GOSPODARKA SUROWCAMI MINERALNYMI – MINERAL RESOURCES MANAGEMENT

2023 Volume 39 Issue 2 Pages 177–194

DOI: 10.24425/gsm.2023.145890

PATRYCJA BĄK[1], MARIAN TUREK[2]

Minimizing the time of breaks and stoppages of mining faces as an opportunity to increase the volume of mining and the efficiency of mines

Introduction

A significant problem with the effective functioning of the hard-coal mining industry, especially in relation to mining enterprises and mines located in the Upper Silesian Coal Basin, are the high costs of mining (Magda 2017; Jonek-Kowalska 2013a, b). The issue of costs in the hard-coal mining industry was addressed by many authors of scientific publications directly related to the problem of mining enterprises (Turek and Jonek-Kowalska 2013; Turek and Michalak 2015; Jonek-Kowalska and Turek 2016a, b). This is due to many reasons, among which, an important issue is the ineffective use of the working time of mining faces (Brodny and Stecuła 2016, 2017). In the scientific literature on this problem, both foreign and domestic, works on the course of the mining production process can be found (Jaszczuk

✉ Corresponding Author: Patrycja Bąk; e-mail: pbak@agh.edu.pl
[1] AGH University of Science and Technology, Kraków, Poland; Poland; ORCID iD: 0000-0001-9109-3369; Scopus ID: 55651726700; e-mail: pbak@agh.edu.pl
[2] Central Mining Institute, Katowice, Poland; e-mail: mturek@gig.eu

and Siwiec 1997; Gumiński 2010, 2011a; Chadha 2014; Lanke et al. 2014). Additionally, the effectiveness and evaluation of the use of machines and devices of mechanized longwall systems, as well as the analysis of the obtained volumes of mining, has been the subject of analysis of international publications (Mohammadi et al. 2015; Fourie 2016; Zhu et al. 2018; Gumiński 2011b, 2015).

The unsatisfactory use of working time caused by unplanned shutdowns of mining faces is a significant reason for the fact that the use of the production potential of the expensive, modern mechanized systems built in them, with the production capacity of around 1,000–1,500 tons per hour, is relatively small – the average daily volume of mining from a longwall working is most often around 3,000 tonnes or even slightly less (Korski et al. 2017, 2019; Palka and Stecuła 2019). A significant reason for this is the occurrence of a large number of interruptions in the continuity of work, mainly caused by equipment failures, the impact of unfavorable geological and mining conditions or technological shutdowns (Profaska and Bielak 2016; Snopkowski et al. 2016a, b).

Two doctoral theses were defended at the Central Mining Institute (Matuszek 2021; Lyczko 2021). In order to prepare them, the authors collected numerous data from a period of several years, including data on production breaks in mining faces. In this article, the analysis of the collected information has been used to consider the methods of analyzing the causes of unplanned shutdowns in such a way that it is possible to obtain the most accurate understanding of their sources. This should enable the taking of appropriate countermeasures aimed at eliminating, or at least significantly reducing, the interruptions that incur the most severe losses.

1. Using the nominal working time of mining faces

In the literature (Lyczko 2021), data on the work of mining faces were statistically collected for 144 longwalls located in eight mines (marked from A to H) in the period from 2016 to 2019. The amounts and causes of downtime in individual walls are not presented in detail, but data on average values are given with regard to:

- daily production,
- monthly progress,
- the so-called rhythm of monthly progress and the impact of geometric parameters of the longwalls on the size of the obtained mining volume.

The production capacity of the mine (i.e. the number of tons of coal that can be obtained with its specific organization and equipment condition) results from the production capacity of the weakest production node, which includes the mining front, horizontal transport, vertical transport, the possibility of ventilating the workings (ventilation) and the processing plant. In all of the analyzed mines, this node was the production front, i.e. the element on the basis of which the volume of production is planned. As can be seen from the compiled data (Table 1), due to many interruptions in the operation of the longwalls, the mining capacity

Table 1. The use of the production capacity of the A–H mines in 2018–2019

Tabela 1. Wykorzystanie mocy produkcyjnych kopalń A–H w latach 2018–2019

Mine	Year	Production capacity (Mg/d)	Obtained output (Mg/d)	4/3 (%)
1	2	3	4	5
A	2018	10,800	3,903	36.14
	2019	6,000	6,082	101.37
B	2018	10,357	7,835	75.65
	2019	7,600	7,412	97.53
C	2018	29,088	25,323	87.06
	2019	29,680	26,058	87.80
D	2018	30,692	20,811	67.81
	2019	19,446	17,276	88.84
E	2018	54,400	37,616	69.14
	2019	37,700	37,411	99.23
F	2018	9,387	7,794	83.03
	2019	8,730	8,407	96.30
G	2018	14,240	10,466	73.50
	2019	10,700	12,000	112.15
H	2018	5,300	4,428	83.55
	2019	4,200	3,354	79.86

Source: Lyczko 2021.

was not achieved in virtually any mine. Only in two mines in 2019 did the use of the front production capacity exceed the assumed levels, but it should be noted that they were significantly reduced compared to 2018.

In the literature (Matuszek 2021), detailed data (copies of dispatcher's reports) concerning stoppages and breaks in the work of eight longwalls (marked from I to VIII) of one of the mines are attached. The mining of the deposit with longwalls was conducted there in 2015–2018 in various geological and mining conditions, the longwalls systems differed in geometrical parameters, technical equipment and work organization (three or four-shift systems). The breaks at work list only the periods of the normal course of longwalls systems (without their start-up and preparation for liquidation).

