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ECONOMIC EFFECTS OF A MINING PLANT RESULTING FROM THE APPLICATION OF A SHORT-FRONT SYSTEM

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Abstract:
The article points to possibilities of using a short-front system as an alternative exploitation system, the application of which has a positive influence on the economic effects of a mining plant. A comparative analysis of the residual exploitation of a deposit by means of longwall and short-front systems has been conducted. The results of the analysis have been discussed, which indicated that the application of mining systems (short-front) can be profitable for mining plants and may lead to rational mining of deposit residual. Moreover, the use of a short-front system allowed a double increase of the analysed seam exploitation.

Key words: *coal deposit mining, short-front systems, economic analysis*

INTRODUCTION

The mining industry remains the major force fuelling the development of global economy and contributing to an increased standard of living. Currently, to maintain a high exploitation level, every mining plant should constantly introduce innovative solutions in the areas of raw materials exploitation. These activities should lead to increased efficiency and a reduction of costs involved in the acquisition of raw materials. Moreover, such activities should have an impact on an increased competitiveness of an enterprise in the mining sector.

One of the problems that must be solved is to create production systems characterized by greater flexibility, which will enable adjusting the system to varied working conditions.

The key tasks faced by Polish hard coal mining include the improved use of the possessed resources base, the size of which has a considerable influence on the viability of some mining plants. The basic area of operation in this scope should be (apart from the construction of new mines, levels, making new deposits available) the development of technologies enabling effective exploitation of these deposits, which are currently abandoned for various reasons [1, 2, 3].

In the mining industry, especially in the case of raw materials exploitation, apart from work safety, the main emphasis is placed on the minimization of exploitation costs accompanied by an increased automation of production and simultaneous reduction of the amount of waste. For this reason, new system solutions are being currently sought for the commonly applied mining systems. These systems must also allow exploiting the deposits that have irregular shapes. Given the depleting deposits of hard coal, it becomes necessary to mine coal occurring in the so-called residue as well as in thin deposits.

According to some sources, the deposits of coal occurring in residues and thin beds are estimated to reach nearly one billion tons, which guarantees minimum several years of work for Polish mines, taking into consideration their current mining capabilities. Similar tendencies can be observed in some European or Asian countries (China, India, Indonesia, Kazakhstan).

Due to systematic depletion of coal deposits, mining plants are looking for alternative solutions, which include the exploitation of the so-called residues. Here, an alternative solution are mechanised short-front systems of mining. These systems make it possible to achieve the goals, i.e. to exploit natural resources, in this case hard coal.

MINING SYSTEMS APPLIED

The variety of deposits forces mining plants to use various mining systems, which differ in the degree of mechanisation and the direction of front shift. These systems should be selected to suit the dimensions of excavations to make exploitation as effective as possible and provide a possibility of obtaining a high concentration of mining at the lowest costs [5].

An analysis of mining technologies that have been applied in Polish hard-coal mining so far allows distinguishing the following systems (Fig. 1) [4, 8]:

- longwall systems,
- short-front systems,
- parallel shortwall systems, including drift and room and pillar mining, as well as special systems (retreat mining, underground coal gasification, etc.).

