per longwalls in SUEK-Kuzbass mines in 2015:
***1* — Kirov Mine; *2* — 7th November Mine; *3* — Ruban Mine; *4* — Komsomolets Mine; *5* — Polysaevskaya Mine; *6* — Talda-Zapad-1; *7* — Talda-Zapad-2; *8* — Kotinskaya Mine**

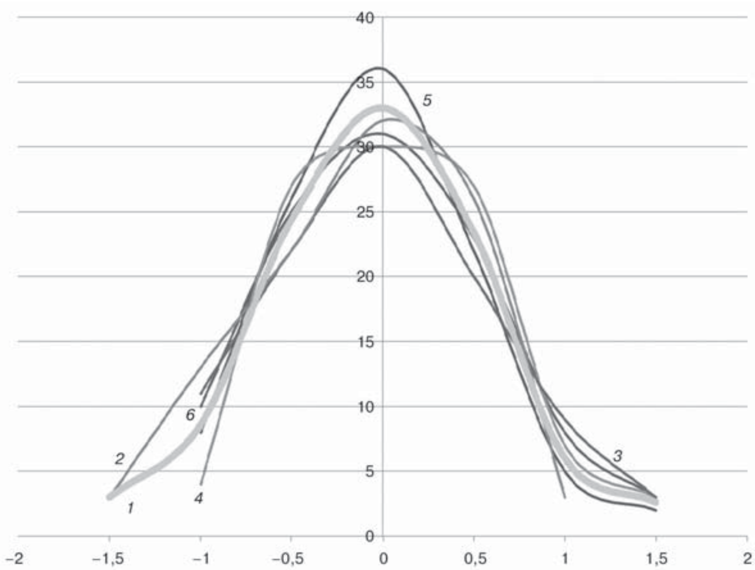

Fig. 4. Probability density functions for relative output per longwall in SUEK-Kuzbass mines:
***1* — Kirov; *2* — Komsomolets; *3* — Talda-Zapad-1; *4* — Ruban; *5* — 7th November; *6* — average value**

2014. The curves display highly uneven output per longwall, i.e., there is a considerable deviation of the performance of shearers and, accordingly, longwalls from the rationality.

Conclusions

Based on the analysis performed, the authors have arrived to the conclusions that:

— the actual output per longwall is much less than the rated value, i.e. the longwall machine system capacity is utilized incompletely;

— the probability density function proves random nature of multi-factor influences while the close-ranged distribution of their values in the modal value and profile is reflective of the common causes that yet remain to be revealed;

— the mentioned factors describe only a generalized characteristic connected with the downtime but also define a specific feature of production, namely, the dependence of time rate of mining process on factors arising in-between idle hours;

— the further study should focus on the stability of the fully mechanized longwall operation in the period free from the downtime influence, and on the analysis of variability of actual feed velocity of shearers, the short-time stoppage of work and the corresponding causes.

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