The data contained in the paper enables the preparation of a list of the number of minutes of downtime for individual longwalls, which were grouped on the basis of eighteen different

Table 2. List of causes and the number of minutes of downtime for Longwalls I–VIII throughout the entire period of their normal running with the determination of the percentage share of each cause of downtime

Tabela 2. Zestawienie przyczyn i liczba minut przestoju ścian I–VIII w całym okresie ich normalnej eksploatacji z określeniem procentowego udziału każdej przyczyny przestoju

No.	Details	The percentage share of each downtime cause															
		Longwall I		Longwal II		Longwal III		Longwal IV		Longwal V		Longwal VI		Longwal VII		Longwal VIII	
1	Correcting the positioning of powered support sections	6,920	9.77%	680	4.16%	700	4.88%	730	2.86%	110	0.54%	1,510	8.57%	210	0.71%	5,600	14.82%
2	Power failure or no power to the powered support sections	1,235	1.74%	430	2.63%	590	4.11%	1,210	4.74%	520	2.56%	310	1.76%	460	1.54%	330	0.87%
3	Transport stoppage – broken belt, belt adjustment. congestion at the transfer station	6,295	8.88%	8,250	50.44%	3,480	24.25%	6,990	27.36%	2,930	14.45%	3,370	19.12%	4,700	15.78%	3,500	9.27%
4	Face conveyor standstill	2,800	3.95%	325	1.99%	1,100	7.67%	230	0.90%	860	4.24%	550	3.12%	1,090	3.66%	240	0.64%
5	Beam stage loader standstill	2,460	3.47%	300	1.83%	470	3.28%	580	2.27%	410	2.02%	140	0.79%	330	1.11%	380	1.01%
6	Heading machine standstill	410	0.58%	160	0.98%	760	5.30%	420	1.64%	1,350	6.66%	320	1.82%	690	2.32%	700	1.85%
7	Rock fall, geological disturbances on the longwall	33,630	47.46%	270	1.65%	2,600	18.12%	5,830	22.82%	1,680	8.28%	5,210	29.56%	6,200	20.82%	12,130	32.11%
8	Maintenance works on the longwall or related to transport	700	0.99%	460	2.81%	490	3.41%	440	1.72%	180	0.89%	230	1.30%	300	1.01%	120	0.32%
9	6 kV power failure in the longwall area	1,620	2.29%	340	2.08%	320	2.23%	600	2.35%	230	1.13%	260	1.48%	710	2.38%	390	1.03%
10	Belt conveyor electrical fault	1,260	1.78%	580	3.55%	360	2.51%	1,020	3.99%	1,390	6.85%	480	2.72%	1,540	5.17%	370	0.98%
11	Face conveyor electrical fault	460	0.65%	310	1.90%	300	2.09%	60	0.23%	920	4.54%	90	0.51%	290	0.97%	170	0.45%
12	Beam stage loader electrical fault	90	0.13%	240	1.47%	160	1.11%	260	1.02%	0	0.00%	70	0.40%	480	1.61%	430	1.14%
13	Heading machine electrical fault	2,395	3.38%	1,900	11.62%	890	6.20%	3,215	12.59%	4,900	24.16%	1,690	9.59%	1,610	5.41%	5,325	14.10%
14	Heading machine cable fault	1,110	1.57%	350	2.14%	490	3.41%	490	1.92%	560	2.76%	580	3.29%	1,610	5.41%	300	0.79%
15	Mining transport devices mechanical fault	4,450	6.28%	1,100	6.73%	260	1.81%	670	2.62%	450	2.22%	1,660	9.42%	1,520	5.10%	3,100	8.21%
16	Heading machine mechanical fault	3,945	5.57%	600	3.67%	1,350	9.41%	2,740	10.73%	3,550	17.50%	690	3.91%	6,010	20.18%	3,470	9.19%
17	Methane safety practices	0	0.00%	0	0.00%	30	0.21%	0	0.00%	0	0.00%	425	2.41%	1,780	5.98%	1,170	3.10%
18	Other	1,080	1.52%	60	0.37%	0	0.00%	60	0.23%	240	1.18%	40	0.23%	250	0.84%	50	0.13%
	Total	70,860	100%	16,355	100%	14,350	100%	25,545	100%	20,280	100%	17,625	100%	29,780	100%	37,775	100%

Source: own elaboration based on (Matuszek 2021).

causes and this is summarized in Table 2. For each longwall, the table also lists three causes with the highest percentage share in the total time of breaks at work.

Additionally, based on mine dispatcher reports, it is also possible to make a statement for each longwall which includes the total nominal duration of all production shifts throughout the entire period of its normal operation and the total time of all unplanned periods of downtime of the longwall system (Table 3). The proportions between these values are presented in the diagram in Figure 1.

Table 3. List of nominal working times and downtimes of the first eight longwalls during their normal operation

Tabela 3. Zestawienie nominalnych czasów pracy i przestojów pierwszych ośmiu ścian w czasie ich normalnej eksploatacji

Specificaiton	I	II	III	IV	V	VI	VII	VIII
Total nominal working time CN (min)	279,450	79,950	90,750	155,700	122,350	118,700	169,900	152,500
Total downtime CP (min)	70,860	16,355	14,350	25,545	20,280	17,625	29,780	37,775
CP/CN (%)	25.4%	20.5%	15.8%	16.4%	16.6%	14.8%	17.5%	24.8%

Source: own study based on (Matuszek 2021).

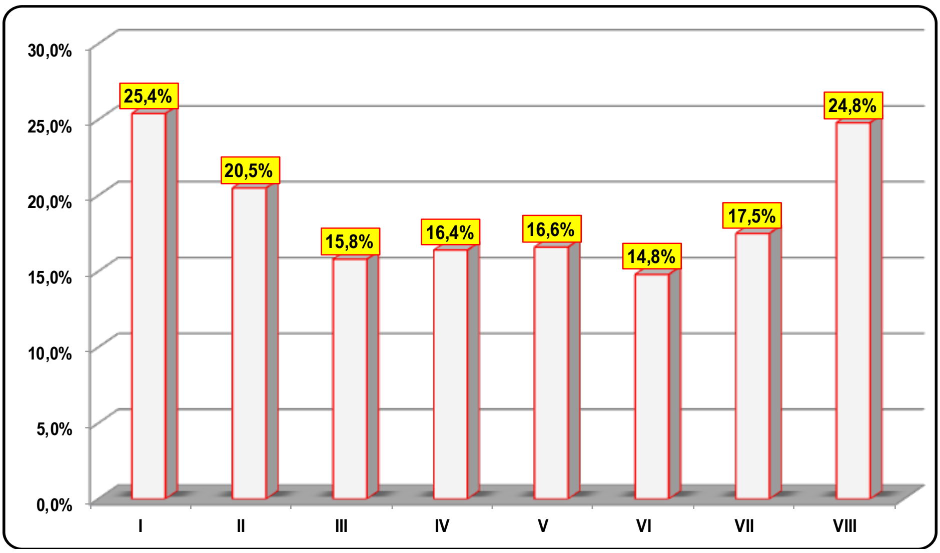

Fig. 1. Percentage of downtime in work in the Longwalls I–VIII in relation to the total nominal working time in the entire period of their normal operation
Source: own study based on (Matuszek 2021)