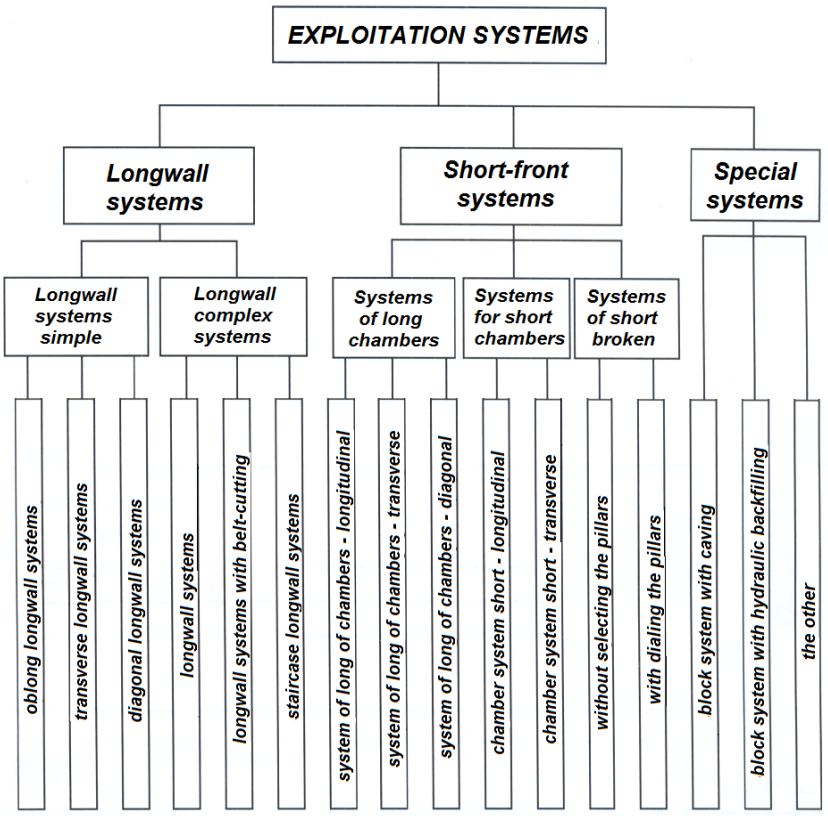

Fig. 1 Division of coal deposit mining systems

Longwall system – mining with this system consists in picking out the deposit at the entire length of the wall, and usually the full height of the face. It is utilised mainly in the mining of stone (coal) [6]:

- packed, using machines or explosives,
- loose and soft, using bucket wheel excavators,
- as well as in the mechanical moulding of the rock into blocks and mining of natural aggregates from underwater deposits.

Short-front system – can be used to mine the leftovers of deposits, parcels of restricted size and parcels of "typical" size, replacing the longwall systems. The characteristic feature of the short-front systems is high progression (the preparatory work per unit of extraction rate increases by 2/3 compared with the longwall system) [10, 11, 12].

PRACTICAL APPLICATION OF SHORT-FRONT SYSTEMS

A considerable part of hard coal in Poland occurs in deposits where exploitation by means of classic mining systems is very difficult and unprofitable (these are mainly residual deposits, shapeless deposits, sloping deposits [3]. One of such mining plants which has o-called residues is a producer of coal (mainly coke) in Poland. The enterprise has documented balance resources reaching ca 193.4 m. Mg, but these are only balance resources of deposits planned for exploitation. At the moment the operative resources of this enterprise reach only 20% of the balance resources. The main reason of these limitations are currently used mining systems and, partially, the concessions at the disposal of the enterprise.

Currently the activities of the enterprise are focused on prolonging the mine's viability. The management board is applying for concessions for making new deposits available. The use of alternative mining systems can help the plant to increase the operative resources while it is waiting for the concession.

The application of short-front systems in the exploitation of hard coal deposits is an effect of continuous searches of new and modifications of the already existing mining systems. Currently European mining plants use almost exclusively long-front (longwall) systems, which are not suitable for the exploitation of shapeless or residual parcels of coal.

Literature analysis and practical experiences indicate that some of the mining plants attempted to mine the deposits using this method [9, 10, 12]. The exploitation was conducted in the following mining plants:

- Kazimierz-Juliusz,
- Borynia-Zofiówka-JasMos,
- Staszic,
- Siltech.

Unfortunately, attempts to mine residual deposits are seldom undertaken, which results from the lack of analysis of the technical possibilities and profitability of such an enterprise.

The short-front mining systems are characterised by big advances (the rate of preparatory works per production unit increases 2-3 times compared to the longwall system), the technological cycle does not considerably differ from a typical longwall system, lasts much shorter, which allows achieving a much higher output, frequently at lower operating costs.

Short-front systems can be applied in the mining of:

- residual deposits,
- support pillars,
- safety pillars in order to protect the surface,
- fields of small lengths,
- fields in difficult geological-mining conditions by eliminating the presence of people in the coal face.

