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Correct use of mining-related fixed assets as a precondition for the favourable outcomes of the concentration of mining operations in a mining enterprise

Introduction

All the restructuring programs that have been implemented in Polish bituminous coal mining as a primary way to reduce mining costs relied on the increased concentration of mining operations. Those efforts especially involved a significant simplification of existing or newly developed structures for accessing or cutting the deposits intended for extraction; the implementation of advanced mining technologies, and the upgrading of machines used in mine faces. However, in order for these to deliver the expected results, it is important to organize mining operations in such a way that those advanced, and usually very expensive, mining-related fixed assets – machinery and equipment – are used in a sensible manner (Jonek-Kowalska 2013; Gumiński 2015).

The aim of this article is the exploration the factors involved in concentration-related decision-making in mining companies, including the underlying mining/technical, organi-

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zational, and economic/financial aspects. A mining company is understood as a group of related mines, the primary business operations include bituminous coal mining, processing, and trading.

1. Fixed assets in mining

In mines that make up mining companies, nearly 70% of the mining costs are fixed costs, sometimes referred to in literature as semi-fixed costs. Their principal purpose is to maintain the technical or physical infrastructure needed for the processes involved in coal mining. The amount of such costs has little to do with the output level or the consumption of fixed assets. A significant portion of such costs are costs associated with mining-related fixed assets, and especially machinery and equipment used for coal mining in mine faces located within the mining areas. Due to the high level of the fixed costs associated with the depreciation of machinery and equipment, it is critical for mining-related fixed assets to be used sensibly by bituminous coal mines.

Therefore, since the discussed problem is one of mining-related fixed assets, it is important to define some basic terminology. Fixed assets include: real property, machines, equipment, means of transport and any other items that meet the following conditions (The Accounting Act 1994):

- they are owned or co-owned by the company,
- they are complete and can be used as at the date they are accepted for use,
- the expected time of their use is longer than one year,
- they are intended for satisfying the needs of the company connected with its business operations, or for being leased on the basis of a lease or some other similar agreement.

Fixed assets include:

- mining-related assets, i.e. those that are used directly and actively for the purposes of mining,
- non-mining-related assets, i.e. those that only indirectly facilitate mining.

There are also long-term (long-lived) assets, such as: buildings and structures, and short-term assets, such as machinery and equipment.

Fixed assets in mining companies include:

- buildings and structures directly and closely associated with mining (commercial coal mining) – shafts, shaft heads, surface access openings, etc.,
- mining machinery, including in particular extraction machines, such as longwall shearers and heading machines, and coal plow systems,
- scraper and belt conveyors,
- fans, air compressors and pumps,
- underground rolling stock and railway,
- electrical equipment – switchboards, switchgear, transformers, rectifiers,
- processing machinery and equipment.

Whenever such fixed assets are used (or not), they generate costs, which are recorded under amortization/depreciation, short- and medium-term repairs, and lease services. The acquisition, or major repairs, of fixed assets constitute capital expenditures.

An overview of the available literature on the subject (Biały and Hąbek 2016; Brodny et al. 2016; Brodny and Stecuła 2016; Bula et al. 1998; Jaszczuk et al. 1995; Jaszczuk and Tejszerski 2008; Jonek-Kowalska and Tchórzewski 2016; Korbiel et al. 2016; Paraszczak 1999) shows that the issue of sensible use of mining-related fixed assets in bituminous coal mining has been explored briefly at most. There is a need to study the related decision-making and to seek effective methods and tools to enhance this process, particularly in relation to the expensive machinery and equipment used to automate and/or introduce information technologies into mining processes.

2. The impact of the utilization time of installed automated systems on the concentration of mining

Efforts to improve the efficiency of mining operations, that is closely connected with the management of mining-related fixed assets, should necessarily focus on the increased concentration of mining operations. Defined in general terms, the concentration of production means *the output per unit of time per mine element:*

$$Q_{cas} = \frac{W_c}{i_c} \text{ (Mg/unit of time)} \tag{1}$$

↳ Q_{cas} – concentration of mining within the mine element during the specific unit of time (Mg/d, Mg/year),

W_c – output per a specific unit of time per selected mine element – mine face, division, or level, quantified as i_c,

i_c – quantitative description of the mined element W_c, e.g. (number of) pieces or meters of haulage roads.

