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Prerequisites for Planning the Volume and Quality of Coal Mining in Poland

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Abstract: *The coal mining activity in Poland is characterized by its unique specificity and is significantly different from other types of economic activity in the market. This is due to several aspects inherent in the mining industry. All mining activities are based on mineral deposits. Mineral deposits, i.e. natural concentrations of minerals, rocks, other solids, gaseous and liquid substances (in the form of seams or other structures), the extraction of which can yield economic benefits, and which are the subject of mining extraction, are required for the functioning of mines and mining enterprises. The most common goal of the planning process is to determine the size of the extraction and the order and method of the deposit exploitation, ensuring the rational deposit management and the required level of safety of the activities carried out.*

The aim of the work is to present selected exceptions of mining production planning in Polish enterprises of coals. The article presents among others planning the extraction of coal, planning the production of a given coal types, the selection of mechanization equipment in Poland.

Keywords: *coal mining, mining activity, detailed exploration*

1. Introduction

The coal mining activity is characterized by its unique specificity and is significantly different from other types of economic activity in the market. This is due to several aspects inherent in the mining industry.

All mining activities are based on mineral deposits. Mineral deposits, i.e. natural concentrations of minerals, rocks, other solids, gaseous and liquid substances (in the form of seams or other structures), the extraction of which can yield economic benefits, and which are the subject of mining extraction, are required for the functioning of mines and mining enterprises [Turek 2010]. In addition, this assumption determines specific features related to the deposit itself. These are, among others [Saługa 2009]:

- Uniqueness - based on the occurrence of a given deposit,
- Non-renewable character - related to the depletion of the deposit,
- Uncertainty regarding the abundance, structure, and deposit conditions,
- The uniqueness of the conditions of operation in each newly started mining excavation.

The production capacity is closely related to the abundance of natural resources. In addition, production conditions are also dependent on underground environmental factors, such as natural hazards, geological conditions of reservoir deposition, and the depth of exploitation [Jonek-Kowalska 2012]. Therefore, many production factors are independent of the entrepreneur and cannot be shaped.

The most common goal of the planning process is to determine the size of the extraction and the order and method of the deposit exploitation, ensuring the rational deposit management and the required level of safety of the activities carried out.

However, taking into account the profitability of operations, mining companies and mines should take into account the possibility of obtaining a product with the best quality parameters, ensuring cost-effective sale while reducing costs in order to obtain long-term profit, already at the stage of planning the future exploitation.

The types of plans developed in mining enterprises may be determined on the basis of various criteria (Fig. 1). In order to maximize the profit from coal sales, in addition to planning the amount of coal produced, it is extremely important to draw up a subjective plan regarding the appropriate product structure, characterized by the highest quality parameters meeting the requirements of the consumers. However, a realistic plan requires, among other things, the knowledge of the geological and mining conditions of the deposits scheduled for future exploitation. This, in turn, should be the basis for the selection of appropriate machines and devices, which will be used in preparation works and during the extraction.

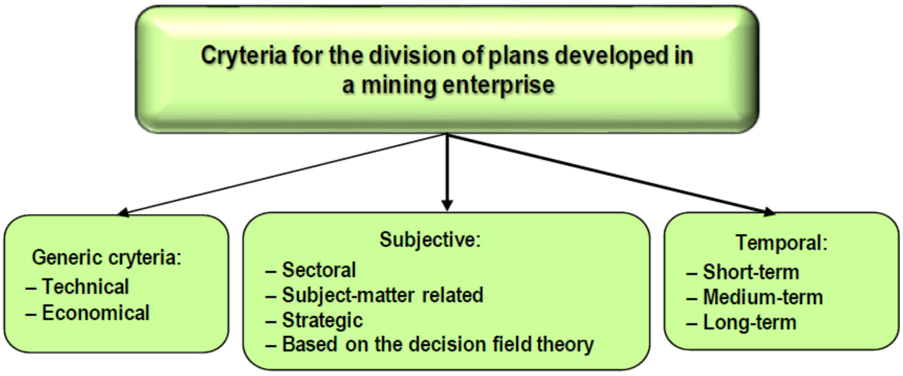

Fig1. *Criteria for the division of plans developed in mining enterprises.*

Source: own work.