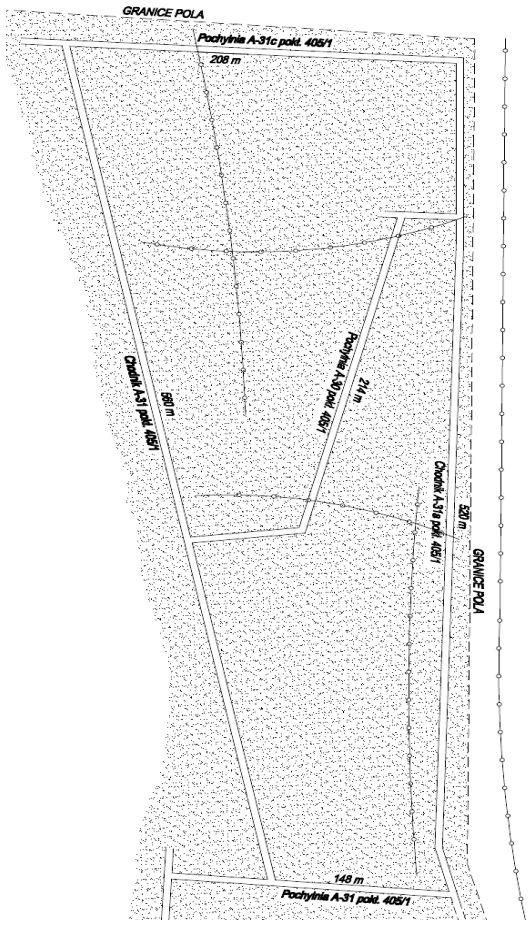

Fig. 2 Deposit A-31 in seam 405/l

EXPLOITATION OF DEPOSIT A-31 IN SEAM 405/1 ŁG

There has been conducted an analysis of the possibilities of using a short-front and a long-front system for mining a part of deposit A-31 (Fig. 2), which is a part of resources belonging to one of Polish mining plants.

In deposit A-31 the following geological and mining conditions were found:

- thickness of coal in the bed 2.10-2.60 m,
- type of coal 35.2 B,
- the deposit contains clay slates with coal laminas, medium hard, brittle, dividable into slabs or cubes, no spark ability,
- no base in seams situated over or below the planned longwall,
- threats:
  - methane hazard – III category,
  - coal dust explosion hazard – class B,
  - rock bump hazard – no liability to rock bumps,
  - fire hazard – I group of self-flammability,
  - water hazard – I degree,
  - hazard of methane and rock outburst – the seam is not threatened with methane or rock outburst,
  - climatic hazard – original temperature of the rocks is ~41^{o}C.

A seam characterized by such geological and mining conditions is difficult to mine due to its non-typical structure (numerous faults). The amount of coal in deposit A-31 is estimated to reach 164844 Mg. Deposit A-31, together with the faults and the existing dog heading has been presented in Fig. 2.