Previous studies, which helped define the term ‘concentration’, have shown that there are clear correlations between concentration measures and the results describing the efficiency of mining. While there have been views arguing that the excessive concentration of mining might threaten operational stability, it has been commonly accepted that it is the concentration of mining operations that is crucial for their cost effectiveness.

It is also important to note that the concentration of mining means a reduced number of jobs in underground excavation sites, which, in turn, lowers the cost of labor (often significantly). In addition, such sites may pose various threats, and this means that a smaller number of people are exposed to such risks. Polish engineers and technicians seem to be well aware of the crucial impact the concentration of mining operations has on their cost effectiveness and work safety.

What, then, determines the level of concentration in automated mine faces, whether these are galleries or mining areas. It is important to consider this fundamental correlation:

$$Q_c = q_r \cdot T_c \text{ (Mg/hour or minute)} \tag{2}$$

↳ Q_c – concentration of mining within a mine face equipped with an automated system (AS), as defined for a specific unit of time (shift/day/month),
q_r – the actual efficiency (per minute) of the AS installed in the mine face, i.e. the efficiency measured during normal (uninterrupted) mining, loading and haulage of excavated material,
T_c – the actual effective time worked by AS, i.e. the time AS served its roles.

The concentration of mining operations is high if, over a specific unit of time (e.g. an hour), the installed AS is able to mine and load a large output on an operational haulage system, and at the same time its effective time worked is as long as possible. If at least one of these conditions is not satisfied, the concentration will be low. This is an undeniable and irrefutable argument.

The answer provided by Formula (1) only seems simple. What makes it actually difficult, both in theoretical and in practical terms, is the word *actual*, as included in the definitions of both the efficiency and the effective time worked of an automated system. Naturally, the actual values of the terms in the formula are estimated rather than known. The estimate is made either on the basis of statistical past data or is the product of multiple factors.

In order to make Formula (1) more viable, it is necessary to introduce a use factor – separately for the nominal (manufacturer's) mining capacity q_n of the AS, and for the number of days (hours) T_k the system is installed within the mine face. The actual efficiency q_r and actual time worked T_k can be expressed on the basis of specific utilization factors η,

$$q_r = q_n \cdot \eta_z \text{ (Mg/min)} \tag{3}$$

$$T_c = T_k \cdot \eta_t \text{ (min)} \tag{4}$$

When put into Formula (1), values (2) and (3) give:

$$Q_c = q_n \cdot \eta_z \cdot T_k \cdot \eta_t \text{ (Mg/hour or minute)} \tag{5}$$

This gives us information on which factors determine the mining output in a mine face. It depends on:

- the nominal efficiency of the automated system used in mine face q_n,
- the number of days (hours) the automated system worked T_k,

- the utilisation factor for the nominal efficiency of the automated system η_z,
- the utilisation factor for the number of days (hours) the automated system worked η_t.

In Polish bituminous coal mines, virtually all output is produced by wall faces. Consequently, the commonly used systems include a cutting machine/shearer, or, less often, a coal plow system, as a mining and loading machine moving along the wall scraper conveyor, a wall scraper conveyor, and powered roof supports. For gallery operations, this is usually a heading machine, which works in accord with the other machines to facilitate the collection of muck or the construction of supports for the mine workings.

The nominal (manufacturer's) efficiency of mining and loading machines is determined by their manufacturers based on the results of tests performed on professional stations. Under specific geological and mining conditions, an efficiency close to the nominal one may only be achieved if the automated system has all the correct machinery and equipment and the mining operations are organized well. Some manufacturers may choose not to specify the output of their machinery. In such cases this needs to be determined in the mine, and is usually done on the basis of previous experience.

