INFORMATICS PLATFORM AS A TOOL SUPPORTING RESEARCH REGARDING THE EFFECTIVENESS OF THE MINING MACHINES' WORK

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Abstract: One of the factors which highly affects the economic effectiveness of production enterprises is the level of the use of technical means. This factor is also significant for mining companies extracting coal. The optimal use of mining machines can impact the future of these companies. The paper presents the authors' solution which is an informatics platform supporting an analysis of the mining machines' effectiveness. It uses a data warehouse to archive, synchronize and analytically process the data obtained from the studied machines. The article shows an example of applying an informatics platform to investigate the effectiveness of the longwall shearer's work. The analysis was based on the data obtained from the industrial automation system. Afterwards, the shearer's availability and performance, and quality of the product, which is coal, were determined. The developed tool should find wide practical application in production companies across different kinds of industries.

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Introduction

The International market of energy resources is highly competitive. It also has a significant influence on the increased competitiveness in the Polish market. For this reason, enterprises extracting natural resources are forced to take activities which will make it possible to continue to exist in the market. One of the key areas that impact about the results of mining companies is the use of the technical means. Opinions of experts, as well as the results from audits, indicate that underutilization of the mining equipment is one of the biggest problems of mining enterprises (Przybyła, 2009). Currently used mining machines and devices are characterized by the high level of reliability and the technical parameters and at the same time are very cost-intensive objects. Therefore, it is justified for mining companies seek to use the equipment in the best manner that they can. In particular, it refers to the increase in their effectiveness. Moreover, this is the subject of this paper. The goal of the research, the results of which are discussed in this article, was to develop an informatics tool which would help to increase the effectiveness of the use of the mining machines. This tool is the informatics platform supporting the process of implementation and application of the OEE model to evaluate the level of the use of mining machines. This solution uses a data warehouse for archiving, synchronizing and analytically processing data which are obtained from the studied machines. It was assumed that the main task of this platform would be to integrate the data collection system and the supporting system using the OEE model. In the first stage of application, this tool will enable the initial evaluation of the effectiveness of the studied machines. In the next stage, it will make it possible to monitor the efficiency of the use of the machines and, thanks to this, assess the implemented changes and modifications. It appears that a significant problem in mining is also the identification of the causes of the low effectiveness of the machines and devices. In the paper, an example of the application of the informatics platform to study the efficiency of the longwall shearer's work has been presented. The basis of the analysis was the data obtained from the industrial automation system. Thanks to this, the availability and the performance of the longwall shearer and the quality of the product, which in the case of mines is coal, has been determined. The developed tool is universal and should find a broad range of practical applications in the production companies of other industries too.

Characteristics of the Studied Object

The basic exploitation system in Polish coal mine is the longwall system. In this kind of system, the coal or other useful mineral is cut out in the zone of the longwall's face. The length of the longwall's face usually ranges from 60 to 300 meters. The height of the longwall can be from 0.6 to 9 meters (Korski & Bednarz, 2012). Such long exploitation walls make it possible to mechanize and automate the process of coal exploitation, especially in coal cutting and transporting. In this area, the machines

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of the mechanized longwall system have significant meaning. They are dedicated to directly cut out coal and transport the coal from the zone of the longwall face. This system includes the longwall shearer, the armored face conveyor, the beam stage loader and the crusher. Also, there is also the longwall roof support designed to protect the work place. From a reliability point of view, these machines form a serial system. It means that they play a significant role in the continuity of the exploitation process and failure of one of these machines makes the entire system stop working. The most complicated and expensive machine of this system is the longwall shearer. It is directly responsible for coal cutting. Figure 1 shows an example of the longwall shearer.