2. Planning the Extraction of Coal

The planned volume of coal production in a given period is set for the entire mining enterprise (or mine) based on detailed analyzes of various factors, including those characterizing the production capacity. Before determining the volume of coal production, the planning process requires a detailed analysis of all factors affecting the production capacity of individual mines. These include:

- Exploitation front,
- Underground transport,
- Vertical transport,
- Ventilation,
- Mechanical processing.

The production capacity of a given mine is the number of tons of mineral that, under existing geological, mining, technical, and organizational conditions, can be extracted over a specified time period. In this respect, the determination of the technical production capacity for the planned period is based on:

- Determining the current production capacity,
- Estimating the production capacity in the analyzed period.

An increase in production capacity may occur as a result of:

- Technological and technical development,
- The commissioning of new projects,
- The implementation of major repairs.

It must be remembered that carrying out major repairs may also work the other way around, that is reduce the production capacity as a result of enforced downtime during the repair process (either the device or the entire system must be shut down).

In general, the level of production in the mine is determined from above. The management of the mine, developing a technical and economic plan (sometimes referred to as the technical-industrial-financial plan), does not deal with determining the size of tasks - it is the domain of the management of the mining enterprise (coal company), which owns the mine. All efforts should be focused on designing and developing measures and methods required to carry out the planned tasks.

Due to the fact that the finished product, i.e. hard coal, is fairly homogeneous in nature, the simplest way of determining the volume of its production is the quantitative representation in natural mass units. In order to avoid possible mistakes when quantifying the production issues, it is necessary to clearly specify the mass units in which the quantities included in the plan are expressed. In the case of hard coal, these are tons.

In certain situations, when a natural unit of measure does not allow to give any significant quality feature of a given product, an arbitrary unit is introduced, while the natural unit is replaced by an index or a conversion factor. For example, without specifying the net calorific value of coal, the amount of coal expressed in natural units, i.e. in tons, does not determine the degree of its usefulness for energy generation. To underline the importance of this parameter, an arbitrary unit , the so-called coal equivalent (a ton of coal equivalent, defined as a metric ton of coal with a net calorific value of exactly 7000 kcal/kg, or approximately 29.3 GJ/Mg), was introduced. As a result of the multiplication of the amount of coal expressed in natural units, tons of coal, by the conversion factors, the amount of coal in arbitrary units, i.e. tons of coal equivalent, are obtained.

The natural and arbitrary units of measure have both advantages and disadvantages; this is due to the fact that different units of measure are used for different types. Expressing the production volume in natural (as well as in arbitrary) units of measurement enables or complicates adding different types of production to each other and summarizing the production of a given mine or enterprise. Thus, the obtained data on the entire hard coal mining sector are even less clear.

Therefore, the use of certain units of measure and using them to express the quantities of individual products does not exclude the use of another units, which overcomes the mentioned shortcomings and reduces the number of products to a common denominator. The value of the production expressed in monetary units - PLN can serve as an example. However, the valuation of the production also has its drawbacks, the most important of which is the fluctuation of the value of money over a period of time, i.e. inflation. For this reason, a purely arbitrary idea of fixed prices, is being used. Unfortunately, fixed prices of coal do not take into account its types (ranks). Due to the fact that not all production expenditures can be recognized in unchanged prices, these prices are primarily used for the valuation of the production. They can be used to evaluate the performance of the mine or its units only in the case when the use of quantitative indicators is not possible. Thus, fixed prices have a limited scope of application and have their shortcomings. Therefore, apart from the quantitative and qualitative approach in constant prices, it is also necessary to evaluate the production in current prices.

After accepting the guidelines on the production volume, the task of the mine management is to plan the assumed production volume. It is divided into two factors:

- Spatial - into mining areas and coal excavations,
- Temporal - into time periods covered by the plan - quarters in the case of annual plans, months for quarterly plans, and days in the case of monthly plans.

The requirements for the safe operation of mines must be respected; in addition, the requirements regarding the appropriate quality parameters, i.e. net calorific value, sulfur content, ash content, and moisture contents, must be taken into account. The net calorific value is a measure of the amount of chemical energy contained in coal, which can be converted into heat in the combustion process. The net calorific value depends primarily on the moisture and ash content in coal, and, to a lesser extent, on the type of coal.

From a theoretical point of view, when determining the mining capacity, there is a certain difference between the exploitation front and the output plan. In the first case, the entire front that could be created in the planned period, as a result of the proper implementation of the exploratory and preparation works, should be presented. However, in the second case, only the output plan, limited by factors outside the exploitation front, should be taken into account.