Rys. 1. Procentowy udział przestojów w pracy w ścianach I–VIII w relacji do łącznego nominalnego czasu pracy w całym okresie ich normalnej eksploatacji

The data presented in Tables 2 and 3 as well as in the diagram illustrate how large a problem the effective use of the nominal working time of mining faces is in Polish hard-coal mines. It should be borne in mind that the long duration of unplanned downtime is not only related to losses in the planned daily or monthly production volumes (no revenues from coal sales), it also often results in a significant "entrapment" of the costly equipment of mechanized systems and the staff at the mining face (depreciation and labor costs), which may even last for several months. For example, the normal course of Longwall I lasted from June 26, 2017 to May 18, 2018, i.e. almost 11 months. During this period, as many as ninety-eight production shifts were recorded, during which not even one ton of coal was obtained – with the four-shift organization of work, this means that for almost twenty-five days, the longwall system was useless. Apart from such extreme situations, it often happened that for a nominal 330 minutes of work, it actually lasted only from 60 to 120 minutes. If the sum of the time of all the stops accounted for more than a quarter of the operation period, it can be assumed that in the absence of downtime or its significant reduction, the mining of the coal seam would not take eleven but seven or eight months.

2. Examples of methods of analyzing the causes of stoppages of mining faces

The effective use of resources, including material resources (including technical equipment) and human resources (employees), is one of the most important factors determining the economic efficiency of each enterprise. In the case of mining enterprises, where the mining of the deposit is often performed in mining faces located at large distances from shafts or dip-headings (sloping faces) connecting the surface with underground workings, it should be very important to effectively use the nominal working time during the shift in the mining face – most often, this is only from 4.5 to a maximum of 5.5 hours. If, due to various downtimes, this time is often even significantly reduced, then it would be very important to perform detailed analyses to determine the causes of downtimes and implement actions aimed at their elimination or significant reduction. It should be noted that such analyses should not only define the immediate causes of the downtimes but also specify their source as precisely as possible.

There are a number of methods and tools that can be used for this purpose. It is true that they were most often created in order to properly manage the quality of manufactured products. However, in the case of mining enterprises and individual mines, if we assume that we want to properly "manage" the effective working time of mining faces, many of them can be successfully used. The following three of these will be presented later in this article:

- two methods that can be used to identify the causes that create the greatest problems, namely the multi-criteria method of hierarchy analysis of decision problems (the analytic hierarchy process (AHP)) and the Pareto-Lorenz diagram;

- one method with the use of which it is possible to determine the basic (root) causes of the arising problems.

2.1. The analytic hierarchy process (AHP) – multi-criteria method of hierarchy analysis of decision problems – (AHP)

The AHP (analytic hierarchy process) method, created by the American scientist T.L. Saaty, is a tool for supporting various decisions and solving complex problems that can be applied in many areas of science and practice (Prusak and Stefanów 2014). Proposals for its use in the hard-coal mining industry have already been presented, inter alia, in works included in the bibliography (Bijańska and Wodarski 2017; Sobczak and Kopacz 2018).

The method is hierarchical and enables the spreading of a complex decision problem and creating a ranking of a set of variants of its solutions. For its application, it is necessary to conduct a research survey among people who are experts in the subject matter in question.

First, identify and define:

- the problem under consideration (*The large number and duration of unplanned stoppages of the mining face are the reason for the unsatisfactory use of working time and increase the costs of mining*);
- all general and specific factors influencing the creation of the problem and the method of its solution – these are criteria that should be used when taking actions leading to the goal;

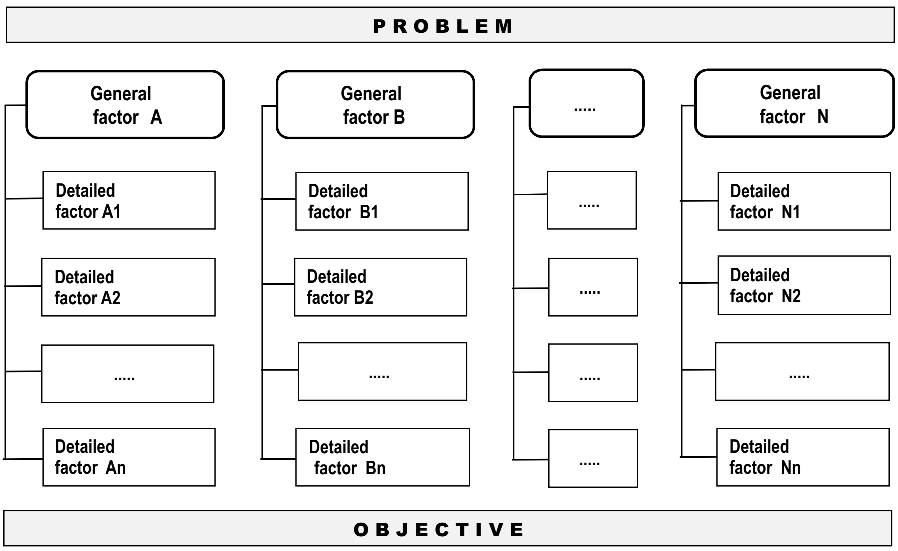

Fig. 2. Model of a hierarchical tree built in the AHP method
Source: own study

Rys. 2. Model drzewa hierarchicznego zbudowany metodą AHP

- the goal that we want to achieve (*Eliminate or at least significantly reduce the number and duration of unplanned stoppages of the mining faces*).

All identified elements are then arranged in accordance with the hierarchy constructed according to the above system. Such a structure is most often presented in the form of a so-called tree (Figure 2). It is important that such a tree does not have an overly complex structure as this will complicate the analysis of the causes of the problem under consideration.

