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MONITORING OF COAL BED EXTRACTION AS AN EFFECTIVE TOOL FOR IMPROVING THE PRODUCTION RESULTS OF A MINE

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Abstract:
The basic source of information necessary for proper and effective management of a hard coal mine is continuous monitoring of the mining process. An increased number of machines and devices used in a mine caused a need for continuous monitoring of mining departments' work. Monitoring of the extraction of hard coal beds is crucial for this process management, as it determines the proper course of the mining process. Hence, monitoring can be considered the most important element of the controlling process, especially in the area of mining process management in a mine. Effective monitoring and proper, quick reacting to any irregularities in this process have a significant influence on the production results of a mine.

Key words: *mine, mining process, monitoring, management*

INTRODUCTION [7]

The main source of objective information necessary to properly and effectively manage a hard coal mine is continuous monitoring of technological processes. Monitoring in the today's meaning of this word appeared in the middle of 1950s as a result of growing demand for hard coal, which caused the development of mining works mechanisation. Mechanisation, which in the initial period concerned simple operations, with time comprised whole technological processes. An increased number of machines and equipment used in a mine necessitated continuous monitoring of production departments' work. For this purpose, dispatch offices were created in mines, the basic equipment of which were devices ensuring communication with employees working underground and overground as well as monitoring of technological processes and the state of security.

The first dispatcher's equipment was installed in the „Wujek" coal mine in the years 1955-1956. It was next followed by DKZ-60 devices, imported from the then Czechoslovakia (other sources quote DZ-56). Moreover, domestic equipment PUD/G-59, WSP-63, CDK-66 and mines' own solutions began to be applied. There began a period of using classical (non-computer) dispatcher's devices equipped with static synoptic tables which provided information on the course of production and the mining plant's security.

The development of coal mechanical mining led to comprehensive mechanisation of the whole mining process, ensuring continuous and stable work of all the machines and devices controlled by man. Attempts were undertaken to automate particular technological processes, which resulted (at the turn of 1960s and 70s) in an attempt to implement comprehensive automation of the whole mine (experimental mine "Jan"). The effect was an increased number of parameters requiring continuous monitoring. The previously applied monitoring methods and devices turned out to be insufficient – the dispatcher was not able to effectively analyse such a large amount of information. Hence, a computer system to support the dispatcher was used apart from static synoptic tables. The task of the system was to select information reaching the dispatcher's room by presenting only information about significant changes of the mine's condition, which required intervention. Such an attempt was implementation of "CES" and "S" systems in the "Jan" coal mine at the end of 1970s. These implementations commenced the application of computer systems supporting the dispatcher's work, which complemented the static synoptic tables.

The years 1978-1980 saw the completion of works on Modular Dispatching System (MSD-80), which became standard equipment of dispatcher's offices in mines. The system also supported works of the rock bump department and ventilation services.

The intensive development of coal mining in Poland entailed a necessity of reaching increasingly deep-lying deposits and extracting coal beds threatened with rock bumps or methane release. This resulted in extending a network of sensors and increasing the amount of various information which had to be provided to the mine's dispatcher. Text messages were replaced by colourful technological flash cards in the form of monitors. A set of monitors used for presentation streamlined the flow of information and was called a dynamic synoptic table. Such a table was first implemented in 1988 at "Moszczenica" coal mine. The process of introducing dynamic synoptic tables in the dispatcher's room was accompanied by modernization of the previous MSD-80 system, which resulted in the creation of MSD-90.

Difficult environmental conditions in a mine and its extensive spatial structure frequently necessitate monitoring of technological processes and security in the conditions of insufficient information. In all periods of monitoring sys-

tems development, the above problem was solved by employing dispatchers from highly qualified staff with extensive professional practice. Using a holistic technique of processing the incoming information (often based on intuition), a dispatcher often took surprising, but most frequently right decisions (without performing a rational analysis of the situation).

Application of dynamic tables did not completely eliminate synoptic tables, as expected at the beginning – they complemented the whole system of mining process monitoring (Fig. 1).

Fig. 1 Modern mine dispatcher's office
Source: [9].

The possibility of eliminating static synoptic tables appeared with the development of big picture technology, which enabled combining the advantages and eliminating the drawbacks of static and dynamic tables in one device.

MANAGEMENT OF THE MINING (PRODUCTION) PROCESS

The basic area of management in the process of mining (production) enterprise management (a mine) is management of the mining process. This process can be described with the Deming Cycle [2]: Plan-Do-Check-Act (PDCA), Fig. 2.

Fig. 2 Deming Cycle

Production management is also defined in the following way: it is a set of activities which create a value in the form of products or services through transformation of expenditure into results. Mutual connections between particular functions of the management process have been presented in Fig. 3.