Figure 1: The view of the longwall shearer

Source: Authors

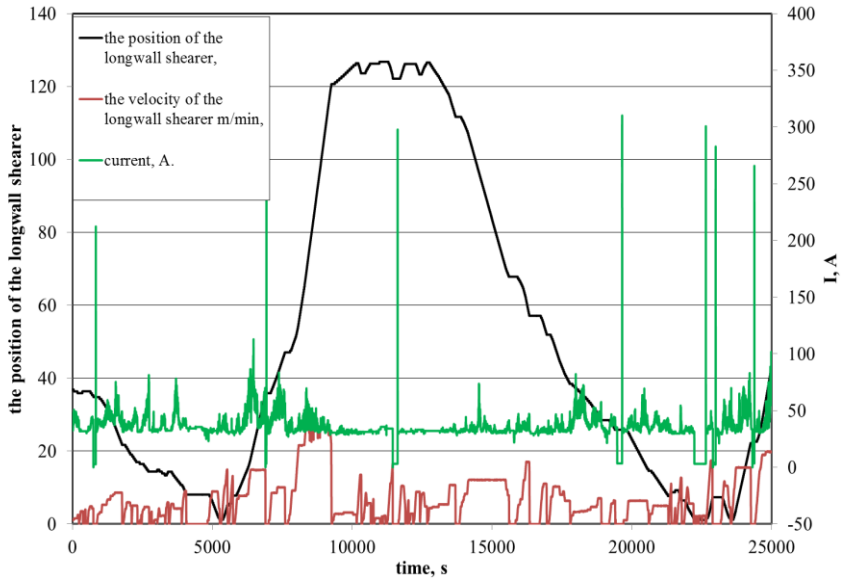
Because of the significant meaning of the longwall shearer for the exploitation process, the authors decided to conduct an analysis of this machine's effectiveness, using the developed informatics platform.

Determination of the Efficiency of the Longwall Shearer

To carry out the research on the efficiency of the mining machinery, it was necessary to choose the appropriate method and tools which would make it possible to evaluate the conducted process objectively. The authors decided to use the Total Productive Maintenance (TPM) strategy in their study. Moreover, to directly assess the utilization of the studied machines they applied the Overall Equipment Effectiveness model (OEE). This model is a quantitative tool for the TPM strategy. Its measure is the OEE indicator which is determined by the three partial indicators that include availability and performance of the machine and quality of the product. By analyzing these three areas, all relevant factors, which impact the effectiveness of the machine or the set of machines, are taken into account (Nakajima, 1988, Matejczyk, 2013).

However, the application of the OEE indicator in the original version to determine the effectiveness of the mining machinery was practically impossible due to the specificity of mining. For this reason, the partial indicators of the OEE indicator have been redefined and adjusted to the specific characteristics of the mining industry (Brodny et al., 2016). The availability values were determined for each of the studied machines (in this case, the longwall shearer), while performance and product quality indicators were calculated for the entire set of machines. The most critical data, which became the basis of availability determination, was obtained from the industrial automation system. This system works continuously and independently from the operator registers machine's parameters and thanks to this, it guarantees high reliability of the data (Stecuła & Brodny, 2016). This data is completely independent of the subjective factors and mistakes resulting from human factor. The data that was used to determine the effectiveness of the shearer was the work parameters, such as the current consumed by the particular shearer's engines, the shearer's position in the longwall about the right section of the longwall roof support, and the feed speed. Figure 2 shows the temporal chosen parameters waveforms of the longwall shearer for one work shift.

Figure 2: Recorded parameters of the longwall shearer's work for one work shift.