In practice, the production capacity of the mine is being planned at a time when guidelines on the volume of extraction are already known. As a result, the production capacity plan taking into account the exploitation front is prepared on the basis of the planned output. Thus, it becomes also a plan for mining activities to be carried out at individual faces and at certain time periods. The possible excess production capacity of the exploitation front in relation to the planned output can be observed based on the area outside the exploitation front.

When planning the output, one should remember about the difference between the coal and run-of-mine coal (excavated material). The amount of mined coal (the coal that comes directly from a mine) and processed coal is different. According to the adopted definitions, the production of coal includes the process of converting ROM coal into marketable product, i.e. the amount of coal that is obtained after it passes through the processing plant. Only this coal meets the quality and technical standards. This amount of coal is called the net coal output (coal yield), in contrast to the excavated material transported to the surface, the so-called gross coal output (including waste rock).

3. Planning the Production of a Given Coal Types

When estimating the coal mining capacity, special attention should be paid to the types (ranks), grades, and sizes of coal. Coal may have different physical and chemical properties, which in individual cases can make it useful or unsuitable for various purposes. The mentioned properties affect the prices, which are often different despite the same production costs. Taking this into account, it is necessary to develop a plan for the volume of coal production divided into its types (ranks), grades, and sizes.

The division into types is based on the natural properties of coal determining its technological suitability (Table 1).

Table1. *Breakdown of coal into types*

Coal type	A distinctive feature	The volatile matter content V^{daf} [%]	The sintering Ability RI	Application:
Flame coal	31,1 31,2	$V^{daf} > 28$	RI ≤ 5	Non-baking coal, high volatile matter content, long and strong flame. Used for energy purposes in all types of boilers and furnaces (industrial and household furnaces, generators).
Gas-flame coal	32,1	$V^{daf} > 28$	5 > RI ≥ 20	Slightly baking coal, high volatile matter content. Used for energy purposes in all types of boilers and furnaces (industrial and household furnaces, carbonization, hydrogenation). In the case of RI close to 20, it can cause problems in boilers with conventional retort burners.
	32,2		20 > RI ≥ 40	Poorly baking coal, high volatile matter content. Used for energy generation in grate, chamber, dust furnaces, and for carbonization.
Gas coal	33	$V^{daf} > 28$	40 > RI ≥ 55	Medium baking coal with high gas and tar yield. Used for energy generation in grate and dust boilers with retort burners. Also used in the gas industry and coal blends for coke production.
Gas-coking coal	34,1 34,2	$V^{daf} > 28$	RI > 55	Strongly sintering coal, with high gas and tar yield, and medium expansion pressure. Used for the production of coke and in the gas industry.
Ortho-coking coal	35,1	$26 > V^{daf} > 31$	RI > 45	Medium to strongly sintering coal, medium volatile matter content, high expansion pressure. Used for the production of metallurgical coke.
	35.2A 35.2B	$20 > V^{daf} > 26$		
Meta-coking coal	36	$14 > V^{daf} > 20$	RI > 45	Medium to strongly sintering coal, low volatile matter content, high expansion pressure. Used for the production of foundry coke.
Semi-coking coal	37,1	$20 > V^{daf} > 28$	RI ≥ 5	Poor sintering coal, medium or low volatile matter content, medium expansion pressure. Used in the coking industry (coal mixtures). It can also be used for energy purposes, i.e. in special furnaces and for the production of smokeless fuel.
	37,2	$14 > V^{daf} > 20$		
Dry steam coal	38	$14 > V^{daf} > 28$	RI < 5	Poor sintering coal, low volatile matter content, short flame. Used in blends for coke production. It can also be used for energy purposes, i.e. in special furnaces and for the production of smokeless fuel.
Anthra	41	$10 > V^{daf} > 14$	–	Non-baking coal. Due to the very low volatile

-cite				matter content it requires the use of special furnaces. Used in blends for coke production. It can also be used for energy purposes, i.e. in special furnaces and for the production of smokeless fuel.
Anthra -cite	42	$3 > V^{daf} > 10$	–	Non-baking coal. Due to the very low volatile matter content it requires the use of special furnaces. Used in metallurgy and in the production of electrodes.
Meta-anthra -cite	43	$V^{daf} < 3$	–	–

Source: own work based on the PN-82/G-97002 standard.

