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Production planning in a mining enterprise – selected problems and solutions

Introduction

Planning in a mining enterprise is a complex and multifaceted action. For this reason, it is necessary to provide its proper organisation and adjust it to the specific conditions of conducting underground mining extraction. The prepared plans must make up a cohesive internal system, unambiguously determining the manner, range and safety requirements of the conducted extraction.

In the most general manner, the various types of plans developed by organisational units of mining enterprises can be divided based on the timeframe, type, scope and object of planning. These are:

- strategic plans – describing in a general aspect the long-term essential undertakings of enterprises,
- tactical plans – the needs within the scope of managing a mining enterprise often impose a necessity to plan economic tasks within a certain, often specifically determined scope. The following types of plans can be distinguished based on this criterion:
  - performance-based, involving a relatively narrow range of tasks covered by the plan, for example *The plan of an economic increase in the utilisation of methane*,
  - problem-based, involving a higher number of tasks, for example *The plan of an improvement in occupational safety conditions*,

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  - complex, involving the entirety of key issues for the accomplishment of a specific goal, e.g.: *The restructuring plan of a company for the years x – y*;
- subject-based plans – distinguishing various issues involving the functioning of mining enterprises; for example, they might focus on: production, marketing, supply, finances.

One of the subject-based plans – a production plan for a mining enterprise – is a document based on which the rate of extraction is determined – the amount of useful resources acquired over a unit of time: a day, a month or a year – and due to this, it is a basis for conducting and accounting for the activity.

1. The information necessary to develop a production plan

In order to properly develop a production plan it is essential to have the necessary information, whose source are:

- the requirements of valid regulations, particularly in relation to the safety of conducted work and the principle of sustainable development, involving the fact that mining activity is subordinate to the idea of reconciling the need to use natural resources with simultaneous elimination of threats emerging from it,
- expectations, recommendations, orders from the owner, which in the case of Polish black coal mining usually means the state (this group may also include the requirements of European Union authorities) or the company's supervisory bodies (Jonek-Kowalska 2015),
- conditions of the market where the company operates (current and forecast possibilities of selling coal of specified types, varieties and quality parameters),
- surface conditions of the mining impact zone, including the range of impact of the planned extraction, particularly in the case of extraction conducted with block caving of roof rocks – land morphology, hydrological conditions, elements of the environment, existing buildings,
- conditions resulting from the enterprise itself – mines belonging to it (the size and geological situation of geological resources in possession, human and technical resources, a spatial and organisational model).

Underground extraction of black coal deposits must be conducted while respecting the rules of sustainable development which satisfies current needs, without compromising the ability to satisfy the needs of future generations. For this reason, it is implemented based on legal regulations, the most important one of which is the Geological and Mining Law Act (The Act of 2011). The legal regulation under which decisions involving underground extraction are made constitutes a collection of acts, its major part being listed in Table 1.

Table 1. Selected legal acts constituting legal bases for making decisions regarding planning and conducting underground extraction of ore deposits, with respect to the safety of operations and surface protection

Tabela 1. Wybrane ustawy stanowiące ramy podejmowania decyzji w zakresie planowania i prowadzenia podziemnej eksploatacji złóż, ze względu na bezpieczeństwo prowadzenia robót i ochronę powierzchni

The Act of 9 June 2011 – The Geological and Mining Law – Journal of Laws 2016, item 1131 – consolidated text	←	The Act of 27 March 2003 on Spatial Planning and Development Journal of Laws 2017, item 1073 – consolidated text
	←	The Voivodeship Government Law Act of 5 June 1998 Journal of Laws 2016, item 486 – consolidated text
	←	The County Government Law Act of 5 June 1998 Journal of Laws 2016, item 814 – consolidated text
	←	The Municipal Government Law Act of 8 March 1990 Journal of Laws 2017, item 1875 – consolidated text
	←	The Act of 17 May 1989 The Land Surveying and Cartographic Law Journal of Laws 2016, item 1629 – consolidated text
	←	The Building Code Act of 7 July 1994 Journal of Laws 2017, item 1332 – consolidated text
	←	The Act of 3 February 1995 on the Protection of Agricultural and Silvicultural Lands Journal of Laws 2017, item 1161 – consolidated text
	←	The Water Law Act of 20 July 2017 Journal of Laws 2017, item 1566
	←	The Act of 27 October 1994 on Toll Motorways and the National Road Fund Journal of Laws 2017, item 1057 – consolidated text
	←	The Waste Law Act of 27 April 2001 Journal of Laws 2017, item 1987 – consolidated text
	←	The Extraction Waste Act of 10 July 2008 Journal of Laws 2017, item 1849 – consolidated text
	←	The Civil Code Act of 23 April 1964 Journal of Laws 2017, item 459 – consolidated text
	←	The Act of 20 July 1991 on the Inspectorates for Environmental Protection Journal of Laws 2016, item 1688 – consolidated text
	←	The Nature Conservation Act of 16 April 2004 Journal of Laws 2016, item 2134 – consolidated text
	←	The Act of 3 October 2008 on sharing information on environment and its protection, he participation of society in environmental protection and environmental impac assessments Journal of Laws 2017, item 1405 – consolidated text
	←	The Act of 27 April 2001 The Environmental Protection Law Journal of Laws 2017, item 519 – consolidated text

Source: Turek 2010.