It is also important to remember that in mining machinery an important role is played by the stress and deformations at the mining face. This is due to the fact that cutting machines for mining operate in a state of bidirectional stress and deformation (Biały 2001). The energy necessary to mine a coal bed depends on the energy required to initiate mining. It has been observed that the energy intensity of mining can be regulated by changing the supporting strength of the powered supports. This, in turn, changes the vertical stress within the coal bed. In situations in which the structure of the rock bed located in the cutting machine's, or plow system's web is damaged early, the machine/system will be mining a larger volume of the bed per the same vertical stress. Under appropriate geological/mining conditions within the wall, and when appropriate powered roof supports are used for the installed automated systems, it is possible to create stresses that will cause the structure of the coal bed to break, which, in turn, will cause its energy intensity to be reduced while increasing mining efficiency. It is important to note that solutions for this are also being provided by studies on the properties of mined rocks and efficiency of various mining systems.

It goes without saying that there is a close relationship between the nominal (manufacturer's) efficiency of mining and loading systems and their installed power/capacity. The huge increase in the efficiency of such systems has been achieved at the expense of a significant increase of installed power, which was also associated with the development of the components responsible for programming start-up, control, logging/recording, and signaling, and this, in turn, caused the prices of such systems to increase substantially. But as a result, the concentration of production can now potentially be increased to a high level. Therefore, we could argue that there is a correlation between the nominal mining capacity of longwall automated systems and their installed power and the cost of such machinery.

What is of considerable importance here are two issues – a good knowledge of the conditions under which the technical equipment is to be operated, and the operating reliability of the machinery. If no planning mistakes were made and the technical quality of the equipment is good, the η_z factor will have no significant impact on the mining concentration level at the wall, and its value can be close to 1.

The next factor is the number of days (or hours) T_k, which should be used to determine the expected results in terms of mining output for the selected AS. Here, it is important to consider two things. The first, less frequently applicable, is whether the considered equipment that is installed in a mine face is to be used by the mining division, or is it available in the mine but not ready to be used. And the second is when the equipment is installed in a mine face but, for various reasons, mining operations have been suspended. For reasons related to the cost-effectiveness of mining operations, it would be optimal if such equipment worked with practically no interruption. In order to be able to objectively assess the wall's output (Fig. 1), it is necessary to determine the operating time of the equipment included in the automated system, and especially that of the mining machine.

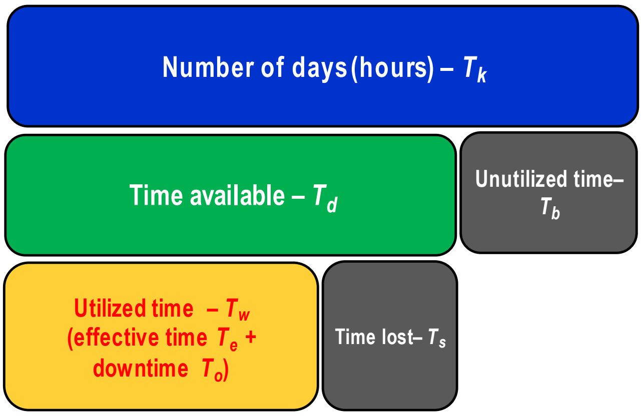

Fig. 1. The number of days the installed automated system is available (for use) vs actually used, and total time
Source: own study

Rys. 1. Liczba dni, w których zainstalowany automatyczny system jest dostępny (do użytku)
w porównaniu z czasem faktycznie wykorzystanym i całkowitym

What is beneficial about this approach is that it provides a transparent overview of how machinery is being used in mine faces, while also showing how much mining power is available but unused. Some time ago this method was known as the potentials method (based on British mining solutions). In the 1970s and 1980s, Polish bituminous coal mining implemented a dispatcher system for the analysis and recording of the operating time of process lines (created in the Central Mining Institute and then developed by COIG). Based on specific assumptions, covering not only the equipment used in mine faces but also in the corresponding process lines, the system enabled the detailed recording of all mining interruptions (Lisowski 2001). The classification of the operating interruptions in mining and their primary sources is presented as a diagram in Figure 2.