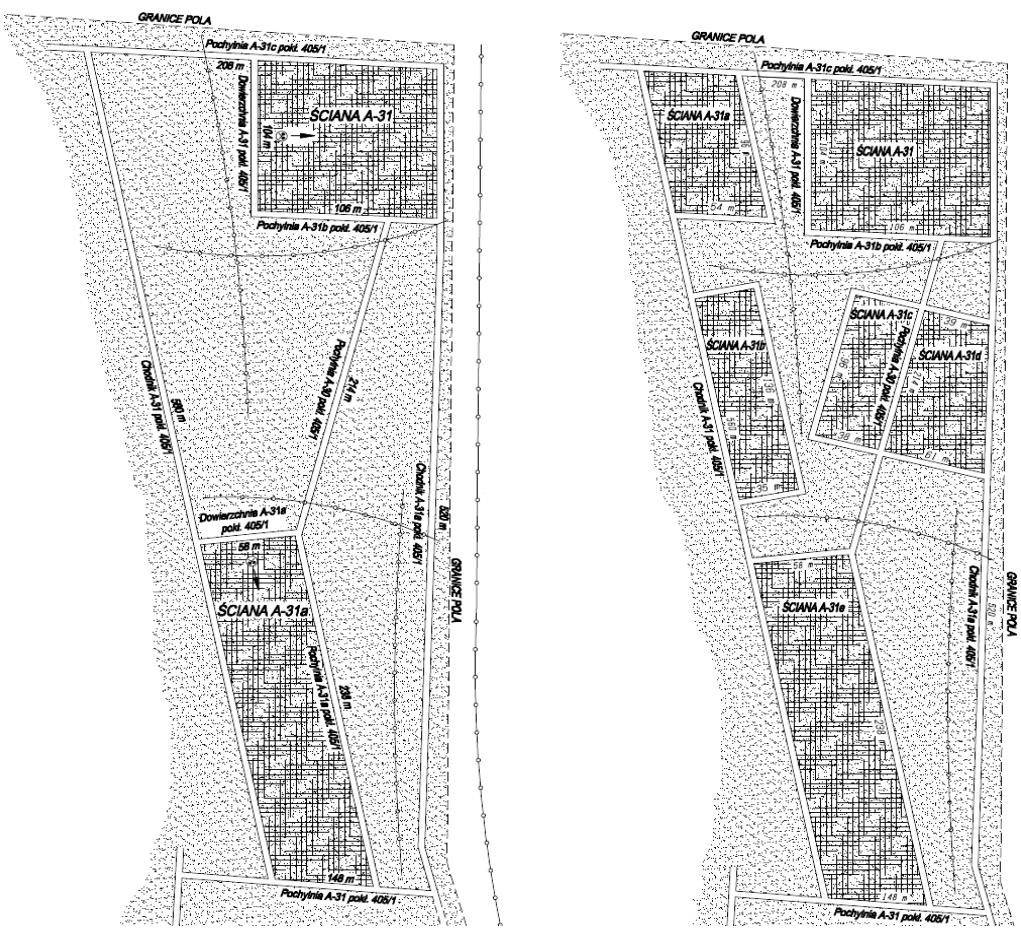

Fig. 3 Management of deposit A-31 by the longwall and short-front system

Table 1
Technical equipment of the longwall

Longwall system	Short-front system
KSW-460 shearer	ESA-60 L shearer
PZS RYBNIK-850	BW-EKF-0V longwall conveyor
PZP COBRA	UiK E82/755, PZG-180/440 scraper longwall conveyor
Sections – Glinik 08/29 Poz W-3 BSN and Glinik 08/29 Poz W-3	BW-25/36-POz Powered support
Belt conveyors	

Table 2
A juxtaposition of operations from the process cards

Operations	cards WK1	cards WK2	cards SŚ	cards KCH	cards LŚ	cards PH
⇨	5	5	5	3	7	2
□	5	6	8	6	7	5
○	3	2	4	3	5	1
△	5	4	3	6	19	5
D	3	4	3	4	0	2
⏀	3	4	5	3	3	3

Exploitation of deposit A-31 of seam 405/l łg can be conducted in two ways, therefore, two separate concepts have been presented. For each concept a plan of deposit management has been prepared, a manner of exploitation has been designed, a fleet of machines has been selected and an economic analysis of profitability has been carried out.

Variants of exploitation field management

For the conditions of seam 405/l łg in deposit A-31 the first proposed manner of field exploitation is the transverse longwall system with roof fall in the direction from the field (the from the boundaries). Due to numerous faults, the field of exploitation has been designed in a way ensuring the most effective working by the longwall system. For this reason, deposit A-31 has been divided into two smaller longwalls, i.e. longwall A-31 and A-31a (Fig. 3).

As an alternative solution, the parallel shortwall system with hydraulic stowing has been proposed. Due to the specific character of the short-front system, deposit A-31 has been divided into six exploitation fields, i.e. coal longwalls: A-31, A-31a, A-31b, A-31c, A-31d, A-31e (Fig. 3).

The deposit was divided into longwalls – two longwalls in the transverse longwall system and five ones in the short -front system after consultations with the mine employees, and the exploitation was adjusted to the geological and mining conditions

Exploitation by the longwall method allows only 31% of the resources to be mined, whereas mining of the same deposit by the short-front method makes it possible to exploit ca 60% of coal deposits (Fig. 3).