The division used is important in determining the suitability of coal for chemical processing. In addition to many other properties, the ash content has a major impact on the possibility of using different types of coal for different purposes. Too high ash content may prevent the use of coal in coking plants and make it necessary to classify it as steam coal.

The characteristics of particular coal types (ranks) are the result of natural processes, i.e. the conditions of coal formation and changes occurring in later geological periods. These characteristics are not affected by the way of mining or other production processes. Contrary to what is claimed, the features determining the type of coal in a specific seam or its part are more or less stable, while the changes affecting the coal type take place quite slowly and infrequently. However, several types of coal can be found in one mine; therefore, already at the planning stage it is necessary to pay attention to the correct classification of coal types.

When developing a coal production plan with the division into types, classification to a particular type of coal is based on the properties of coal after passing through the processing plant that is the properties of coal supplied to the consumer. Therefore, the amount of coal extracted from a seam containing gas-coking coal is not equal to the amount of gas-coking coal in the production plan; a given coal, with the parameters corresponding to the properties of gas-coke coal, can be included in the production plan only after passing through the processing plant. This is illustrated by the examples below:

- Coal from the seam containing coal type 33 and coal type 34.
- The mixture of different types of coal during the transport of run-of-mine coal (excavated material to the surface due to the lack of appropriate technical and organizational solutions.

As a result, such coal can only be used by energy consumers and often is sold at significantly lower prices.

Therefore, when developing plans for mining activities to be carried out at individual seams and faces, the type of coal should be taken into account. However, the global production plan should take into account the coal that passed through the processing plant and is received by the recipient. Indeed, the inclusion of one or another type of coal in the production plan should be based on the sales plan and the requirements of specific recipients. It is also worth remembering about the level of pollution included in the mining plan.

Planning coal mining by type is similar to planning the entire extraction. Tasks related to the production of coal of specific type should be spread over those coal mines and areas, where coal is assigned to a specific type. In addition, the possibility of isolating this coal in the transport and processing processes should be taken into account; furthermore, the ash content in the marketable coal should be monitored in order to not exceed the permissible limits and to prevent the type change.

Table2. *Coal size*

Grade	Coal size	Symbol	Grain size [mm]		Highest oversize content * [%]	Highest residual content * [%]
			Upper	Lower		
Coarse	Bean coal	Ks	–	Above 125	–	5
	Cobble coal I	Ko I	200	125	5	6
	Cobble coal	Ko II	125	63	5	8
	II	Ko	200	63	5	8

	Cobble coal Nut coal I Nut coal II Nut coal	O I O II O	80 50 80	40 25 25	5 5 5	8 8 10
Medium	Pea coal I Pea coal II Pea coal	Gk I Gk II Gk	31,5 20 31,5	16 8 8	5 5 5	10 10 10
Coal dust	Coal dust I Coal dust II	M I M II	31,5 20-10	0 0	5 5	– –

Source: own work based on the PN-82/G-97001 standard.

** – coal for energy production.*

The classification by size is of major technological importance and is based on the size of coal grains. A set of grains of more or less the same size is referred to as the coal size (Table 2).

As a result of its natural structure, extraction method, mining methods, type and method of transport, and processing, the coal is to a greater or lesser extent crushed to pieces of various sizes. The share of production of coal with a given grain size is, for a given mine, fluctuating in relatively small ranges. It may be subject to major changes only in longer periods, as a result of technological changes or the exploitation of other seams. Coals of different size have different sales prices, which results from the different net calorific value and availability of coal of specific sizes. Different boilers are adapted to different coal sizes. In the case of boilers used outside the power industry, the most sought-after are coarse and medium-grained coals, whose share in the total production of a particular mining company or mine typically ranges from 30 to 10%.

A correctly conducted process of planning the mining activity should focus on ways to reduce the output of fine coal. Planning the mining activity should not be based on a statistical analysis of the previous or current period updated with changes in the share of production from individual seams. It is necessary to take into account the effects of changes and organizational improvements that can be implemented in the mine in the discussed planning horizon. Such changes may include simplified methods of disposal of run-of-mine coal (excavated material), the reduction of the number of separation points, and changes in mining technology.

The coal grades characterize it as an energy raw material and allow the potential recipient to become aware of its suitability for defined purposes. The basis for the division into grades are: the net calorific value, ash content, and sulfur content. A given grade is marked with a three-part symbol, e.g. 30-07-05 denotes coal with a calorific value of 30 000 kJ/kg, the ash content of up to 7%, and sulfur content of up to 0.5%, the 19-15-11 code is used for coal with a net calorific value of 19 000 kJ/kg, o, the ash content up to 15%, and sulfur content of up to 1.1%.