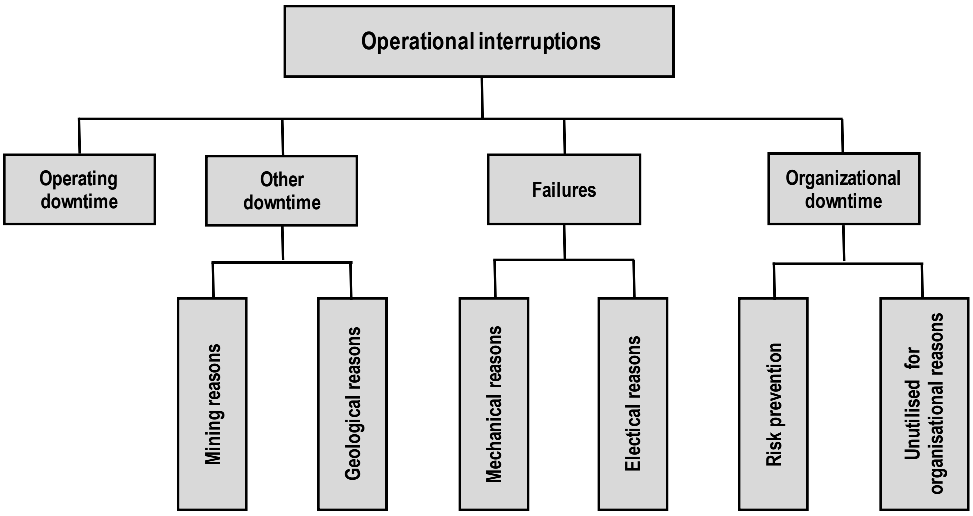

Fig. 2. Operating interruptions to mine face operations and their primary causes
Source: own study

Rys. 2. Przerwy operacyjne na kopalniach i ich pierwotne przyczyny

However, as the range of comprehensive automation services and mine face equipment costs increase, it becomes necessary to ensure that the available machinery and equipment provide superior reliability. At this point, what is of primary importance to deliver efficient and cost-effective mining processes is to concentrate your mining power on as few mine faces as possible. A practical solution to this has been a mechanism for the concentration of mining operations based on efficiency, operating time, and reliability of specific automation systems. This caused mine management and supervision personnel, as well as machinery manufacturers, to gradually become more interested in the timeline elements that corresponded to the reliability of the equipment and efficiency of the electrical power and mechanical services in the mine and manufacturer's service.

When the focus is on increasing the concentration of mining and improving mining efficiency, the key element are the components of the supplementary time, as included in the following formula:

$$T_k = T_w + T_{dp} = T_w + T_b + T_s \quad (6)$$

T_k – number of days/total time,
T_w – utilized time,
T_{dp} – supplementary time,
T_b – unutilized time,
T_s – time lost.

Therefore, in practice, it is important to strive for the effective time worked by the automated system T_w to be as close to the number of days/total time T_k during which it is installed in the mine face. This means that it is necessary to do whatever is necessary to eliminate the components of the supplementary time T_{dp}. If the supplementary time is considered to be a factor with the potential to increase the effective time worked on mine faces, it means that it can also increase their output.

3. The impact of the operation reliability of installed automated systems on the concentration of mining

Longwall faces are currently undergoing continuous improvements in the field of mining technologies, which is related to the application of state-of-the-art automated systems. On the one hand, for quite a long time, this has been imposed by a specific work organization system (while at the same time harmoniously combining the use of the system with individual components of the mining production process), on the other, it significantly influences the size and speed of longwall face advance. The output is related to the development of mining technologies, which also results from the need to apply machines and devices, and appropriate forms of production organization. It is most of all the outcome of the performance of a mining machine and its effective operation time (in practice, maximizing the output of longwall mining during a single shift or day is often limited by the performance of the haulage system) (Turek 2010).

It should be stressed that in longwall excavation sites which are comprehensively automated, the individual work processes are combined together. The structure of the work cycle in the longwall area can be characterized by work organization based on straight-line production. As it has been mentioned before, in the longwall area, various activities are combined together in time and space, which results in the fact that the delay in commencing the mining in relation to the activities entailing roof control is insignificant. The mining and loading machine is the leading element in this system, affecting the number of coal cuttings made during a single shift (day). The remaining activities, i.e. the operation of conveyors and roof control, are closely linked to its operation advance and do not extend the time of a single coal cutting.