Likewise, in relation to the safety of conducting operations in underground workings, the valid requirements have been established based on the provisions of (The Act of 2011), two most important ones of which are:

- Resolution of the Minister of Economy dated 28 June 2002 on occupational health and safety, development and specialised fire protection in underground mining facilities (Resolution of the Minister of Economy 2002),
- Resolution of the Minister of Environment dated 29 January 2013 on natural risks in mining facilities (Resolution of the Minister of Environment 2013).

Under the conditions of market economy, orders and recommendations from state authorities no longer involve the amount of planned output (as they did before 1990), and they are usually related to the regulations of implementing the directives of various authorities of the European Union.

A mining enterprise may be a company consisting of several mines or a standalone mine. In the former case, the magnitude of planned production is determined at the level of the company board, and subsequently divided into individual mines, where the scope should be planned and the concept of excavating and extracting operations should be developed such that the predefined amounts could be obtained.

The market of the receivers of the product – commercial coal – is of major significance when planning the extraction rate. In order for a mining enterprise (mine) to function efficiently, one should absolutely abide by the rule that extraction involves only seams with such quality parameters that the coal extracted from them would find a buyer, and in such amounts that their entirety could be sold (Wodarski et al. 2017).

The surface conditions of a mining impact zone are very often a factor limiting the scope of planned extraction, especially conducted with block caving of roof rocks. Disadvantageous impacts manifesting themselves on the surface in the form of so-called mining damage make it so that, particularly in the case of the presence of numerous buildings in that area, the scope of planned extraction must be frequently limited, and in the most extreme cases it cannot even be implemented.

Each enterprise (mine) holds a concession for conducting extraction in a precisely determined part of a deposit, meaning it has at its disposal a specified amount of resources – geological, economic, industrial and extractable. It also has a specified spatial model which consists of:

- openings providing access to the deposit from the surface – shafts, dip headings,
- levels opened at various depths – for extraction, ventilation, transport,
- access openings on and between levels, enabling extraction and any associated processes (the transport of people and materials, the conveyance of extracted materials, ventilation, supplying electrical energy and other utilities) – cross-entries, cross-cuts, declines, dip headings or small shafts.

Main gate made from the surface, levels at specified depths and openings on the levels and between them form a predefined geometrical arrangement which is called a spatial model of the mine (Fig. 1).

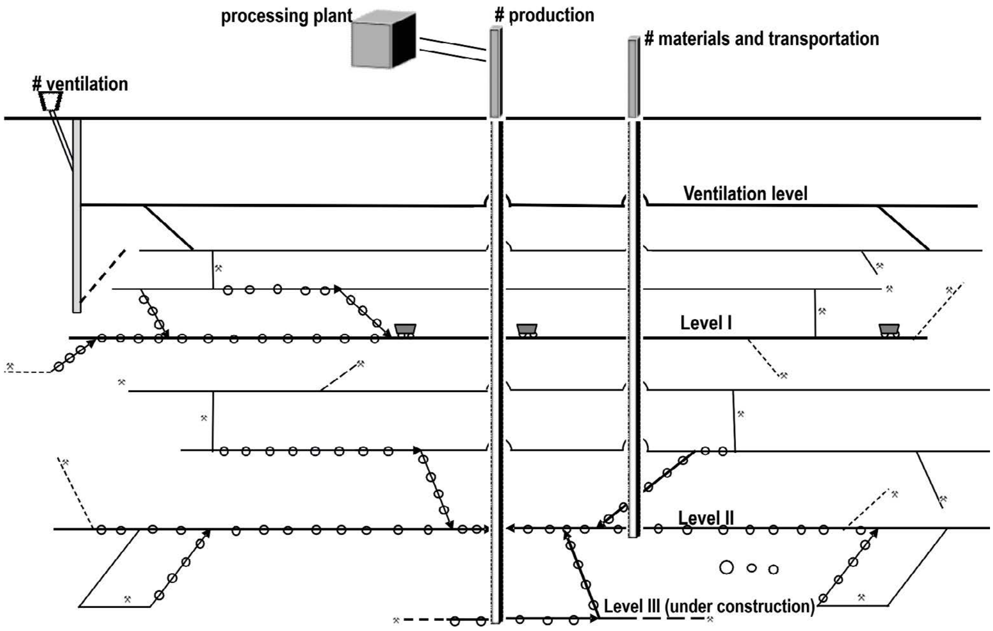

Fig. 1. A sample spatial model of a mine
Source: own research

Rys. 1. Przykładowy model przestrzenny kopalni

The model of the mine and the amount of resources which it provides access to (especially extractable) are factors which to a major degree determine the planned rate of extraction. Combined with the technical equipment installed in underground excavations and in the processing plant, they determine the production capacity of the mine, meaning the maximum amount of commercial coal possible to produce.