In order to better illustrate the procedure, previous work (Lyczko 2021) has listed general and specific factors (Table 4).

Table 4. Summary of the considered general and specific factors

Tabela 4. Zestawienie uwzględnionych czynników ogólnych i szczegółowych

General factors	Specific factors				
A. Human resources	A1. Personnel	A2. Skills	A.3. Attitudes	A4. Knowledge	
B. Natural hazards	B1. Methane	B2. Rockbusts	B3. Climate	B4. Water	B5. Fire
C. Technical equipment	C1. Technical condition	C.2 Durability	C3. Susceptibility	C4. Reliability	C5. Use
D. Properties of the orogen	D1. Geological disturbance	D2. Properties of roof and floor rocks	D3. Past operating properties	D4. Depth of mining	

Source: own study based on (Lyczko 2021).

In the next step, a form should be constructed on the basis of which the persons participating in the study make a pairwise comparison of all identified factors, both general and specific. Preferences of the participants of the study are determined by relative importance ratings, expressed as numeric values in a Saaty scale ranging from 1 to 9 (or less frequently from 1 to 7). An example of a preference survey form in relation to the general factors listed in Table 4 is presented in Figure 3.

After collecting experts' assessments, square preference matrices are created at each level of the hierarchy, which are characterized by pairwise consistency: a given matrix element is equivalent to itself and the value of the assessment of element "a" with respect to element "b" is the reciprocal of the assessment of element "b" with respect to element " a". In order to check whether the collected assessments contain any errors (discrepancies), the CI coherence index and CR coherence index are calculated (the method of calculating the CR index is included in the literature (Prusak and Stefanów 2014; Cabała 2016). Matrix assessments can be considered to be consistent when CR takes values less than 0.1.

	Advantage									
	Total	Very strong	Strong	Weak	Equivalent factors	Weak	Strong	Very strong	Total	
	9	7	5	3	1	3	5	7	9	
Human resources										Natural hazards
										Technical equipment
										Rock mass properties
Natural hazards										Technical equipment
										Rock mass properties
Technical equipment										Rock mass properties

Fig. 3. An example of a survey form for research conducted using the AHP method (Lyczko 2021)

Rys. 3. Przykład formularza ankiety do badań prowadzonych metodą AHP

The last step of the AHP method is to calculate the following weighting factors:

- local – the arithmetic mean of the values obtained in the rows of the normalized matrix created at the stage of determining the CR index;
- global – presenting the importance of a given factor against the background of all factors included in the research.

The weighting factors that are finally obtained are used to determine the influence of individual factors on the occurring interruptions in the work of mining faces that disturb the course of production.

The presented description shows that the use of the AHP method to identify the causes of the disturbances is laborious; it requires the construction of an appropriate questionnaire sheet and the conducting of research surveys followed by the performing of a series of calculations. Thus, it can be much simpler to use another method, namely the development of the Pareto-Lorenz diagram.

2.2. Pareto-Lorenz diagram

With the use of the Pareto-Lorenz diagram, it is possible to present the values of the share of individual factors influencing the issue under consideration on a graph, with drawing the