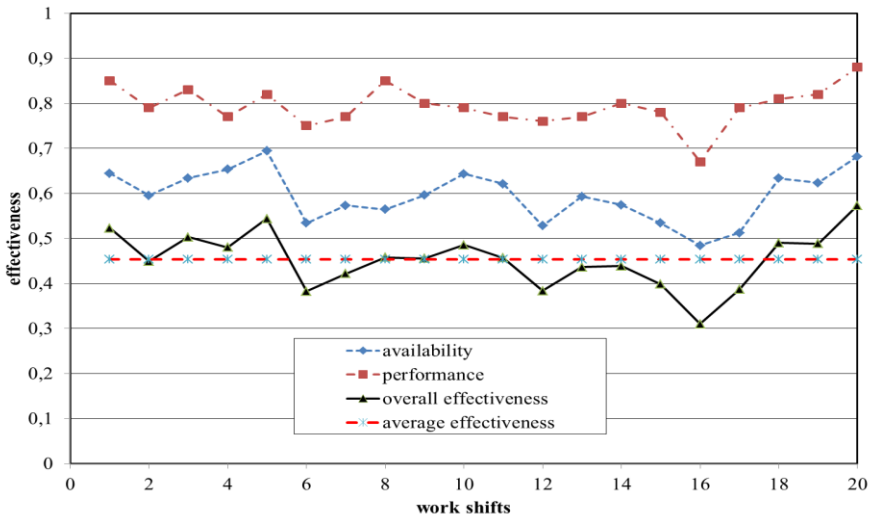


Source: Authors

Based on the obtained data, it was possible to determine the value of the availability indicator which is defined as the ratio of the real work time to the normative work time of the shearer (in this case, 360 minutes). By the recorded waveform, the level of the shearer's availability was determined for the studied 20 work shifts. The performance indicator was determined thanks to the planned and the real extraction. The quality indicator was calculated based on the information from the processing plant. This information related the assortment and the gangue content in the valuable mineral. Due to the method of measurement, the qualitative data was averaged for the entire studied period. After determining the values of the partial indicators, it was possible to calculate the value of the shearer's OEE indicator for 20 work shifts. Figure 3 shows the availability and performance values and the OEE values of the longwall shearer for 20 work shifts.

The results indicate that the use of the longwall shearer should be considered as low during the studied period. Therefore, it is necessary to develop a proper methodology to identify the causes of this state and plan the precise activities to improve the effectiveness.

Figure 3: The values of the availability, performance and OEE indicator of the longwall shearer



Source: Authors

Application of the Informatics Platform

The huge amount of data obtained from the industrial automation system needed the application of the appropriate informatics tool that would allow the archiving and analyzing the data. For this purpose, an informatics platform has been built to support the analysis of the effectiveness of the mining machines. This solution uses data warehouse for archiving, synchronizing and analytically processing the data which comes from various machines. The data warehouse is thematically oriented, chronological, coherent and unchanging in its data collection. Its task is to support decision-making processes. It will help solve the decision problem by analyzing its data (Inmon, 1992). In the research, the data in the thematic bases concerns the work parameters of each of the tested machines. The database is a set of data and objects which are related to a given topic or task (Kopertowska-Tomczak, 2009). Also, the data warehouse integrates the data and process it analytically. As a consequence, it is possible to determine the specific values.

The use of the longwall shearer's parameters to determine its availability and overall effectiveness is only the first step in the application of the developed platform. In the next stage, it is necessary to conduct an analysis of losses in the production process. In particular, it concerns the identification of the structure and the causes of all types of breaks in the longwall shearer's work.

These losses were divided into several categories. The first category includes the losses of the availability of the very machine or the entire set of machines. Such losses are most often caused by random events that generate failures and downtimes. The second layer is about performance losses. They are related to a machine's work. The third layer includes the losses in the quality of the product, which, in this case, is coal. For each of the three layers, the value of the proper indicator is calculated. Then, the final Overall Equipment Effectiveness indicator can be determined.

In the next stage of the study, conclusions are drawn by the level of determined effectiveness indicators. To achieve it, the quantitative qualification of the negative events has to be done first.

The quantitative analysis is understood as the determination of the duration of a given event and the frequency of its occurrence. Also, the losses should be analyzed in a qualitative context which means that the specific cause of the given failure or downtime has to be found. The described informatics platform using a data warehouse for archiving and analyzing the work parameters has supported the research on the effectiveness of the longwall shearer. What is more, it will be used to study the entire set of the mining machinery further. It will enable quick and profound analysis, the results of which will be used in a further study.

Conclusion

In the current economic reality, every company is forced to optimize their production costs. This also applies to mining companies. One of the areas, in which there are significant reserves, is the use of the mining machines and devices. The informatics tool in the form of the platform, which is presented in this article, is aimed at facilitating the process of assessing and improving the effectiveness of the mining machinery. In the presented example, the study of only one machine, the longwall shearer, has been described. However, in practice, thanks to the developed platform, it will be possible to analyze the work of many machines that are involved in the technological process of coal mining. It should be highlighted that the essential meaning for the credibility and the quality of the analysis has input data. Relying on the industrial automation systems while obtaining the data guarantees the high quality and the independence from human factors. The results clearly showed that the level of the use of the longwall shearer is unsatisfactory. The availability, as well as the total effectiveness, are low despite the fact that there were no major failures during the period that could reduce the value of these indicators. The results confirm the validity of the use of IT tools and the industrial automation systems for analyzing the utilization of the mining machines. The results presented in the article are only a small part of the results of the whole longwall system research. However, even this little portion of research shows the large scale of the problem regarding the effectiveness of the technical potential which mining companies face.

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