The interdependence defining the use of the automated system in the longwall face area is expressed as the straight-line operation ratio p.

$$p = \frac{T_e}{T_m} \tag{7}$$

↳ T_e – effective operation time of a mining machine (h),
T_m – shift time (h).

As mentioned before, as regards the output from a single longwall, it is essential to select a proper mining machine taking the geological and mining conditions into account (Turek 2007). The accuracy of this selection can be determined by the so called machine efficiency ratio *w*.

$$W = \frac{W_n}{W_m} \quad (8)$$

↳ W_n – the nominal efficiency of a mining machine,
W_m – maximum haulage efficiency.

If the mining machine and haulage equipment are selected properly, the *w* ratio value should not exceed 1, while higher values might indicate that the haulage transport efficiency limits the production capacity of a given longwall. In turn, if the value is significantly lower than 1, this might indicate a superfluous "overestimation" of the haulage system parameters.

The actual mining output value Q_r during a single production shift in the longwall area may be determined by applying the following formula:

$$Q_r = T_e \cdot W_n \quad (9)$$

In turn, the theoretical maximum potential output of a longwall face may be determined by applying the following formula:

$$Q = T_m \cdot W_m \quad (10)$$

Given the above, the concentration of mining ratio *K* during a single work shift may be expressed as:

$$K = \frac{Q_r}{Q} = \frac{T_e \cdot W_n}{T_m \cdot W_m} \quad (11)$$

The above relationship clearly demonstrates that the greater the share of the effective operation time of a mining and loading machine (T_e) in the shift time (T_m), the higher the concentration of the mining ratio.

Given the specific nature of the works in the area of comprehensively automated longwalls, the division of calendar (clock) time (T_k) may be illustrated in another way to facilitate the possibility to increase the effective time (T_e). This will support a reasonable increase of the concentration of mining (Fig. 3).

As follows from the diagram in Figure 3, the T_k time can be divided into:

- T_d time – time with staffing allowing the performance of works with the use of the installed automated system (so called "staffing with production"),
- T_b time – time without such staffing.

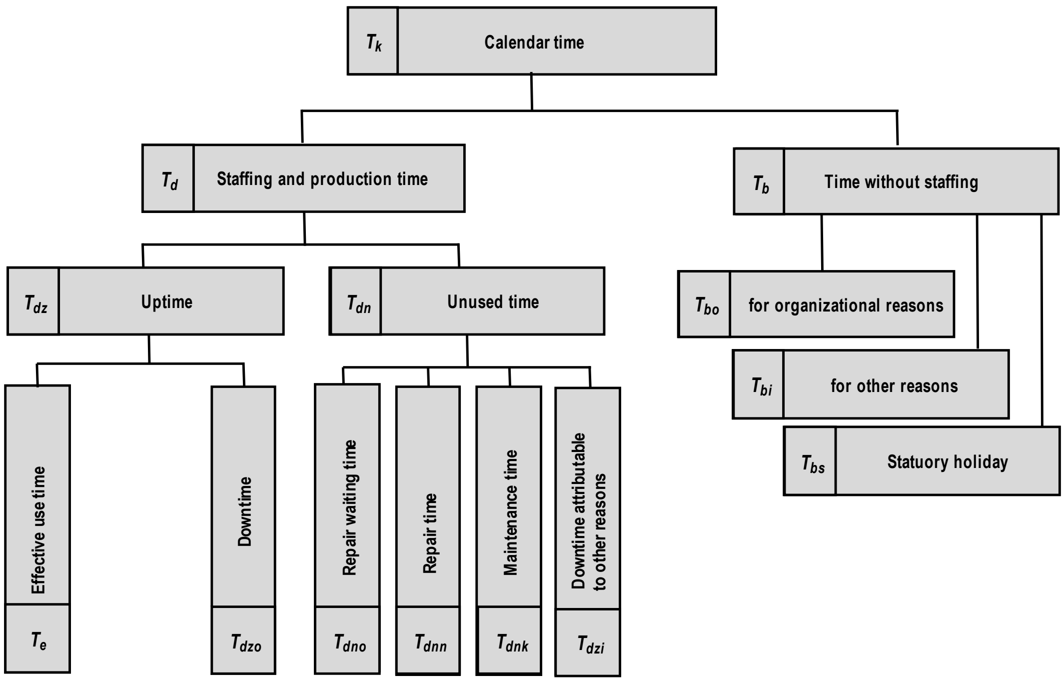

Fig. 3. Division of calendar time with the built-up automated system
Source: own study based on (Lisowski 2001)