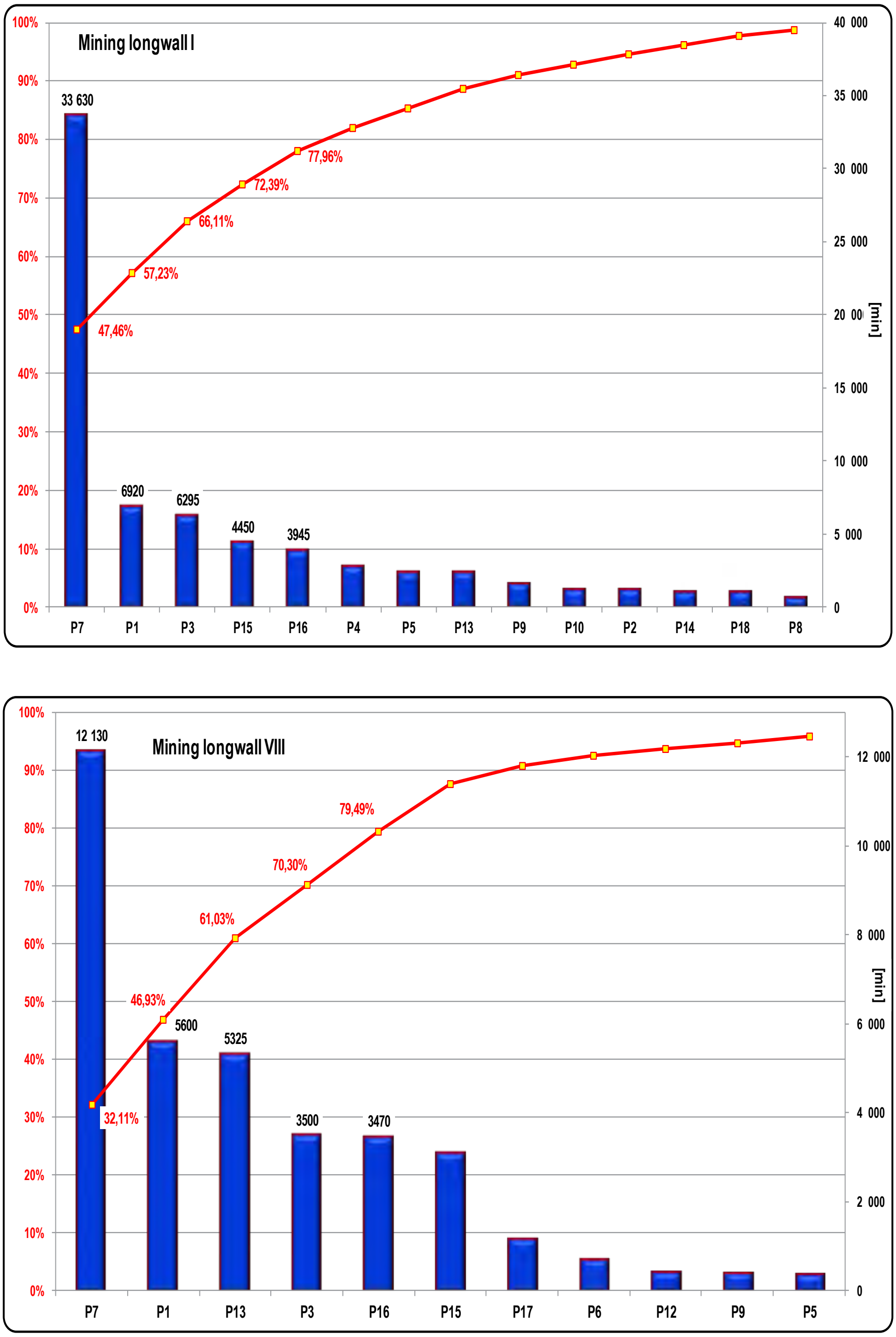

Fig. 4. Pareto-Lorenz diagram for Longwalls I and VIII
Source: own study

Rys. 4. Diagram Pareto-Lorenza dla ścian I i VIII so-called Lorenz curve, illustrating the cumulative effect of the influence of the individual factors. The idea of the diagram is based on the 80/20 rule created by the Italian economist Vilfredo Pareto, stating, inter alia, that *80% of the problems are created by 20% of the causes* (Koch 2003). He stated that the elimination of these 20% should significantly improve the final result, and that, in addition, focusing attention on the selected values does not allow the minor causes of the problems to be tackled. It should be noted that the basis for the correct implementation of the Pareto-Lorenz diagram is the collection of an appropriate amount of data on the studied phenomenon – it would then be possible to distinguish several categories of causes of the problem under study.

In order to illustrate the procedure in the case of the analysis of the causes of disturbances in the mining of a deposit, the data collected in Table 2 can be used. It contains several years of information on the basic causes and durations of instances of unplanned downtimes of mining longwalls in one of the mines. Graphs were prepared for Longwalls I and VIII – the individual columns indicate the duration of downtimes caused by one of the eighteen causes "P" listed in Table 2 (Figure 4).

The presented diagrams show that the main source of stoppages in both workings, especially in Longwall I, are geological problems (P7) – falling of roof in the mining longwalls and at their inlets and outlets, disturbances occurring in the excavated body of the coal. If the works related to the necessity to properly set up the powered support section (P1) are included, then only these two reasons are responsible for over 57% of the downtimes in Longwall I and almost 47% of downtimes in the mining longwall VIII. As can be seen from the presented example, if you have an appropriate amount of necessary data collected over a long period, the analysis based on the Pareto-Lorenz diagram is simpler and takes much less time than the AHP method. Both of the above methods are used for a general understanding of the causes of unplanned stoppages. If a more detailed analysis is needed in this area, which also enables the identification of the sources of these causes, the 5 Whys method can be used for this purpose.

2.3. The 5 Whys method

The 5 Whys method (another name – 5W) enables the very accurate identification of the causes of the arising problems. Its author is the Japanese industrialist Sakichi Toyoda, the founder of the Toyota car concern. It consists of asking the question "why?" several times. Most often, answering the subsequent five questions enables the determination of the source of the problem under consideration and thus to identify the root cause of the problem. It happens that a smaller number of questions may be enough to establish it – such a cause is recognized by the fact that its removal completely eliminates the problem (Brożyńska et al. 2014). A diagram of such a procedure is shown in Figure 5.

The use of the method in the mine will facilitate the earlier preparation of the appropriate analytical sheets containing the developed databases of the main root and root causes of the

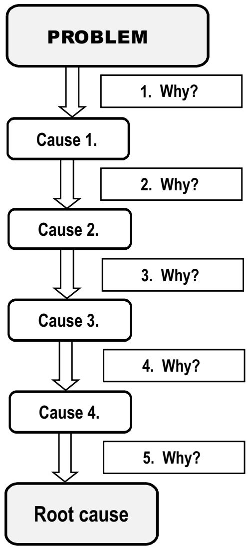

Fig. 5. Scheme of proceeding in the five successive steps of the 5 Whys method
Source: own study

Rys. 5. Schemat postępowania w pięciu kolejnych krokach metody *5 Whys*

occurrence of stoppages (they should be frequently updated) – this will enable the creation of selection lists for people filling in the sheets. It is also very important to choose the right people to complete the sheets. They should, above all, be employees closely related to the problem under study as they are the people who know the most about the place or causes of the problem (Pacana 2021).

The method of practical use of the 5 Whys method can be illustrated, for example, for two groups of causes presented in Table 2: P7 – rockfall, geological disturbances in the wall and P3 – haulage stoppage – broken belt, route adjustment, blockages at transfer points (Figure 6). These were the reasons for the greatest number and length of downtimes at work, and thus they caused the greatest losses.

The results of the analyses performed in the presented example are specific root causes that show the real causes for interruptions in the mining operation. It can be seen that conducting analyses using the AHP and 5 Whys methods allows the mutual verification of the obtained results, which certainly strengthens the certainty of defining the root causes of the problems. It is possible to assign specific detailed factors to them used in the AHP method, listed in Table 4. And so, the source factor:

- "Too few employees" corresponds to the specific factor A1 "Personnel status" of the AHP method;
- "Extensive mining tasks" corresponds to the AHP specific factor A2 "Skills" (for those who develop mining longwall routing and volume planning).