2. The production capacity of a mine – a primary factor determining the planned output

The production capacity of a mine is the extraction rate possible to achieve within an assumed timeframe (which is usually one day), expressed in tonnes of extracted coal or commercial coal, determined by the resulting (lowest) production capacity of the individual elements of the production process (Fig. 2) (Bąk 2012):

- vertical transport – in the case of shafts it is determined by the capabilities of transporting the extracted coal to the surface, depending on the number and type of individual shaft hoists (skips, cages, skip-cages), as well as their technical and mobile characteris-

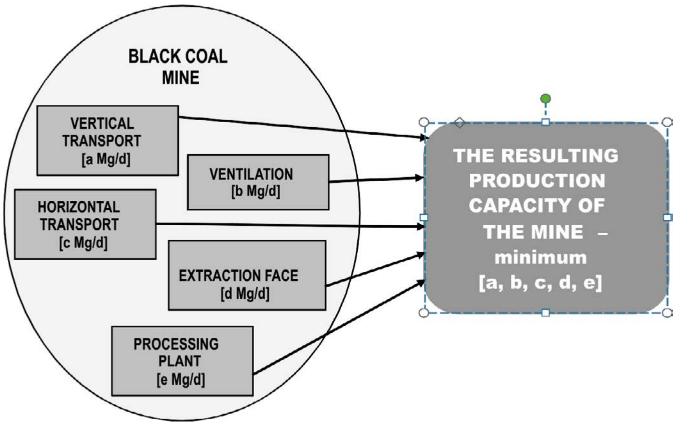

Fig. 2. The main elements of a production process determining the production capacity of a black coal mine
Source: own research

Rys. 2. Główne ogniwa procesu produkcyjnego determinujące zdolność produkcyjną kopalń węgla kamiennego

tics (travelling speed, loading and unloading time), and in the case of dip headings – on the parameters of conveyors for extracted material installed inside them,

- ventilation capabilities – determined by the parameters of installed primary fans and the capacity of air flow routes – determining the amount of fresh air which can be delivered to faces where operations are conducted, and the amount of exhaust air discharged from them, and due to this the number of these faces,
- horizontal transport – determined by the transport capabilities of devices for the divisional delivery of extracted coal (the parameters of delivering conveyors) and devices for the collective delivery of extracted coal along main transport routes (the parameters of delivering conveyors or the transport capabilities of wheeled delivering devices),
- the extraction face – meaning the net extraction rate of coal possible to obtain, depending on the number and parameters of extraction openings (usually longwalls) and in a small part on the number and parameters of corridor work faces (the opening of corridor workings). From a theoretical point of view, there is a certain difference between the approach to the distribution of extraction when calculating the production capacity of a mine in terms of the extraction face and the distribution in the plan of extraction. In the former case, one should present the whole face possible to be generated in the planned period as a result of accessing and preparatory work. However, in the latter, only this face, both active and backup, which is necessary for a plan of extraction limited by factors present outside the extraction face. In a situation when other mining operations limit the rate of extraction, the distribution of mining operations for the calculation of production capacities will be the same as the distribution of operations resulting from the planned extraction,

- the processing plant – determined by the amount of extracted coal (the so-called raw coal) transported from the underground, which may be processed into a commercial product of predetermined varieties and quality parameters, depending on the processing technologies used, as well as the parameters of technical equipment and the actual duration of its operation.

The resulting production capacity of the mine is measured in net tonnes of saleable coal – one should remember about the difference between the amount of saleable coal and extracted coal. A different amount of coal is extracted underground and transported to the surface, and a different one leaves a processing plant as a saleable product with the required quality parameters. In accordance with the adopted definitions, coal output constitutes the finished goods, meaning the resulting amount of coal once it has passed through the processing plant.

Most frequently, the parameter deciding about the magnitude of the production capacity of a mine is the extraction capacity of the excavation face (in some mines it may be so that the capabilities of the face are limited by the number or parameters of shafts not providing adequate capabilities of transport and ventilation).

The resulting magnitude of the production capacity of a mine is not a permanent value – during the functioning of a mine it can:

- increase, e.g. due to the modernisation of existing units of technical and technological equipment, or the commissioning of new ones, or accessing new parts of deposits,
- decrease, e.g. due to the depletion or destruction of the existing pieces of technical and technological equipment or the depletion of available extractable coal resources, or due to the necessity to introduce extraction limitations due to the increasing level of natural risks or a change in surface conditions (the addition of new objects requiring protection).

When willing to properly plan the rate of extraction in a mining enterprise (mine), particularly over a larger timeframe, it is obligatory to consider the possibilities of changing the production capacity of the individual elements of the saleable coal production process.

To sum up – with the existing:

- amounts of resources and geological parameters of a deposit,
- spatial and organisational model of a mine,
- occurrences of natural risks,
- surface conditions,
- the possibilities of selling commercial coal of specified types, varieties and quality parameters,
- proper planning of future extraction – its division, intensity and order – is of utmost significance for safe and efficient functioning of a mine (mining enterprise). Its first stage is planning the scope and schedule of accessing and preparatory work. Its preparation and the following implementation determine the course of the following extraction to a considerable degree.

3. The planning of accessing and preparatory work

Each functioning black coal mine already has main openings accessing the deposit from the surface and at specified depths, the so-called levels. Due to this, the need for their design and excavation may usually result from:

- the necessity (possibility) of optimising the networks of existing openings providing access,
- accessing new, previously undeveloped seams or parts thereof.

The plan of further access to a deposit in the mining area of a mine should ensure:

- the activation of an extraction face which would ensure reaching the planned extraction rate,
- the safety and rational costs of maintaining transport and ventilation routes,
- rational concentration of operations, and thus high efficiency and low labour intensity of the individual technological processes.

In order to fulfil these requirements one must plan proper division of a deposit into parts, meaning levels, fields and storeys. It is necessary to develop a rational method for accessing and excavating them. During the process of planning and executing the operations, a proper sequence should be retained for the extraction of levels, fields and storeys, taking into account the existing geological conditions. In order to maintain the rule of rational extraction of a deposit, it is necessary to divide it within the mining area into smaller units. When going down in a direction corresponding to the depth axis, the deposit is divided by planes into parts which are usually extracted independently. In this manner levels are created at depths determined by the distance from land surface (from the shaft collar).