The sequence of the above mentioned management elements is not accidental (planning, organising, motivating, controlling), as managing people (managers) use these functions in the above quoted sequence. Since management is a continuous process at every moment of the functioning of a production plant (in our case – a mine), it forms a certain cycle, which is often repeated at various levels of management, with reference to different organisational solutions. It is obvious that the duration of a cycle may be (and is) different depending on the decisions it concerns. Implementation of subsequent functions of the classical process of production management does not always take place in the economic reality, particularly in the case of the mining process management. For this reason, the "Controlling" function, including mining process monitoring, should be closely related to all the remaining functions of the decision-making process, as the very activity of observing basic parameters' deviations from the values adopted at the second stage of planning does not provide a possibility to improve the situation so as to achieve the goals set (e.g. coal parameters) (Fig. 4). Hence, irrespective of the occurrence of particular management functions in the form of a closed cycle, there should exist a cross relationship between the controlling function and the remaining functions of the management process.

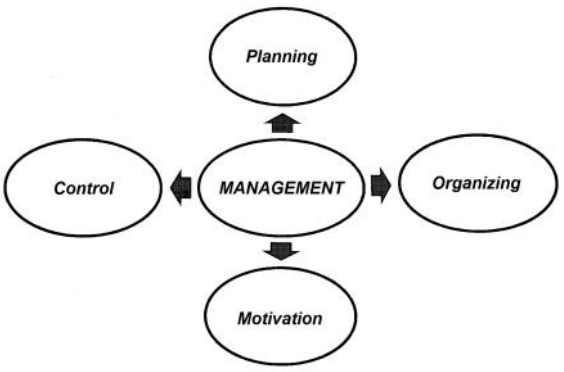

Fig. 3 Management process

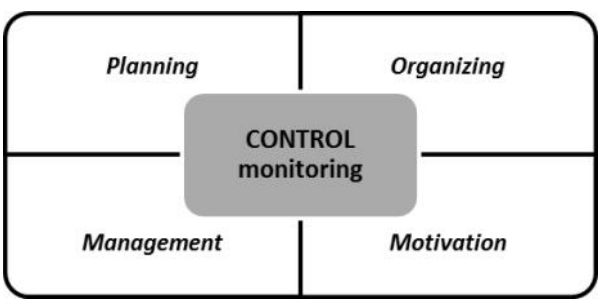

Fig. 4 Correlation between the controlling function (monitoring) and management process functions

In Polish mining industry, coal beds are extracted in a longwall system, by means of mining cutting machines. For this reason, one of the important areas of mines' activity is operation of machines and equipment. This activity should among others consist in continuous monitoring of rational and effective use of machines and equipment in the mining process.

Technical systems of hard coal mines are characterized by:

- considerable scattering,
- complexity,
- limiting the area of work by the size of underground headings.

The main task of maintenance teams is to ensure the continuity of currently working machines and devices. As a result of these activities, the costs of machine maintenance are reduced, and, in consequence, the costs of production, i.e. mining plant activity, are lower. Any disturbances to the process generate huge losses [6].

In the mining process one can distinguish the following stages [1] (Fig. 5):

- winning process,
- horizontal transport,
- vertical transport.

The process of mining is a serial system. A failure of one of the above mentioned links "switches off" the remaining elements of this series.

Continuous monitoring and optimization of the mining process requires using an integrated computer system. The above system should be an integral part of the mine's management computer system.

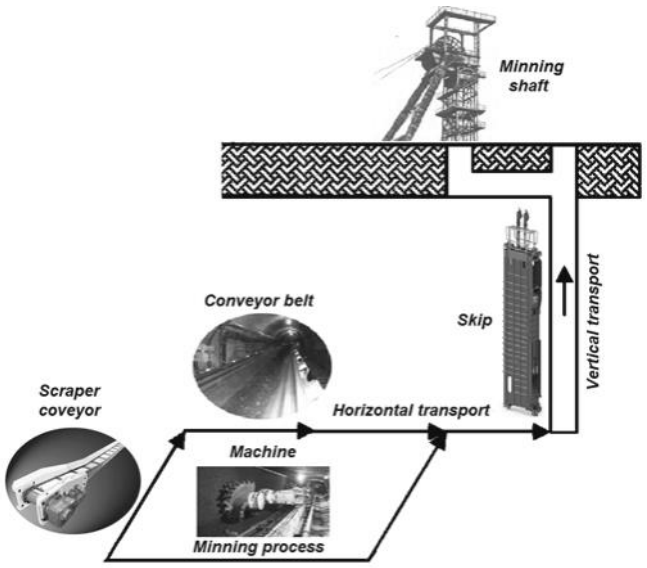

Fig. 3 Mining process

THE ROLE OF MONITORING IN THE MINING PROCESS

Monitoring is crucial for the management of hard coal mining, as it determines a proper course of this process. Information obtained as a result of monitoring and subjected to analysis enables taking proper decisions regarding the mining process as well as making necessary corrections. Hence, monitoring can be considered the most important element of the controlling process, especially in the area of the mining process management. When designing a system of the mining process control and monitoring, one should bear in mind that information is the most important element in the decision-taking process. A basic condition for effective management of the mining process is to have updated and credible data describing this process, which is very difficult in mining conditions. Hence, continuous monitoring of the mining process is one of the major ways of obtaining reliable information about this process. Information must have three basic features:

- credibility,
- completeness,
- availability in due time.