Since the net calorific value of coal depends significantly on the ash content, it must be borne in mind that exceeding the permissible ash content may result in the need to classify a given coal to an inferior grade and /or a lower type (rank of coal). Naturally, this leads to a reduction in the revenue generated.

The ash content in the run-of-mine coal is, to a large extent, a natural feature of coal. Depending on the processing system used, its amount after processing (net coal) can be significantly reduced. The ash content in the coal coming out of the processing plant is largely dependent on the equipment of the plant and the assumed degree of processing.

Coal is generally classified into types and grades. The two main types are steam coal and coking coal.

The gradation of steam coal is based on the net calorific value and ash content. In the coking coal group, the division into grades is based solely on the ash content, because the net calorific value of coals in this group is always high; the chemical processing of coal does not require further division. The same limit value of the permissible ash content has been set for all grain sizes of the given type and grade of coal. This coal is most often crushed into small sized pieces.

Regarding the planning of the production taking into account coal grades, it should be noted that it does not present serious problems, provided that the production plan has been correctly designed (this also applies to the division into types and grain sizes). However, attention should be paid to the compatibility of the grades, to which each type and grain size belong. In other words, the planned production of each type of coal to should be broken down into individual grain sizes, and each grain size (in each type) should be classified to the appropriate grade.

4. The Problem of Detailed Exploration of Coal Deposits

The natural conditions prevailing in coal seams affect not only the choice of exploitation methods, but also the size and quality of coal output. Any imperfections in the planning process result not only in a lower hard coal yield, but also in a greater contamination of the excavated material, which worsens the quality of the production and entails additional costs.

When planning the extraction process, it is necessary to adopt an exploitation system that determines the methods for the exploitation of coal seams while taking into account the factors determining the solving of exploitation problems. The quality and volume of coal production is largely affected by natural conditions. Undoubtedly, these include the depth of the seam, its thickness, dip angle, floor and roof conditions, the workability of coal and accompanying rocks, and the gas content of the deposit.

The deposition conditions and properties of the deposit significantly affect the assessment of the operational efficiency, which is crucial for decisions in the operation planning process. Due to the need for exploitation at ever greater depths, the mining process is conducted in increasingly difficult conditions, which also complicates the process of planning mining operations. However, it should be remembered that we have more and more possibilities to accurately determine the seam conditions.

The pressure of the rock mass increases with the increase in the depth of exploitation; this increases the risk of rock bursts and difficulties related to the dimensions of mining excavations. In addition, the climatic conditions worsen and the fire hazard increases. Hence, the need to develop specific excavation methods.

The thickness of the seams affects the choice of exploitation methods. In addition, it must be emphasized that the thickness of the seam is a factor that not only affects the quality and volume of production, but also its effectiveness. The commonly used, and recognized as the most efficient, longwall mining is the most advantageous in the case of medium seams, i.e. with a thickness from 1.5 to 3.5 m. During planning, it is necessary to pay attention whether the thickness of the seam in the entire mining area is more or less the same; the changes should be within the height of the powered roof support.

The exploitation method significantly affects the dip angle of the seam. The exploitation of seams with a large dip angle requires the use of methods and measures aimed at protecting the crew and equipment against the falling excavated material. The need to apply additional security measures affects both the size and quality of production, as well as its effectiveness.

The roof and floor conditions are another factors that have a significant impact on the size and quality of production. They also determine the scope of the mechanization process that can be applied, sometimes even making it difficult to use powered roof supports. Good floor conditions are of particular importance for the high efficiency and significant improvement of work safety.

When planning the exploitation process, the proper selection of lining and mining machines is of great importance. Therefore, it is crucial to carry out a preliminary analysis of the physicochemical properties of coal and surrounding rocks. The key parameters determining the physico-chemical properties of rocks and the scope of their use are presented in Table 3.