Selection of machines and devices

Pursuant to the regulations in force, in the area of the planned longwall it is necessary to use machines, devices, systems, materials and plastic products which fulfil the requirements specified in the Ordinance of the Minister of Economy dated 28th June 2002 (the Journal of Laws, No. 39 item 1169) with subsequent changes in in separate regulations [8]. Technical equipment for the planned longwalls have been presented in Table 1.

The technical equipment has been chosen by analysing the machinery stock owned by the company and consulting it with the employees of the Production Preparation department.

Mining process

In order to illustrate the scope of activities which occur on a given stage of the mining process, process cards were created. The main aim of these process cards is to demonstrate the processes which occur more often than others, which system is more mechanised and which is more labour-intensive. The analysis of the process cards conducted allowed us to propose changes which would improve the short-front system presented as an alternative.

A juxtaposition of operations from the process cards for both the longwall and short-front systems has been presented in Table 2.

The results of the analysis

Having conducted the analysis we were able to reach the following conclusions:

- the drilling of the dog headings is done similarly in both cases. Dog headings, due to their functions, have to be well secured, equipped with the right materials and devices which will allow further mining. It is a relatively lowly mechanised process,
- the differences in mining with the analysed systems are significant,
- the longwall system, due to the mechanised longwall complex, seems to be more efficient. The mining process, however, is more labour-intensive, which requires a larger number of workers. Moreover, because of the mining technology, a large part of the operations in the longwall system is devoted to activities connected with reinforcing and securing the wall,
- a significant problem in the short-front system is the amount of work performed manually. The scope and

number of mechanical-manual operations results from the mining system adopted. The number of technological operations results directly from the mining technology of a particular system,
- research work connected with the mechanisation of certain operations, such as securing the excavation sites, should be started,
- removal of a wall in the longwall (long-front) system, involves a number of manual operations and is closely related to the final stage of seam mining. In the short-front system, the removal of a wall is an independent process, which reduces the labour-intensity significantly.

Economic analysis of the mining operations – results

For the purposes of the economic analysis of the two systems the following data (average) has been adopted:
- the length of the excavation face – 50 m,
- length of the open-end – 200 m,
- the height of the operating door – 3.1 m,
- assumed selling price of coal, on average 349 PLN/t,
- assumed cost of a daily wage 480.00 PLN net,
- time (period) of reinforcement, operation and decommissioning of an open-end – 90 days,
- processing loss factor s = 0.23,
- excavation purity factor α = 0.95.

Table 3 presents the number of workers and the daily progress of the front wall in both systems.

Table 3
Daily progress and number of workers

	Longwall system	**Short-front system**
Daily progress	**5.0m** (1050 t/day)	**8.0m** (1650 t/day)
Number of workers	**9** workers/shift	**8** workers/shift

Table 4 shows the results of an economic analysis for the longwall and short-front mining systems.

Table 4
Results of the economic analysis

Data	**Longwall system**	**Short-front system**
Daily yield [Mg/day]	1050	1650
Financial surplus	**126.62**	**185.58**
Cost of excavation [PLN/Mg]	111.19	80.39
Coal resources [Mg]	**51942**	**90420**
Number of workers/shift	9 workers	8 workers

CONCLUSIONS

As a result of the analysis of the two mining systems, we can conclude that:
- the daily yield in the short-front system (due to the nature of the system) is higher than in the longwall system; this is caused by the difference in time needed to reinforce a wall compared to the classical longwall system,
- the unit cost of excavation for 1 tonne of coal is higher in the longwall system due to the cost structure, i.e.: the cost of labour-intensity, amortisation, and wall reinforcement,
- in a seam exploitation project for the short-front system (Fig. 3) it can be seen that due to the possibilities offered by the short-front system (i.e. the ability to mine the residual parcels), the number of mining fields is higher and thereby so are the coal resources which can be mined,
- implementation of the short-front system allows for simultaneous mining at a wall and drilling of a transport lane along with the progression of the open-end with the technical equipment available at the complex, which decreases the number of workers needed at every wall and, therefore, the excavation cost,
- the proposed short-front system allows for residual or irregular parcels to be mined. Mining of the analysed part with the longwall system allows only for 31% of the resources to be mined while excavation of the A-31 part with the short-front system allows for approx. 60% of the coal resources in the seam to be mined.

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