Currently mining plants have at their disposal single solutions related to the mining process, but they mainly concern the mining process rather than the winning process (Fig. 5) – there is no one consistent strategy of IT implementation. These solutions concern mainly:

- coal bed quality characteristics,
- computer systems for visualizing coal beds and creating map documentation of mining excavations,
- ventilation of excavations,
- threat (e.g. CH_4) monitoring,
- supporting the work of OSH services.

Mines are following their own strategies, hence problems faced by the managerial staff, which are mainly related to mines' low profitability or management efficiency [3].

Specialist companies dealing with problems related to the control and management of the production process [4] attach great importance to the automation of this process monitoring. There have been distinguished four layers of production hierarchical structure, where every layer represents another level of enterprise management as well as production process management and supervision. This division is as follows:

- Level I – production process control in real time. This level is a bridge between man and technological machines (devices). At this stage, data is collected from devices directly involved in the production process, necessary reports are generated and data to be archived is prepared.
- Level II – visualization and supervision over the production process. This level is closely related to level I, and their functions are often intertwined. At this level functions related to technological support and product tracking in a particular process or whole process line are performed.
- Level III – production management (MES – Manufacturing Execution Systems). This level is responsible for an exchange of data between I and II systems and ERP (Enterprise Resources Planning) – it takes over functions related to monitoring and documentation of the process from level I and II. The following tasks are carried out:
  - production process modelling,
  - monitoring of the flow of materials and the means of production in an enterprise,
  - visualization and supervision of production and man-machine relation,
  - readout and archiving of process data,
  - quality management,
  - supervision over production documentation,
  - dynamic management of plant maintenance,
  - generating of reports,
  - introduction and enforcement of good manufacturing practices.
- Level IV – enterprise management (ERP) – responsible for managing the resources of the whole enterprise, orders, purchases, finances, accounting, costing, forecasting, planning. At this level it is possible to optimize the production process in terms of costs or quality assurance [5].

The basic aim of so developed system is to monitor the production (mining) process in all its phases, in order to ensure that relevant services can influence the course of the process in a way that enables achieving the desired quality of the final product. Such activities allow describing the production (mining) process with relevant indicators, which will enable the course of the process to be documented [8].

In the extractive industry (coal mining) there is a considerable time difference between the moment of taking a decision on the mining process and the actual period of achieving the effects in the coal extraction process. The scope of information necessary to take a proper decision regards mainly some distant future. As a result, decisions taken today, irrespective of the criteria they are based upon, must forecast future conditions. Hence, decisions regarding a future mining process are made in the conditions of uncertainty, and the risk (understood as an effect of uncertainty) grows as the time between taking the decision and mining process start-up increases. Risk in the mining industry results from deposit geological structure, spatial structure as well as technical and organisational conditions. For this reason, in the mining industry one can distinguish

specific types of risk, which may considerably influence the process of making a deposit available, preparing and extracting the deposit [6], which include:

- geological risk – the amount of resources, quality of resources, availability of resources, mineralogical composition,
- technological risk – deposit extraction technology, technical mining possibilities, processing possibilities, natural threats.

FINAL REMARKS

As shown above, a mining plant is a complex economic organism, so it should attach special importance to the control and continuous regulation of mining processes. It is therefore important to monitor the real parameters of the mining process, such as:

- duration of particular operations,
- sequence of operations,
- parameters of machines' work,
- natural threats,
- parameters of the coal bed and the surrounding rocks.

The above parameters can be obtained directly from measurement devices, control instruments, devices which control machines or from measurements taken by specialised mine services. After being subjected to appropriate processing and analysis, information from the mining process monitoring can directly or indirectly influence this process. It is important that updated information, without any distortions, is available on a continuous basis to staff responsible for the mining process. Information should be an effective instrument of control for relevant services.. Monitoring of the mining process as well as analyses and reports based on it may concern different periods of time and should enable an effective improvement of the process parameters.

In the production (mining) process management a number of tools for processing the information related to various aspects of process improvement or quality control are used. They are applied to monitor the whole production (mining) cycle.

The final product is considerably influenced by the quality of domestic coal in the mined bed. Miners have no influence on certain elements of the mining process, among others the quality of coal mined. The main problem is water accumulation in the mined rock, purity of coal getting and foreign contaminations. An ideal solution would be "sorting" the coal underground, depending on the customer's needs and the coal deposits quality, and, next, mixing appropriate coal grades until the final product is obtained.

Such „quality technologies" are among others used in Australia [4]. Coal is transported from a mine to a cargo handling port, where it is sorted with regard to quality, and next, depending on the customer's orders, coals having appropriate parameters are added to the coal stream until the parameters required by the customer are obtained. However, the whole procedure takes place outside the mine, which only delivers the raw material. Unfortunately, in Polish coal mining industry we will have to wait long for such solutions.

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