Table3. *Parameters defining physical and mechanical properties of rocks.*

Parameter	The purpose of determining the parameter
Unaxial compressive strength	Determination of strength parameters of coal and surrounding rocks (dry and subjected to long-term exposure to water), characterizing their behavior during exploitation, for the proper selection of mine workings
Unaxial compressive strength in the state of water saturation	
The impact of humidity on the durability	
Tensile strength	
The Young's Modulus	
The Protodyakonov Index (the strength coefficient of the coal (f))	Determining the properties that enable the proper selection of a mining machine
The Poisson's Ratio	Determination of characteristics, modulus of deformation, and the bending strength of the rock mass for proper selection of linings.
The specific weight of the rock	Engineering calculations, e.g. the weight of a unit of volume in the relaxed state

Rock quality test	Determination of properties enabling proper selection of a mining machine and linings.
Slakeability	Determination of strength properties under the influence of long-term moisturizing - for proper selection of linings.
The potential elastic energy	The determination of rock burst tendency for the exploited deposits
The Burst Energy Index for coal	
Residual deformation	
Critical deformation	
The post-critical fall module	
The class of the roof of the deposit	Determination of properties enabling proper selection of linings.
The Workability Energy Index	Determining the properties that enable the proper selection of a mining machine
Volumetric density	The calculation of compressive strength - for the correct selection of mine workings.

Source: [Turek 2010].

The gradual depletion of the available deposits has led to the need to exploit the deposits under unfavorable geological and mining conditions. These conditions result in many difficulties; for example in the case of high methane content, methane drainage of the coal seam is required before any mining activities in the area. In addition, when planning mining activities in coal deposits containing large amounts of methane and mixtures of other gases, e.g. carbon dioxide, one should take into account the risk of rock outbursts and squealers. In this situation, it is necessary to use special, less effective methods of selection, which, unfortunately, can reduce the volume of production and negatively affect the quality of the output.

When planning mining activities, the knowledge on the degree of exploration of working cavities is necessary. The type and quality of coal output spoil should be identified based on the samples collected from the seam in their natural state. However, the possible contamination of the excavated material, for example as a result of the fall of roof rocks or as a result of dinting, should be taken into account. Therefore, the need to analyze the deposit samples collected during different phases of its operation should be taken into account already during planning the exploitation. Mining activities have proved that it is worth to carry out such analyzes in advance in order to gain knowledge on the deposit conditions.

The safety of mining activities is affected by fissures of rocks in the roof of the excavation. Structures with the lowest strength and cracks occurring in the seam and surrounding rocks have an impact on the safety of conducted activities, labor consumption of the mining process, and the fragmentation of the output. Therefore, the selection of sites for preparatory excavations and stopping faces should be preceded by the development of the so-called fissuration grid or "rose of fractures"(rose diagrams of fractures in roof rocks).

Particular attention should be paid to the geological structure of coal seams. It is extremely important to:

a) Determine changes in the thickness of the seam, (the extent of leaching, thinning, thickening, etc.)

b) Determine the course of faults and estimate the stratigraphic throw.

The method of reflected waves, which is commonly used in underground mines and works well in the detection of these disturbances, can be applied for this purpose. A high efficiency in terms of technical and methodological solutions ensuring the sufficient accuracy of determining the location of coal seam discontinuities has been confirmed in a work by [Siata 2007]. However, in order to ensure the proper efficiency of the seismic recognition, it is necessary to properly select the methodology of measurements and their parameters. However, when determining the course of the fault, it is often important to rely on drilling works; the information obtained along with the seismic data will enable a satisfactory geological interpretation. It should be remembered that both measurements and their interpretation have certain limitations, resulting from the accessibility conditions and the physical parameters of propagation of seismic waves in the rock medium. In turn, the seismic scanning method makes it possible to determine the isolines of distribution of the measured parameters in the analyzed part of the seam. This is the basis for identifying the so-called abnormal zones, which indicate various geological forms disrupting the continuity of the seam. It should be emphasized that at individual stages of planning, mining maps should contain continuously updated and accurate data on the occurrence of tectonic disturbances. Such disturbances, due to the overstress, may require increasing the parameters related to the stability of the powered roof support, hinder, or completely prevent mining activities.

The mentioned factors significantly affect the size and functionality of the production, while their implementation ensures safe mining activities.

In the course of planning work, the knowledge of the course and size of deformations of dog headings is of great importance. This particularly applies to the so-called longwall galleries, because their condition determines the pace of the planned production. Any shortcomings under the conditions of high production concentration are unacceptable. The damaged longwall galleries hinder the production process due to the following reasons:

- The increase of methane hazard,
- The problems with the efficiency of the ventilation system,
- The hindered transportation,
- The difficulties in transporting the run-of-mine coal (excavated material).