Extraction fields are accessed by corridor openings known as the main openings. They must be planned in such a manner that they could properly serve the execution of processes enabling the extraction of the deposit. They constitute a structure of openings providing access to seams present on the extracted level. The access openings have a zero or slight inclination (apart from ramps or dip headings, usually prepared with an inclination not exceeding 18°, which enables the installation of conveyors for transporting the extracted material inside them) and a relatively large cross-sectional area, allowing the flow of larger amounts of air and the installation of devices for conveying the extracted material. Their opening is conducted using explosive materials or, less commonly, heading cutters adapted to winning rocks with compressive strength exceeding even 140 MPa.

Preparatory openings divide seams into fragments enabling their extraction according to plan. Subsequently, they serve as ventilation and transport routes, as well as routes for the delivery of utilities (water, electrical energy, compressed air) to the places where operations are conducted and for the removal of extracted methane or water. Proper planning of their course is of primary significance for conducting future extraction, which is why decisions involving their location, determining the cross-section, installation and equipment, the choice of functions, should always be made with particular carefulness. Main gate should be designed in such a manner that they would:

- not impede the rational development of a deposit and provide as clean an extraction of the ore as possible, with no unnecessary losses,
- provide the highest possible safety and comfort of work for the employed crew,
- provide the performance of effective extraction of a deposit with its proper utilisation.

In places where main gate intersect coal seams scheduled for extraction, operations usually involve the preparation of the so-called short primary headings, from which in the seams there are subsequently made preparatory openings which enable cutting through the seams and preparing for the execution of extraction operations. Most frequently designed preparatory excavations include:

- headings – mining opening corridors, dividing the extracted field into storeys subsequently extracted by longwall winning (longwall headings), excavated in coal or partially in barren rock and partially in coal, whose length results from the geometrical parameters of a specific seam, with a relatively small cross-sectional area, extending horizontally or with a slight longitudinal incline enabling the installation of conveyors for extracted material and transport devices. In order to ensure uniform length of the longwall along its whole run, longwall headings should be straight and, if possible, parallel.
- ramps, dip headings – connecting longwall headings, usually for ventilation, transport, conveyance etc. (in order to decrease the scope and costs of preparatory operations, they are often used in one seam to convey the extracted material from the walls of other seams – only short cross-cuts are made then to connect openings between seams),
- longwall cross-cuts (raise galleries) – corridors excavated in the seam, where the walls begin, connected to longwall headings, due to which each longwall has ventilating connections with the rest of mine workings.

The location of main gates, dividing a deposit as well as preparatory workings and seams into extraction parcels, performed at the stage of designing the initial excavation, should enable:

- proper ventilation of the mine, in accordance with the requirements of safety and fire protection regulations,
- optimal choice of the number of extraction workings, enabling complete extraction of the deposit with the smallest possible scope of work associated with the preparation of opened corridors,
- optimal choice of conveyance routes for the extracted coal and the transport of people and materials, providing the possibility to install the lowest possible number of devices for conveyance (which is particularly significant due to the minimised number of transfer points for the coal, which result in its crushing and thus in decreasing the amount of coarse coal of much higher selling prices) and transport.

Subsequently, a schedule of accessing and preparatory work is prepared for the planned extraction of a deposit (Fig. 3). This document is a layout of the whole range of operations associated with the preparation of mine workings within an adopted time period (usually

Top heading 13	D9R	a	800-1000	720	720													
Longwall cross-cut 14	D9R	a	800-1000	250	250													
Heading 15	D9R	a	800-1000	50	50													
Research heading 17	A7-B7	e	800	951	90	AM-50 no. 4 MINE	60	30										
Heading 18	C8	f	1000	2 110	2 110				100	160	160	150	150	150	150	150	130	100
Longwall cross-cut 19	C8	f	1000	230	230													
Top heading 20	C8	f	1000	740	740													
Longwall cross-cut 21	D8	b	800	195	35	AM-50 no. 1+MW AM-50 no. 5 COMPANY	35											
Research heading 22	C8-D8	e	800	130	130			50	50	30								
Ventilation ramp 24	D9	f	1000	290	290						50	130	110					
Cross-cut 25	D9	e-f	1000	200	200								30	50	50	50	20	
Ramp 26	C8	k	1000	240	240												70	70
Top heading 27 (west)	C8	k	1000	640	640													
Top heading 28 (east)	C8	k	1000	740	740													
Research heading 29	C7-D7	e	800	32	20	MW MINE	20											
Research diagonal 30	C9	c	1000	251	165	MW COMPANY	90	75										
			Total rate of advance of work				455	425	500	520	470	510	520	510	640	605	545	650
			Rate of advance of work – external companies				125	125	50	30	50	130	140	110	160	145	175	210
Work performed by mine crews			Rate of advance of work – mine crews				330	300	450	490	420	380	380	400	480	460	370	440
Work performed by external companies			Annual rate of advance of work				6 350											
			Annual rate of advance of work – external companies				1 450											
			Annual rate of advance of work – mine crews				4 900											

Fig. 3. A sample annual schedule for conducting accessing and preparatory work
Source: own research

Rys. 3. Przykład rocznego harmonogramu prowadzenia robót udostępniających i przygotowawczych during a year). For each working separately, the period during which it will be opened is determined, specifying the monthly rate of advance of work, the manner of working (mechanical – using a cutter or explosives) or whether it will be opened by mine crews or by the employees of an external company.