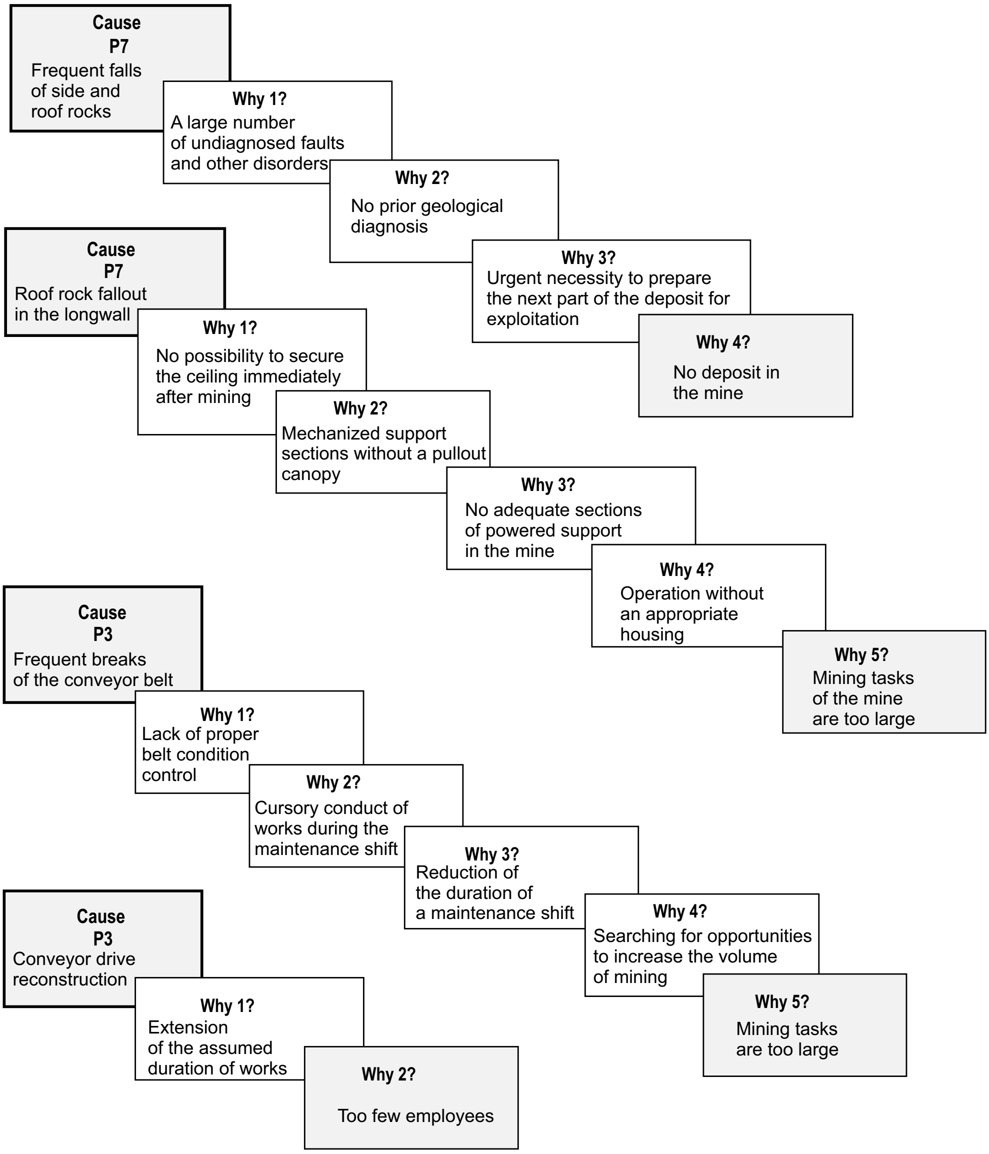

Fig. 6. An example of an analysis using the 5 Whys method for selected groups of causes of downtimes
Source: own study

Rys. 6. Przykład analizy metodą *5 Whys* dla wybranych grup przyczyn przestojów

There is a problem with the "No coal deposit in the mine" factor – it will be rather hard to eliminate or reduce it. The appearance of such a statement should be a signal to the management of the company and the mine management about the need to make a decision regarding the meaningfulness of the further operation of the mining plant.

Cause P7	Why 1?	Why 2?	Why 3?	Why 4?
Frequent falls of side and roof rocks	A large number of undiagnosed faults and other disorders	No prior geological diagnosis	Urgent necessity to prepare the next part of the deposit for exploitation	No deposit in the mine

Cause P7	Why 1?	Why 2?	Why 3?	Why 4?	Why 5?
Roof rock fallout in the longwall	No possibility to secure the ceiling immediately after mining	Mechanized support sections without a pull-out canopy	No adequate sections of powered support in the mine	Operation without an appropriate housing	Mining tasks of the mine are too large

Cause P3	Why 1?	Why 2?	Why 3?	Why 4?	Why 5?
Frequent breaks of the conveyor belt	Lack of proper belt condition control	Cursory conduct of works during the maintenance shift	Reduction of the duration of a maintenance shift	Searching for opportunities to increase the volume of mining	Mining tasks are too large

Cause P3	Why 1?	Why 2?
Conveyor drive reconstruction	Extension of the assumed duration of works	Too few employees

It should also be noted that with appropriate modification, the use of the presented methods, especially the Pareto-Lorenz diagram and 5 Whys, can be used not only for mining works but also for drilling corridor workings.

Conclusions

High operating costs are currently the biggest problem affecting the domestic hard-coal mining industry. This is due to many reasons, for which the unsatisfactory use of the effective working time of mine workings is of significant importance. Determining the causes for this is therefore extremely important.

The course of the mining process in a mine is influenced by both the parameters of the exploited deposit and the number and quality of machines and devices used, i.e. material resources, as well as the number and skills of employees who constitute its human and non-material resources. The available resources determine the conducted exploitation – they are its factors of qualitative and quantitative nature. In order to appropriately take into account their impact on the production process, a suitable method must be used to determine the causes of the disturbances, which takes into account the dual nature of the above-mentioned factors.

These methods can be the proposed AHP method, the Pareto-Lorenz diagram or the 5 Whys method. If sufficient data is available, each method enables the exact root causes of the problem to be pinpointed as specified – runtime disruptions and unplanned downtimes. This, in turn, allows measures to be taken to improve operational efficiency.

The paper presents results of research conducted in AGH University of Science and Technology no. 16.16.100.215.

REFERENCES

Bijańska, J. and Wodarski, K. 2017. *Use of AHP method in strategic decision-making in hard coal mines in a crisis situation*. [In:] Jonek-Kowalska, I., ed. *Economic and technological conditions of development in extractive industries*. Gliwice: Publishing House of the Silesian University of Technology.

Brodny, J. and Stecuła, K. 2016. *Analysis of the effectiveness of the use of a set of mining machines*. [In:] Knosal, R., ed. *Innovations in Management and Production Engineering*. Opole: Publishing House of the Polish Production Management Society.