5. The Selection of Mechanization Equipment in the Aspect of Mining Quality

The proper selection of mechanization systems, their dimensions, power, strength parameters, and control systems significantly affects the pace of the planned mining production process, and the size and quality of production.

In the hard coal mining industry, the devices that make up the mechanization systems for exploratory and preparatory works and extraction are constantly being improved. They are improved both in terms of construction and technology, obtaining increasingly better operation parameters. The technologies of conducting works with their use are also improved. Bearing in mind the high prices of mechanization systems, it is necessary to accurately identify the geological and mining conditions of the exploited deposit already at the stage of planning mining activities. The right choice of complex mechanization equipment may give better production results. In contrary, the use of improper equipment can significantly hinder the pace of mining activities, reducing their safety and efficiency.

As stated in the section four, the main factors determining the operating conditions, and, at the same time, significantly affecting the selection of equipment, must include: the thickness, dip angle and floor conditions of the seam, and the mobility of unmined coal and accompanying rocks and their physico-chemical parameters, in particular the workability.

When choosing the technical equipment, it is also needed to determine the range of variability of natural conditions in the proposed exploitation area. This is due to the fact that individual parameters influence the selection of mechanization systems in a variety of ways and in a diverse range. This particularly applies to changes in the thickness and dip angle of the seam, the structure of the floor and roof of the seam, strength properties of floor and roof rocks, mobility of unmined coal, floor microtectonics, methane content, hydrogeological conditions, and gas and rock outbursts.

The thickness of the seam significantly affects the choice of device parameters. The proper selection of mechanization systems in the case of thin seams is of particular importance. The powered roof support determines the height of the face, which is the size of the so-called exploitation gate, i.e. the average thickness of the seam between the roof and the floor. It should be remembered that the height of the longwall face cannot be greater than the extension of the powered roof support, reduced by the reserve of slide and extension. The slide reserve in the lower range and height of the powered roof support section must take into account the maximum subsidence of the roof part in the anti-breaking down mining support. In addition, a reserve is needed for drawing off the sections and their proper shifting

In addition to the powered roof support, the selection of a mining machine is also very important, as it allows avoiding the need for roof or floor ripping. This results not only in the deterioration of the quality of raw material, but also reduces the pace of production and leads to increased costs. In this case it is often necessary to use coal plough instead of combined cutter loader.

The dip angle of the seam has a significant impact on the selection of machinery and equipment used, but also on mining activities including preparatory works and extraction. During the planning process, keep in mind the so-called stick-slip phenomenon, which affects both machines and equipment used, as well as excavated material. Often, this unfavorable phenomenon can already be felt at an angle of even below 10 °. In such case, the top of the planned longwall should be ahead of the lower part.

The best possible identification of various properties of rocks surrounding the planned stops and dog headings is extremely important in the process of selecting the equipment for the mechanized complex. The proper cooperation with the rock mass in the case of dog headings requires the selection of the powered roof support, including longwall-heading crossings protection.

The roof rocks, not only in the working faces, but also in longwalll faces, are often disintegrated and fall to the excavation. Of course, there is a big difference between the work of the powered roof support and the individual housing, which, provided that the work is carried out with care, supports the roof continuously until drawing off. When designing longwalls, it must be remembered that the roof rocks are repeatedly pressed, because the individual housing sections are cyclically loosened, moved, and re-expanded. Therefore, they are quickly destroyed and tend to fall to the excavation. This is also the reason for the deterioration of the quality of the run-of-mine coal (excavated material) and the increase in transport costs. In addition, it adversely affects production economics. For this reason, floor conditions should be taken into account when planning mining activities, and if there are doubts as to the strength properties, appropriate tests should be carried out in advance. These include the analysis of:

- Strength properties of roof rocks,
- The layering of roof rocks,
- The structure of drill cores in the roof,
- The quantity and quality of horizontal and vertical floor cracks,
- The macropetrographic composition of roof rocks.

The scientific base has research methods and tools that can be used to study the floor conditions and select the proper roof support.

In design works, it is also very important to take into account changes in the cross-section of longwall galleries and disruptions of the floor and side walls resulting from the existing geological and mining conditions. This is due to the fact that the key decisions regarding the dimensions of the excavations and the excavation support are taken at the planning stage, which in turn affects the safety and costs of mining works. This is of particular importance in the case of deep exploitation, high tectonic stress zones, soft layers in the coal seam and floor, and significant waterlogging. According to S. Prusek „*When it comes to the stability of longwall workings, the bearing capacity of the floor is often an underestimated factor*" [Prusek 2016].

