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Prospects for development movement in the industry concept 4.0

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INTRODUCTION

Exploitation in technical terms is the extraction, use of natural resources, the use of technical devices in accordance with their intended use, and the maximization of benefits through the exploitation of someone or something. In the literature one can also find a broader scope of the definition of exploitation, which says that it is a set of ordered technical organizational, normative legal and economic measures, undertaken and implemented by a man using appropriate resources in the period from the beginning of the system to its implementation.

From the model of the process of satisfying needs according to J. Dietrych (Fig. 1) exploitation is the final stage of the object's life cycle. Looking at the scheme, it can be seen that it causes feedback, which is the source leading to the modification of previous or new technical measures (Loska, 2012, Loska, 2015).

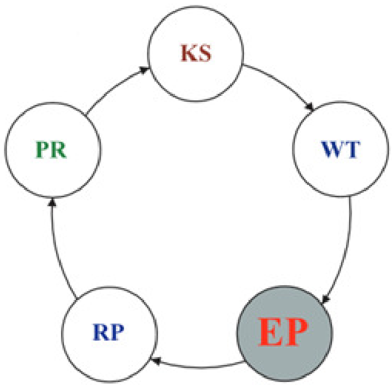

Fig. 1 The model of the process of satisfying needs according to J.Dietrych

In order to more easily identify exploitation, one should become acquainted with operating systems that create subsystems of use (elements in accordance with its purpose function in the design and construction process) and maintenance (maintenance of the facility in serviceability or restoration of technical facilities). The layout of two subsystems ensures unambiguous allocation of each operational task.

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Under the influence of various concepts of operation in organizational and technical conditions, new subsystems are emerging (Loska, 2012).

We can refer to exploitation systems in a model approach, that is, to adopt a diagram showing relations between selected features described in the field of technical systems operation. The basic models describing technical objects include system and functional models. To create a system model, one should define a given technical object, unit, assembly, subassembly and elements taking part in it. The functional model, on the other hand, presents the influence of selected elements and relations in terms of the functioning and control of the facility/technical system (Loska, 2015).

Any technological system may lead to operational events that may be intentional or unintentional. Intentional events result from conscious human activity in relation to the exploitation object (eg inspection and maintenance of machines and devices), while adverse events are related to random situations without prior conscious decision-making of people (eg failures of machines and devices) (Loska 2012).

The area that deals with the supervision, diagnosis, elimination of machine and equipment failures, as well as the above-mentioned operational events is the maintenance of traffic. It has a huge impact on the proper functioning of the company in the production proces (Tychoniuk, Wyczółkowski, 2018).

KEEPING MOTION

The dynamic development of the world of digitization, manufacturing technology and widely understood technology significantly changes the client's expectations, and thus the production processes. The constantly increasing competition on the market forces employers to implement the most modern solutions of production equipment. Due to the high direct costs (purchase costs) and indirect (operating) costs, as well as the increasing complexity of the applied solutions, higher reliability of selected machines and devices is expected. This causes an increase in the importance of maintaining the UR traffic carried out by the SUR (Walczak, 2012).

Maintaining traffic is called activities and processes implemented within the framework of generally understood production, mainly related to ensuring the availability of technical infrastructure of the plant and aimed at guaranteeing its proper operation. This means smooth implementation of production orders by maintaining the availability and operation of machines at the highest level. The efficient functioning of this aspect of production is possible only due to responsible supervision of many areas at the same time. To this end, the plant should adopt an appropriate UR strategy and implement measures not only of a corrective but also preventive and predictive nature. An important element is to carry out regular inspections and repairs as soon as possible. Other activities carried out by SUR include: keeping a register of full equipment of the plant, maintenance, repairs and inspections of machinery and equipment, ongoing removal of failures and ensuring proper operation of machinery, management of spare parts management and care for optimal inventory, ensuring safety of people and the working environment , maximization of effectiveness and efficiency of manufacturing processes, ensuring optimal media consumption, implementation of the adopted maintenance strategy (Legutko, 2015, Walczak, 2012).

The process of machine maintenance in the highest degree of reliability includes three subprocesses: preparation of machines for work, repair and maintenance. Preparation of machines for work enables efficient takeover of a machine ready and adapted to work at a given machine production by an employee. The repair occurs only in the event of a machine failure and is performed personally by the maintenance technician or in particularly complicated cases by the service technician. Maintenance is carried out according to the maintenance plan and based on the analysis of the production schedule. During its implementation, the conservator uses his own knowledge and experience as determinants of its proper performance (Loska and Paszkowski, 2017).