Rys. 3. Podział czasu kalendarzowego z wbudowanym automatycznym systemem

Such a division is significant, since it can clearly demonstrate which part of the calendar time (T_d) can become the effective time (T_e). The staffing and production time (T_d) was, in turn, divided based on the criteria related to the responsibility for the output volume. The manufacturers of the machines and devices, who should warrant not only their specific efficiency but also reliability, are to a great extent responsible for the uptime of the automated mining system (T_{dz}). The mining staff and the power engineering and mechanical services also have their share of responsibility in this respect, but only with regards to ensuring the proper operation conditions. Therefore, if the devices are properly matched to given geological and mining conditions, they operate without any failures, and the face is properly staffed for production, while the haulage system is selected and used in a reasonable way, the unused time should be short. Thus, the uptime (T_{dz}) should, to a great extent, translate into the effective time (T_e).

In practice, miners who operate the machines and devices of the automated system, the staff of the power engineering and mechanical service, and the manufacturer's service staff are accountable for the unused time (T_{dn}). They make decisions on:

- the time required to perform maintenance works and periodic overhauls,
- the duration of current repair works performed to remove malfunctions or failures (often with the time required to prepare the site for the works),

- the time between the device shut-down and the beginning of works aimed at removing a given malfunction,
- the repair time.

The duration of the aforementioned activities can be significantly affected by a sufficient identification of the sources of the defects, the waiting time before the service team arrives, and the waiting time before spare parts or sub-assemblies are delivered.

Therefore, it is crucial to place a sufficient emphasis on the reliability of operation, which in practice is expressed as the mean machine operation time (or the operation of its parts or sub-assemblies) between the occurrences of damage or failure. In addition, difficult work conditions impose increasingly stringent requirements in this respect. The notion of reliability is often treated as equivalent to the notion of durability, which is not measured in time units, but in production output, e.g. the number of tons or advance metres.

It should be stressed that the reliability of machines and devices, as their vital feature, is related to the costs of their purchase, as the price of a reliable device must be respectively higher than the price of lower-quality equipment. However, the conditions of the underground mining production processes, also due to the costs of overhauls and repairs (in difficult conditions of underground excavation, the repairs and overhauls are difficult and expensive to perform), are the reason why the mining face is equipped with highly reliable machinery. In such situations, stringent requirements are also imposed on maintenance services. The cooperation with the manufacturer's service staff should also be taken into consideration here, as only then any potential structural or manufacturing flaws found in machines and devices can be effectively eliminated. Based on our long-standing experience, we can state that a successful cooperation between the manufacturer and machine operators can have a positive influence on the reliability of equipment used in the face area.

Conclusion

In order to define a reasonable production capacity of each longwall face, it is necessary to apply various criteria related to the mining and technical aspects, occupational safety, and organizational and economic aspects. Only then will it be possible to evaluate the expected effects in the field of concentration of mining in a mining company and in the mines which form part of such enterprises.

The principal determinant of the increase of concentration of mining is the proper use of working time. Notwithstanding whether we are dealing with a longwall face or a gallery, if it is equipped with a reliable mining and loading device characterized by specific performance, the only effective method of reaching satisfactory production output is to maximize the effective operation time (T_e), and its approximation to calendar time (T_k) in the greatest extent possible. This will support high mining output values in longwalls and the advancement in excavation driving. Such performance indirectly results from the outlays incurred for the purchase of equipment. We need to bear in mind, however, that for various reasons, the application of equipment with the highest performance and reliability parameters, which is expensive, is not always possible in certain conditions. Decisions in this respect should always be made at the planning stage, based on analysis results. Any shortcomings in this area might generate substantial costs, since every minute of downtime in the face area, which has been equipped with excessively expensive machinery, can result in a serious financial loss.