Both scientific research and mining practice indicate that in the case of rocks with a high mineral content and significant waterlogging, the bearing capacity of floor rocks should be of particular interest already at the planning stage [Prusek 2016, Rajwa 2009, Rajwa 2016, Rajwa et al. 2015]. The complex method, which seems to be effective, can also be used for this purpose because the correctness of the operation of a foot piece lifting system, in addition to calculations of the range of fracture zones in floor rocks, is determined based on bench testing [Witek 2014].

In addition, the expected deformations of longwall galleries, and configurations and micro-tectonics of the floor are also important when taking into account the proper selection of equipment used in the disposal of excavated material.

The parameters of mining machines, especially their efficiency, to a large extent depend on the floor and roof structure and the tendency of coal and coal partings to separate from unmined coal during the mining process - i.e. the workability. It is an important parameter characterizing the properties of rocks, which results from

- The physico-mechanical properties of coal in the seam,
- Stresses in the rock mass resulting from the exploitation pressure, which disrupts the structure of the coal seam at the longwall face,
- The layout of petrographic layers of the coal seam,
- The adhesion of layers of the coal seam on the contact with the floor and roof,
- The type of floor and floor rocks and their impact on the coal seam,
- The occurrence of coal partings and their size,
- The pace of mining activities carried out at the exploitation front,
- The method of supporting the ceiling.

At the planning stage, it is necessary to observe the principle that the workability decides about the power of the mining machine, the type and size of cutting drums, the type of blades and their distribution on these organs. Coal seams in the deposits of the Upper Silesian Coal Basin (USCB) are generally hard-to -mine. As the coefficient of workability increases, the efficiency of mining machines can be reduced. Hence, the tendency to increase the power of mining machines up to 3 MW for combined cutter loaders and 1.5 MW for coal ploughs. In addition, the most important issue related to the workability is the selection of the proper cutting drums and blades, which can have a significant impact on both the size and quality of production.

In contrast, the effectiveness of excavation depends to a large extent on many natural properties of the seam and accompanying rocks (genesis, tectonics), as well as on mining factors. Undoubtedly, the latter include the pressure and the degree of elastic recovery in the seam at the longwall face. To a large extent, these parameters depend on the pace of mining activities - when a slow pace is planned, elastic recovery of the unmined coal in the longwall face will be observed. In the case of rapid progress, it should be taken into account that the coal seam in the zone not subjected to the elastic recovery will be harder to mine. It is commonly believed that the strength properties of coal seams in the deposits of the Upper Silesian Coal Basin are highly variable. Hence, it is very important to correctly measure the machinability in the zone not subjected to the elastic recovery.

6. CONCLUSION

The production planning in a mining enterprise, in addition to the assumed production volumes in the mines, should also apply to the qualitative and grain size structure of the the marketable coal.

In each mine, the basis for determining the volume of extraction is the production capacity, either currently existing at the time of the plan's development or anticipated (increased, diminished) at the time of the plan's implementation. The natural unit of measure in hard coal mining is ton. However, if it is necessary to determine the usefulness of this product for energy purposes, arbitrary units, the so-called tons of coal equivalent - equal to coal with a net calorific value of 7000 kcal/kg (29.3 GJ / Mg) can be used. After multiplying the amount of coal expressed in natural units (tons) by conversion factors, the information on the amount of heat that can be produced from coal is obtained.

If it is necessary to determine the amount of planned production for the purpose of economic analysis, it can also be expressed in „unchangeable PLN", taking or not taking into account the inflation.

In mining enterprises, in order to obtain the largest possible income from operations, the assumed production volume should take into account spatial and temporal factors. This will allow obtaining a product with the highest possible quality parameters - net calorific value, sulfur content, ash content, and moisture content. Determining the specific types of coal in the individual seams and separating them during transportation and processing enables the production of larger amounts of coal with better quality parameters.

In addition, the process of planning the volume of coal production should focus on ways to reduce the output of fine coal. As a result, the marketed coal will have better quality parameters. This, in turn (often significantly), increases sales revenues despite the same production costs.

It should be underlined that achieving the highest possible results is, to a large extent, also dependent on the correct selection of the equipment for the mechanized complexes in future mine workings, which should be done already at the stage of planning mining activities and based on the results of relevant tests and analysis.

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