In order to provide the highest possible feasibility of the prepared schedule, the planning of monthly progress of operations must take into account the following basic conditions.

1. The assumed method of penetration – the use of a heading cutter or explosives, as well as the degree of mechanisation of work significantly affect its rate of advance.
2. The type of rocks in which the extraction will be conducted – if the height of the extraction in a working is lower or equal to the thickness of the seam in which it is being made, we call it a coal extraction. However, usually, and due to the fact that the height of the extraction exceeds the thickness of the seam, there is a need for the so-called flitching of the roof or bottom, and then the extraction is executed as the coal-rock-type or the rock-coal-type. Such conditions are present when making preparatory openings. Access workings are usually extractioned in rocks over their whole cross-sectional area, and they are defined as the rock-type.
3. The geological structure – expected disturbances in the seam – in extreme cases making it impossible to use a cutter, may impose a modification in the extractioning method, decreasing the rate of advance of work considerably. A precise identification of the course of tectonic and sedimentary disturbances is also very important for the efficiency of the following performance of extraction operations.
4. The location of the faces of operations for preparation (and thus for the following extraction) should be preceded by the making of fracturing grids or a graphical plot of measurements of frequency distribution for the directions of fractures (cleavage) of the worked rocks, the so-called fracture rose diagram, but also of the fracturing grid of a seam in a plane parallel to the top of the seam. It is only after a combined analysis of both plots that a basis is given to make a rational decision about the direction of the face. A correct selection of the direction of the face in relation to the direction of cleavage planes facilitates the cutting of rock mass, and during extraction it significantly affects the possibility of increasing the share of coarse coal varieties.
5. One should obey the rule to deliver air to the workings via an intake shaft (shafts) to the lowest accessed level, and subsequently via upward currents it should flow through ventilated areas to an exhaust (ventilation) shaft (shafts).
   Regarding the regulations, only in exceptional, justified cases is it permitted to deliver air to a dip angle of 10° (downward air current). Unfortunately, in practice in Polish mining industry, it has become quite common to deliver air to areas located below the accessed level. This occurrence, resulting from economic reasons, is absolutely undesired – the initial extraction and the following extraction of coal seams should not be planned in this manner. Under such conditions, safe ventilation of the area is only possible with a smooth (trouble-free) operation of the ventilation network.

The occurrence of any emergency conditions usually causes a sharp increase in the risk involving ventilation and gases, fire and heat.

6. The existing natural risks, especially related to methane, rock bursts and water – impose the use of threat prevention, often including the limitation of the daily rate of advance of conducted operations, for example due to the necessity to decrease the number of crew shifts.

   In a case of a very high methane content, it is necessary to remove methane from the deposit, preferably even before commencing extraction. This may be associated with the necessity to design and initiate additional extractions – methane headings with extending pipelines for the collected gas, or with the need to drill boreholes to remove methane.

7. The size of the cross-sectional area of an opening and the resulting proper selection of its casing are the main factors which make it possible to subsequently maintain the required dimensions of the opening. They should be selected based on the identification of natural and mining conditions present in the extracted area, as well as phenomena occurring in the rock mass in its surroundings. The conducted extraction, the impacts of extraction edges of other seams and the load of the rock mass often result in deforming the headings due to the subsidence of the roof, collapse of the walls or uplift of the bottom of the opening. It is then necessary to rearrange the openings, which is costly and difficult to implement. Which is why it is often more feasible to make workings with larger cross-sectional areas – in a manner of speaking, "oversized", or use heading casing of considerable supporting capacity, made of steel with increased strength properties, compared to the later payment of expenses associated with their recreation.

   It is very important to have forecasts involving the course and magnitude of deformations for longwall workings and those which are to be placed in the areas of planned extraction. It is crucial to know the factors deciding about the deformations of these workings. One of them is the supporting capacity of the casing used in them. The available literature (e.g. Prusek 2008) describes the methods of forecasting, as well as changes in the predicted cave-ins of the headings. The performance of forecasts involving the cave-ins of longwall headings will enable both choosing the right casing as well as determining the dimensions of workings which would ensure the conditions of safe and rational execution of the mining production process.

8. Employment figures regarding workers with the required professional qualifications in divisions conducting opening work – human resources of the mine. A considerable scope of operations necessary to perform (high number of faces, long openings) within a specified timeframe may impose the necessity to employ an increased number of workers. If the divisions of the mine do not have them, it is necessary to investigate the possibilities of hiring the workers of external enterprises.

4. The planning of extraction operations

The completed accessing and preparatory operations divide black coal seams into individual parts and their parcels, in which extraction operations will be conducted. Due to the fact that today in Polish mines the extraction of a deposit is conducted virtually only by a longwall system with block caving of roof rocks, further considerations involving proper planning of the extraction rate will relate to this system of extraction.

Having made assumptions regarding the magnitude of production, it is the task of the management of the mine to plan the assumed extraction rates. They are divided based on two aspects:

- spatial, into divisions and individual extracting openings,
- temporal, into intervals of time included in the plan – quarters in an annual plan, months in a quarterly plan, days in a monthly plan.