Brożyńska et al. 2014 – Brożyńska, M., Lis, A., Kowal, K. and Szymczak, M. 2014. *5 times why. First method manual*. Łódź: 2KConsulting Publishing House.

Cabała, P. 2016. Analysis of the consistency of assessments in the process of making strategic decisions. *Scientific Journals of the Silesian University of Technology, Series: Organization and Management* 88.

Chadha, R. 2014. Mine improves operations through OEE and waterfall analysis. *Quality Progress 2*.

Fourie H. 2016. Improvement in the overall efficiency of mining equipment: a case study. *The Journal of The Southern Africa Institute of Mining and Metallurgy* 116(3), pp. 275–281, DOI: 10.17159/2411-9717/2016/v116n3a9.

Gumiński, A. 2010. Effective working time of employees in a hard coal mine (*Efektywny czas pracy zatrudnionych w kopalni węgla kamiennego*). *Przegląd Górniczy* 66(9), pp. 104–107 (*in Polish*).

Gumiński, A. 2011a. Factors determining the effective work time of employees in a colliery (*Czynniki obniżające efektywny czas pracy zatrudnionych w kopalni węgla kamiennego*). *Scientific Journals of the Silesian University of Technology, Series: Organization and Management* 56, pp. 89–104 (*in Polish*).

Gumiński, A. 2011b. Labor intensity of removing failures in a hard coal mine (*Pracochłonność usuwania awarii w kopalni węgla kamiennego*). *Wiadomości Górnicze* 62(1), pp. 29–33 (*in Polish*).

Gumiński, A. 2015. Analysis of the possibilities of increasing the efficiency of the use of production means in the mining longwalls of a hard coal mine (*Analiza możliwości zwiększenia efektywności wykorzystania środków produkcji w ścianach wydobywczych kopalni węgla kamiennego*). *Scientific Journals of the Silesian University of Technology* 78, pp. 167–177 (*in Polish*).

Jaszczuk, M. and Siwiec, J. 1997. Assessment of the use of potential technical possibilities of longwall shearers based on the measurement of operating parameters. [In:] *Conference materials "New possibilities of mining machines"* – international scientific and technical conference, Szczyrk, March 1997.

Jonek-Kowalska, I. 2013a. *Different views on efficiency in an enterprise*. [In:] Turek, M., ed. *Analysis and evaluation of costs in hard coal mining in Poland in terms of improving mining efficiency*. Warszawa: Difin Publishing House.

Jonek-Kowalska, I. 2013b. *Assessment of the possibilities of improving the efficiency of hard coal mining.* [In:] Turek, M., ed. *Analysis and evaluation of costs in hard coal mining in Poland in terms of improving mining efficiency*. Warszawa: Difin Publishing House.

Jonek-Kowalska, I. and Turek, M. 2016. Effectiveness determinants in hard coal mines in Poland in the current market and geological-mining conditions (Zmienność uwarunkowań rynkowych jako źródło ryzyka w planowaniu produkcji górniczej i jej ekonomicznych rezultatów). *Inżynieria Mineralna* 18(2), pp. 207–214 (*in Polish*).

Jonek-Kowalska, I. and Turek, M. 2016. *Data Envelopment Analysis in the measurement and optimization of technical efficiency in Polish hard coal mines*. [In:] Sroka, W., ed. *Modern enterprise management. Conditions, trends, perspectives*. Toruń: Scientific Society of Organization and Management "House of the Organizer".

Koch, R. 2003. The 80/20 Rule. *Better results with less effort and resources*. Warszawa: Wydawnictwo Medium sp. z o.o.

Korski et al. 2017 – Korski, J., Tobór-Osadnik, K. and Wyganowska, M. 2017. Mining Machines Effectiveness and OEE Indicator. *IOP Conference Series: Materials Science and Engineering*.

Korski et al. 2019 – Korski, J., Tobór-Osadnik, K. and Wyganowska, M. 2019. *Internal Client and Efficiency in the Mining Process*. [In:] *World Multidisciplinary Earth Sciences Symposium WMESS 2018*, Institute of Physics, Czech Republic, No. 012102.

Lanke et al. 2014 – Lanke, A., Hoseinie, H. and Ghodrati, B. 2014. Mine Production Index (MPI): New method to evaluate effectiveness of mining machinery. *World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering* 8(11).

Lyczko, A. 2021. *Factors determining the volume of production in mining faces on the example of Polska Grupa Górnicza SA*. PhD thesis (unpublished). Katowice: Central Mining Institute.

Magda, R. 2017. Increase in the degree of utilization of production capacity and reduction of fixed costs as the basic directions of restructuring activities aimed at reducing the unit cost of mining production (*Wzrost stopnia wykorzystania zdolności produkcyjnej i redukcja kosztów stałych jako podstawowe kierunki działań restrukturyzacyjnych zmierzających do zmniejszenia jednostkowego kosztu produkcji górniczej*). *Przegląd Górniczy* 73(1), pp. 98–103 (*in Polish*).

Matuszek, Ł. 2021. *A new method of planning the production volume in a hard coal mine.* PhD thesis (unpublished). Katowice: Central Mining Institute.

Mohammadi et al. 2015 – Mohammadi, M., Rai, P. and Gupta, S. 2015. Performance Measurement of Mining Equipment. *International Journal of Emerging Technology and Advanced Engineering* (5)7.

Pacana, A. 2021. *Principles and methods of quality management* (*Zasady i metody zarządzania jakością)*. Rzeszów: Rzeszów University of Technology (*in Polish*).

Palka, D. and Stecuła, K. 2019. *Concept of Technology Assessment in Coal Mining*. [In:] *IOP Conference Series: Earth and Environmental Science* 261(1). Gliwice: Mining of Sustainable Development Conference.

Profaska, M. and Bielak, M. 2016. *Analysis of the causes of the type of failure of the KSW-460 / NZ longwall shearer loader in terms of its impact on the available time*. [In:] Badura, H., Michna, A., Czerwiński, S., ed. *Support Systems in Production Engineering. Górnictwo – perspektywy i zagrożenia* 1(13).