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CORRECT USE OF MINING-RELATED FIXED ASSETS AS A PRECONDITION FOR THE FAVORABLE OUTCOMES OF THE CONCENTRATION OF MINING OPERATIONS IN A MINING ENTERPRISE

Keywords

mining enterprise, concentration of mining operations, fixed assets in mining

Abstract

All the restructuring programs that have been implemented in Polish bituminous coal mining as a primary way to reduce mining costs relied on the increased concentration of mining operations. Those efforts especially involved a significant simplification of existing or newly developed structures for accessing or cutting the deposits intended for extraction; implementation of advanced mining technologies, and upgrading of machines used in mine faces. However, in order for these to deliver the expected results, it is important to organize mining operations in such a way so that those advanced, and usually very expensive, mining-related fixed assets – machinery and equipment – are used sensibly. In order to define a reasonable production capacity of each longwall face, it is necessary to apply various criteria related to the mining and technical aspects, occupational safety, and organizational and economic aspects. Only then will it be possible to evaluate the expected effects in the field of concentration of mining in a mining company and in the mines which form part of such enterprises. Decisions in this respect should always be made at the planning stage, based on analysis results.

The aim of this article is to explore the factors involved in concentration-related decision-making in mining companies, including the underlying mining/technical, organizational, and economic/financial aspects. A mining company is understood as a group of related mines, the primary business operations of which include bituminous coal mining, processing, and trading.

WŁAŚCIWE WYKORZYSTANIE PRODUKCYJNYCH ŚRODKÓW TRWAŁYCH WARUNKIEM KORZYSTNYCH EFEKTÓW KONCENTRACJI WYDOBYCIA W PRZEDSIĘBIORTWIE GÓRNICZYM

Słowa kluczowe

przedsiębiorstwo górnicze, koncentracja wydobycia, środki trwałe w procesie produkcji górniczej

Streszczenie

Wszystkie programy restrukturyzacyjne, wdrażane dotychczas w polskim górnictwie węgla kamiennego, jako jeden z najważniejszych czynników mających wpływ na obniżenie kosztów produkcji węgla, wskazywały na wzrost stopnia koncentracji produkcji. Działania podejmowane w tym zakresie wiązały się przede wszystkim ze znaczącym upraszczaniem, istniejących lub nowo wykonywanych, struktur udostępniania i rozcinki pokładów przewidzianych do wybierania, wdrażaniem nowoczesnych technik i technologii eksploatacji oraz modernizacją parku maszynowego stanowiącego wyposażenie przodków. Jednak, by przyniosły one spodziewane efekty, konieczne jest takie zorganizowanie robót prowadzonych w przedsiębiorstwie górniczym, aby posiadane nowoczesne, a przy tym zazwyczaj bardzo kosztowne produkcyjne środki trwałe – maszyny i urządzenia – były wykorzystywane w sposób racjonalny. W celu ustalenia racjonalnej zdolności produkcyjnej każdego przodka ścianowego, konieczne jest stosowanie różnych kryteriów w zakresie górniczo-technicznym, bezpieczeństwa pracy oraz organizacyjno-ekonomicznym. Tylko pod takim warunkiem będzie możliwe ocenienie efektów założonych w zakresie koncentracji wydobycia w przedsiębiorstwie górniczym i kopalniach wchodzących w jego skład.

Celem niniejszej publikacji jest określenie uwarunkowań procesów decyzyjnych, podejmowanych w ramach przedsiębiorstwa górniczego w zakresie produkcyjno-technicznym, organizacyjnym i ekonomiczno-finansowym, dotyczących możliwości wzrostu koncentracji wydobycia. Przy czym, przez przedsiębiorstwo górnicze rozumie się zespół powiązanych ze sobą zakładów górniczych, których podstawowym przedmiotem działania są wydobywanie, przeróbka i obrót handlowy węglem kamiennym.