The completed division of extraction is presented in the form of a schedule of longwall runs and the distribution of extraction (Fig. 4). This document plans the distribution of extraction over a selected period (usually a year). For each longwall, there is a determination of the period during which it will be supported, extracted and shut down, specifying: the amount of resources to be extracted by the longwall, geometrical parameters, the total (remaining) and monthly advance, the number of the tonnes of coal planned to be acquired from 1 metre of advance, and the equipment of the mechanised complex installed therein.

Firstly, the process of planning the extraction rate of a mine should include the determination of the proper order (sequence of extracting seams, parcels), intensity and coordination of extraction. This is caused by its crucial significance for fulfilling the valid requirements, including primarily those related to the safety of conducted operations (Turek 2010).

A general principle (with exceptions established by safety regulations), effective when determining the order of extraction, is the necessity to extract a seam (or a part thereof) located above prior to the one located below.

For establishing the proper intensity and coordinating the extraction (directions of longwall faces, extraction rates, the rate of advance of faces) it is very important to adjust it properly due to:

- safety – in relation to the presence and magnitude of natural risks and the resulting limitations of extraction, particularly in the case of methane and rock bursts,
- ventilation – in relation to the possibility of an optimal design of the distribution of air delivered to underground openings and redirected from them, in the aspect of their proper ventilation, especially under the conditions of existing risks related to methane and fire,
- economy – in relation to the production capacities of the individual elements of the production process and the possibilities of selling saleable coal.

This is particularly related to seams in danger of rock bursts – the proper coordination of conducted extraction has a very huge impact on the safety of work, as well as the protection

Division	Seam	Face number	Avg. length [m]	Height [m]	Advance 1.01.20__. [m]	Resources [thousand t]	Number of tonnes from 1 m of progress	Equipment	Plan	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
										21	21	22	20	21	20	22	22	20	23	21	18
G1	a	1	248	1,6	151	100	661	cutter	Extraction rate t/d	2 115	1 600	1 500	2 800	2 700	2 400						
			245	1,4	300	170	566	face conveyor	Plan m/month	66	51	50	99	100	85						
								longwall conveyor	Plan increment.	66	117	167	266	366	451						
					451	270		mechanised support	Other advance	385	334	284	185	85	0						
G2	b	2	246	1,3	567	326	574	cutter	Extraction rate t/d	3 063	2 700	2 600	2 700	1 700	1 300	1 300					
								face conveyor	Plan m/month	117	99	100	94	62	45	50					
								longwall conveyor	Plan increment.	117	216	315	409	472	517	567					
								mechanised support	Other advance	450	351	252	158	95	50	0					
G1	a	3	240	2,8	1 100	1 204	1 094	cutter	Extraction rate t/d						300	2 900	5 600	5 600	3 800	3 800	3 800
								face conveyor	Plan m/month						5	58	113	102	80	73	63
								longwall conveyor	Plan increment.						5	64	176	279	359	431	494
								mechanised support	Other advance						1 095	1 036	924	821	741	669	606
G2	c	4	250	1,8	720	566	786	cutter	Extraction rate t/d									700	2 500	2 500	2 500
								face conveyor	Plan m/month									18	73	67	57
								longwall conveyor	Plan increment.									18	91	158	215
								mechanised support	Other advance									702	629	562	505
G3	d	5	245	3,6	1 283	1 869	1 457	cutter	Extraction rate t/d	5 612	5 600	5 500	5 800	5 800	5 800	5 800	5 800	5 800	5 800	5 800	5 800
								face conveyor	Plan m/month	84	81	83	80	84	80	88	88	80	92	84	72
								longwall conveyor	Plan increment.	84	165	248	327	411	491	578	666	745	837	920	992
								mechanised support	Other advance	1 199	1 118	1 035	956	872	792	705	617	538	446	363	291
									Total [t/d]	13 358	12 431	12 134	13 874	12 747	13 416	13 146	13 983	15 403	15 448	15 426	15 394
									Extr. rate with prep. work [t/d]	1 142	900	900	900	900	900	900	900	900	900	900	900
									Mine extraction rate [t/d]	14 500	13 331	13 034	14 774	13 647	14 316	14 046	14 883	16 303	16 348	16 326	16 294
									Number of faces	3	3	3	3	3	4	3	2	3	3	3	3
									Avg. face extr. rate [t/d]	4 453	4 144	4 045	4 625	4 249	3 354	4 382	6 992	5 134	5 149	5 142	5 131
									Face extr. rate [t/m-c]	280 518	261 057	266 939	277 472	267 686	268 324	289 205	307 629	308 055	355 294	323 953	277 099
									Extr. rate with prep. work [t/month]	23 982	18 900	19 800	18 000	18 900	18 000	19 800	19 800	18 000	20 700	18 900	16 200
									Mine extraction rate [t/month]	304 500	279 957	286 739	295 472	286 586	286 324	309 005	327 429	326 055	375 994	342 853	293 299
										I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII

Face in advance
Face in reinforcement
Face in shutdown

4 933	Average face extraction rate per year	t / d
3,0	Average number of faces per year	pc.
3 714 214	Total extraction rate per year	tonnes

Fig. 4. A sample annual schedule for the advance of longwalls and the distribution of extraction
Source: own research

Rys. 4. Przykład rocznego harmonogramu biegu ścian i rozkładu wydobycia of surface – it is important to situate the faces so as to avoid the unwanted impact of the created so-called extraction edges. Regulations valid in that regard stipulate that (Resolution of the Minister of Economy 2002):

- with a simultaneous extraction of the neighbouring parts of seams, the extraction faces should be situated with respect to each other so as to exclude their mutual engagement to an extent that would generate risk,
- during the extraction of neighbouring seams, the horizontal distance between extraction faces in the individual seams should amount to at least twice the distance between them, but no less than 30 m.