Prusak, A. and Stefanów, P. 2014. *AHP – analytical hierarchy process, Building and analysis of decision models step by step* (*AHP – analityczny proces hierarchiczny. Budowa i analiza modeli decyzyjnych krok po kroku*). Warszawa: Wydawnictwo C.H. Beck (*in Polish*).

Snopkowski et al. 2016a – Snopkowski, R., Napieraj, A. and Sukiennik M. 2016a. Concept of belt conveyor reliability testing with the use of quality management tools (*Koncepcja badań niezawodności przenośników taśmowych z wykorzystaniem narzędzi zarządzania jakością*). *Przegląd Górniczy* 72(8) (*in Polish*).

Snopkowski et al. 2016b – Snopkowski, R., Napieraj, A. and Sukiennik M. 2016b. Method of the Assessment of the Influence of Longwall Effective Working Time onto Obtained Mining Output. *Archives of Mining Sciences* 61(4), DOI: 10.1515/amsc-2016-0064.

Sobczyk, P.J. and Kopacz, M. 2018. Assessing geological and mining condition nuisance and its impact on the cost of exploitation in hard coal mines with the use of a multi-criterion method. *Archives of Mining Sciences* 63(3), pp. 665–686, DOI: 10.24425/123690.

Stecuła, K. and Brodny, J. 2017. Meaning of Knowledge to the Increased Effectiveness of the Use of Mining Machines. *Silesian University of Technology Scientific Papers, Organization and Management, Scientific Paper No. 111, Management in Mining Production, Economic, Social and Technical Perspectives and Experiences*.

Turek, M. and Jonek-Kowalska, I. 2013. The possibilities of Improvement of Production Effectiveness in the Polish Hard Coal Mining. [In:] *23rd World Mining Congress & Expo*, Montreal, Canadian Institute of Mining, Metallurgy and Petroleum.

Turek, M. and Michalak, A. 2015. Labor productivity and the efficiency of mining enterprises. *Economics and Organization of Enterprises* 6.

Zhu et al. 2018 – Zhu, X., Chen, Y. and Feng, C. 2018. Green total factor productivity of China’s mining and quarrying industry: A global data envelopment analysis. *Resources Policy* 57, pp. 1–9, DOI: 10.1016/j.resourpol.2017.12.009.

MINIMIZING THE TIME OF BREAKS AND STOPPAGES OF MINING FACES AS AN OPPORTUNITY TO INCREASE THE VOLUME OF MINING AND THE EFFICIENCY OF MINES

Keywords

mining face, standstill, analysis, method, cause

Abstract

A significant problem with the effective functioning of the hard-coal mining industry, especially in relation to mining enterprises and mines located in the Upper Silesian Coal Basin, are the high costs of mining. This is due to many reasons, among which, an important aspect is the ineffective use of the working time of mining faces. The unsatisfactory use of working time caused by unplanned shutdowns of mining faces is a significant reason for the fact that the use of the production potential of the expensive, modern mechanized systems built in them, with the production capacity of around 1,000–1,500 tons per hour, is relatively small – the average daily volume of mining from a longwall working is most often around 3,000 tonnes or even slightly less. A significant reason for this is the occurrence of a large number of interruptions in the continuity of their work, which is mainly caused by equipment failures, the impact of unfavorable geological and mining conditions or technological shutdowns.

The article deals with the problem of the unsatisfactory level of the effective use of working time in mining faces (longwalls) in Polish hard-coal mines. The main reason for this is the occurrence of a large number of unplanned stops and interruptions, sometimes lasting several days. Their elimination or at least reduction would significantly contribute to the improvement of the existing situation. The condition for this, however, is reliable analyses aimed at detailed the identification of their causes. It was proposed to use three methods – the analytic hierarchy process (AHP), the development of the Pareto-Lorenz diagram and the 5 Whys method. Examples of their practical application are also presented.

MINIMALIZACJA CZASU PRZERW I POSTOJÓW PRZODKÓW WYBIERKOWYCH SZANSĄ NA WZROST WIELKOŚCI WYDOBYCIA I EFEKTYWNOŚCI KOPALŃ

Słowa kluczowe

przodek wybierkowy, postój, analiza, metoda, przyczyna

Streszczenie

Znaczącym problemem dotyczącym efektywnego funkcjonowania branży górnictwa węgla kamiennego, szczególnie w odniesieniu do przedsiębiorstw górniczych i kopalń zlokalizowanych na terenie Górnośląskiego Zagłębia Węglowego, są wysokie koszty prowadzonej eksploatacji. Wynika to z wielu przyczyn, wśród których istotne miejsce zajmuje nieefektywne wykorzystanie czasu pracy przodków wybierkowych. Niezadawalające wykorzystanie czasu pracy spowodowane nieplanowa-

nymi postojami przodków wybierkowych jest istotną przyczyną tego, że wykorzystanie potencjału produkcyjnego zabudowanych w nich kosztownych, nowoczesnych kompleksów zmechanizowanych, o możliwości produkcji około 1000–1500 ton w ciągu godziny, jest stosunkowo niewielkie. Znaczącą przyczyną tego jest występowanie dużej liczby przerw w ciągłości ich pracy, spowodowanych głównie awariami urządzeń, wpływami niekorzystnych uwarunkowań geologiczno-górniczych lub postojami technologicznymi.

W artykule poruszono problematykę niezadawalającego poziomu wykorzystania efektywnego czasu pracy w przodkach wybierkowych (ścianach) w polskich kopalniach węgla kamiennego. Główną przyczyną tego jest występowanie dużej liczby nieplanowanych postojów i przerw, czasem trwających nawet po kilka dni. Ich wyeliminowanie lub przynajmniej zredukowanie znacząco przyczyniłoby się do poprawy istniejącej sytuacji. Warunkiem tego jest jednak rzetelne przeprowadzenie analiz mających na celu szczegółową identyfikację przyczyn ich powstawania. Zaproponowano do tego wykorzystanie trzech metod – wielokryterialnej metody hierarchicznej analizy problemów decyzyjnych AHP, opracowanie diagramu Pareto-Lorenza oraz metody *5 Whys*. Przedstawiono także przykłady ich praktycznego zastosowania.