In the process of planning the extraction rate of mines in which there are various types of coal, in terms of coordinating the extraction it is imperative to take into account one more factor – adopting in the schedule of longwall advance such distribution of extraction as to avoid mixing different types of coal with each other during transport to the surface and to the processing plant. This is particularly important in mines with coal used for energy purposes (types 31–33) and with coking coal (types 34–38), with much higher selling prices. This might be executed by separating the extraction of the specified type of coal and a proper coordination of the conveyance of extracted coal to a processing plant.

With specified geometrical parameters of a longwall (its height and length) as well as the technical capabilities of the devices of a mechanised complex installed therein for cutting and conveying the extracted coal, it is possible to determine the rate of advance of the longwall face, and therefore the resulting rate of extraction – which is usually calculated per day. However, in order for the developed plan of progress of the face of an extraction opening and of the resulting extraction rate to be real, the following conditions must be taken into account.

1. Even if it does not prevent extraction, the necessity to protect surface objects present on the surface of a mining impact zone may require slowing down its rate of advance in order to diminish land subsidence.
   Regulations regarding the protection of buildings undergo changes compared to those valid in the previous years and based on the observations of surface deformations under the conditions of relatively low concentration with small progress rates, and with extraction frequently conducted in a continuous manner or for six days a week. One should attempt to (Kowalski 2008):
   - considerably increase the credibility of forecasting surface deformations resulting from the planned extraction, assuming the option of its considerable rate of advance,
   - use patterns for forecasting unspecified deformations,
   - establish the extent of preventive measures intended to decrease the scope of mining damage.
2. The necessity to precisely identify the geological conditions of a seam along the advance and the length of the longwall – changes in thickness, inclination and the occurrence of disturbances.

In the commonly accepted categorisation of seams into thin, medium and thick, one can distinguish a specific approach towards the method of extraction for each of these groups, and thus also for its planning. In the case of thin seams, the issues concerning the flitching of the roof and the bottom should be resolved already during the preparation stage. The process is complex in that the technological aspects regarding making the intersections of walls with longwall headings are often difficult to combine with the properties of roof and bottom rocks. Medium seams are usually extracted over the whole thickness (without dividing them into layers), and when designing preparatory work the headings are usually also excavated in coal. However, when planning underground operations, one should also exercise appropriate care in the aspect of making the intersections of the longwall with the headings. In turn, the extraction of thick seams is associated with serious risks of rock bursts and fire. Therefore, when planning the extraction of this type of seams, one should take into account on the one hand the issue of dealing with those hazards, and on the other hand look for attempts to obtain its satisfying efficiency.

The inclination of a seam affects the method of its extraction considerably. This results primarily from the necessity to use such means that would enable proper protection of both the crew and the devices against sliding rocks. This is why seams with inclinations above 35° are not extracted. Any attempts at such extraction made so far proved neither safe nor efficient.

Bottom and roof conditions primarily determine the level of mechanisation of extraction, but also numerous technological solutions affecting the efficiency of this process. For example, one should mention the still unexploited possibilities regarding the use of anchor bolt supports in Polish mines.

The possible occurrence of geological disturbances – tectonic and sedimentary – along the advance of the longwall considerably affects the assumed progress of the extraction face.

3. Due to the fact that the performance of extraction is conditioned by the possibility to create safe working conditions, it is always important to prevent the occurrence of natural risks – the rate of advance of the face should be correlated with the requirements resulting from the preventive measures used. Depending on the occurring risk and its intensity, it may be necessary to conduct actions affecting the advance rate of the extraction face. For example, with a present methane hazard or risks of rock bursts, the daily progress of the face may be limited to a specified number of metres, in order to enable the degassing of the seam or a decrease in the occurring stresses. However, in turn, in the case of a risk of endogenous fire, it may be necessary to increase the advance rate in order to shorten the duration of the inflow of air into the workings.

   A more complicated situation will take place in the case of the so-called combined natural threats, meaning those which coexist and affect each other, which may lead to a change in the symptoms and the intensity of their occurrence. An individual analysis should be performed then in order to determine which one of the risks should be considered predominant and what methods could be used for its limitation, with a simultaneous maximum limitation of the occurrence of other threats (Kabiesz 2002).

4. It is necessary to properly select a mechanisation arrangement in an extracting longwall face and in the whole area of the conducted extraction, including in particular the choice of a proper cutting machine. The workability of coal is an important parameter deciding about its proper selection.

The research conducted in the Central Mining Institute enables the measurement of workability indices, whose results should be taken into account at the operation planning stage. Currently, longwall cutters are in common use, with coal planers being less common. It is also important to properly choose the size of cutting heads, the efficiency of machines and their power.

While conducting extraction, previously unpredicted unfavourable changes in conditions involving geological aspects or/and natural risks may occur. This results in distorting the planned course of production and in a failure to reach the assumed rate of extraction. This may be avoided by excavating and preparing a so-called backup face. However, it should be kept in mind that this results in the necessity to pay higher expenses. The question how much higher, and whether such a manner of decreasing the risk of disrupting the assumed production rate would be profitable for the company, should be answered based on the performed economic analyses.

Summary

Due to the specific nature of mining production, manifested, among other things, by such features as (Turek and Michalak 2009; Bąk 2008):

- the diversity of conditions for conducting the activity, resulting from the changing geological-mining conditions of the deposit,
- low flexibility of the production process, associated with the impossibility to conduct alternative production,
- the continuous migration of the locations of conducted operations,
- the considerable diversity of individual processes constituting extraction, combined with their coexistence,
- a very long-lasting investment process,
- high capital intensity, both of the investment and operational activities, additionally characterised by a high level of fixed costs

planning the course and magnitude of production in a mining enterprise must proceed with the highest possible diligence. One should take into account a wide range of presented environmental, organisational and technical conditions, deciding about the safety and correctness of the course of the assumed production activities. However, in order to make them economically feasible and produce satisfying results in that regard, it is also necessary to analyse them carefully with respect to financial outcomes.

The decisive assumption should involve absolute compliance with the principle that any undertakings are only planned in seams which may produce commercial coal with quality parameters allowing a justified supposition that it will be saleable. This means that one must not produce coal for which they cannot find a buyer, and which will be stored in heaps.

It may be argued that if the current approach to the manner of their management is unchanged, in particular, if the economic aspects of the conducted activity are not attributed greater significance, then certainly any, even the most drastic actions intended to decrease the production costs and improve the efficiency of functioning without precise location of the places and causes of their high level, these actions will always be only temporary, possibly resulting in a short-term improvement.

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PRODUCTION PLANNING IN A MINING ENTERPRISE – SELECTED PROBLEMS AND SOLUTIONS

Abstract

Planning in a mining enterprise is a complex and multifaceted action. For this reason, it is necessary to provide its proper organisation and adjust it to the specific conditions of conducting underground mining extraction. The prepared plans must make up a cohesive internal system, unambiguously determining the manner, range and safety requirements of the conducted extraction. In the most general manner, the various types of plans developed by organisational units of mining enterprises can be divided based on the timeframe, type, scope and object of planning. These are strategic plans, tactical plans and subject-based plans. The aim of the article is to present the issue of production planning in a mining enterprise and for the preparation of such a plan, first and foremost, information about, among other things, applicable legal regulations, market conditions and the specificity of a mining enterprise are necessary. Underground extraction of black coal deposits must be conducted while respecting the rules of sustainable development which satisfies current needs, without compromising the ability to satisfy the needs of future generations. Due to the specific nature of mining production, manifested, among other things, by such features as the diversity of conditions for conducting the activity, resulting from the changing geological-mining conditions of the deposit, low flexibility of the production process, associated with the impossibility to conduct alternative production and a very long-lasting investment process, planning the course and magnitude of production in a mining enterprise must proceed with the highest possible diligence. One should take into account a wide range of presented environmental, organisational and technical conditions, deciding about the safety and correctness of the course of the assumed production activities. However, in order to make them economically feasible and produce satisfying results in that regard, it is also necessary to analyse them carefully with respect to financial outcomes.

Keywords: planning, strategic plan, mining enterprise, production capacity of mine

**PLANOWANIE PRODUKCJI W PRZEDSIĘBIORSTWIE GÓRNICZYM –
WYBRANE PROBLEMY I ROZWIĄZANIA**

Streszczenie

Planowanie w przedsiębiorstwie górniczym jest działaniem złożonym i wieloaspektowym. Z tego powodu konieczne jest jego właściwe zorganizowanie i dostosowanie do specyficznych warunków prowadzenia podziemnej eksploatacji górniczej. Sporządzone plany muszą tworzyć spójny układ wewnętrzny, jednoznacznie określający sposób, zakres i wymogi bezpieczeństwa prowadzonej eksploatacji. Różnego rodzaju plany, opracowywane przez komórki organizacyjne przedsiębiorstw górniczych, najogólniej można podzielić ze względu na okres, rodzaj, zakres i przedmiot planowania. Zalicza się do nich plany strategiczne, plany taktyczne oraz plany podmiotowe. Celem artykułu jest przedstawienie zagadnienia planowania produkcji w przedsiębiorstwie górniczym i dla opracowania takiego planu niezbędne są przede wszystkim informacje dotyczące między innymi obowiązujących przepisów prawnych, uwarunkowań rynkowych oraz specyfiki przedsiębiorstwa górniczego. Podziemna eksploatacja złóż węgla kamiennego musi być prowadzona z poszanowaniem zasad zrównoważonego rozwoju, który zaspokaja obecne potrzeby, nie zagrażając możliwościom zaspokojenia potrzeb przyszłych pokoleń. Ze względu na specyfikę produkcji górniczej, przejawiającej się w wielu aspektach, począwszy od zróżnicowanych warunków prowadzenia działalności, poprzez małą elastyczność produkcji, kończąc na długotrwałym procesie inwestycyjnym planowanie przebiegu i wielkości produkcji w przedsiębiorstwie górniczym, musi być prowadzone z jak najwyższą starannością. Pod uwagę powinien być brany cały szereg przedstawionych uwarunkowań środowiskowych, organizacyjnych oraz technicznych, decydujących o bezpieczeństwie i prawidłowości przebiegu założonych działań produkcyjnych. Jednak, aby były one sensowne ekonomicznie i przynosiły zadawalające efekty w tym względzie, konieczne jest także ich staranne przeanalizowanie pod względem skutków finansowych.

Słowa kluczowe: planowanie, plany strategiczne, przedsiębiorstwo górnicze, zdolność produkcyjna kopalni