UR is a continuous process requiring proper planning. To this end, each company should carry out a thorough analysis and audit of its own needs, requirements and production processes so that an optimal long-term action plan can be adopted. The various concepts can be helpful in creating the UR strategy, each of which emphasizes a slightly different aspect (Legutko, 2015). Such concepts include:

TPM – Total Productive Maintenance

Widely used in many manufacturing companies, which is one of the methods of lean management, serving to ensure maximum efficiency of machines and devices.

Its main goals are:

- increasing the stability of production processes,
- extending the service life,
- reducing the costs of maintaining machines and devices.

An important aspect in the goals of this method is to achieve zero unintentional events, i.e:

- zero work-related accidents,
- zero gaps,
- zero failures.

The whole concept of Total Productive Maintenance is based on eight pillars, which are also responsible for supporting the entire system:

1. Autonomous Maintenance – it is based on the knowledge of machines by operators who are able to detect certain abnormalities of machines and devices, that is why their task is to control, clean, remove the causes of pollution effects, supervise the operation of devices
2. Kaizen improvement – the Kaizen method is primarily an increase in efficiency at the same time as low-cost process improvements.
3. Planned Maintenance – planning maintenance activities to eliminate, among others, emergency machine downtime.
4. Maintenance for Quality, whose task is to identify production conditions and – most importantly – maintain these conditions.
5. Training. Total Productive Maintenance is a concept that requires continuous learning, continuous acquisition of knowledge and extending skills.
6. Total Productive Maintenance at the Bureaux – activities improving the office processes, focused on the flow and processing of information.
7. Safety, Health and Environment – eliminating risks to employees and the environment.
8. The 5S tool is a tool whose aim is to create a structured and the best organized workplace.

RCM – Reliability Centered Maintenance

Reliability-oriented maintenance (RCM) consists in determining the necessary operations in the field of operational efficiency of the device/machine, taking into account conditions of use, working conditions, technical condition and history of machine operation. Their significance for the course of the production process and the quality of the product is also taken into account (Loska, 2012).

The essence of the RCM approach is illustrated by the seven basic questions formulated in 1999 by the International Society of Automotive Engineers:

1. What functions does the technical facility meet and what performance standards meet them (eg efficiency, product quality class, operating cost, safety) in the context of current production tasks?
2. How can an object fail in fulfilling a function (how do damage occur)?
3. What could be the cause of any functional damage?
4. What are the consequences of each of these damages (what happens when the damage occurs)?
5. What is the significance of each of the effects of these damages?
6. What can you do to predict or prevent any damage?
7. What should be done when the appropriate "proactive" preventive action can not be found?

Looking at the above-mentioned questions, we can conclude that an important concept is damage and, in principle, a failure that accompanies each company in the maintenance of machinery and equipment.

A distinction is made between two types of functional failure (damage to the assembly or part to perform the functions of certain operating standards) and potential (identification of physical signs that functional failure will occur).

Maintenance workers in the RCM system are not always able to answer all the above questions, therefore team work is important in which every person in the team provides the necessary information about the operation of devices and machines.

5S – 5S method

The 5S method ensures care for discipline, order and diligent management at a given workplace. This name comes from the Japanese words:

- seiri – selection (get rid of unnecessary things),
- seiso – cleaning (clean up the workplace)
- seiton – systematics (a place for everything and everything in its place),
- seiketsu – neatness (set standards),
- shitseke – self-discipline (keep standards).

It engages all employees to maintain cleanliness, order and security at workplaces.

The 5S method in maintaining traffic causes: the sense of ownership and pride in relation to the workplace by the operators, increased attention to devices and their maintenance through preventive actions and early detection of faults, shortening the time of preparation and retooling of machines thanks to the segregation of parts and tools for this purpose, eliminating contaminated products and operator errors (supporting quality control), facilitating problem solving by revealing irregularities.

SUPPORTING TOOLS UR

Currently, in the world of dominant technology, the most popular tools supporting the organization of UR departments are IT solutions. Smaller companies mainly use Excel spreadsheets or simpler and general available free computer programs. Enterprises with a better segregated and organized SUR unit prefer more professional tools, ie CMMS systems. They are solutions dedicated to technical departments and people associated with the so-called maintenance (Walczak 2012).

The most effective use of the CMMs/ERP system is based on the work of a large number of people who run the database creating information resources. The high functionality of the systems is proven by their basic features: IT structure, information security, integration capabilities, reporting method, usage and service, ability to manage distributed enterprises. CMM's tools include: ensuring the maintenance of technical facilities, planning and implementation of maintenance and repair work, disposing of repair resources and reporting of maintenance and repair work (Walczak, 2012, Winkler 2012, Piechowski, Szafer, Wyczółkowski, Gładysiak, 2018).

MAXIMO is an example of these systems. It has a modular structure, allowing for logical ordering of data characteristic for the considered area. Detailed construction is shown in the diagram below, Fig. 2.

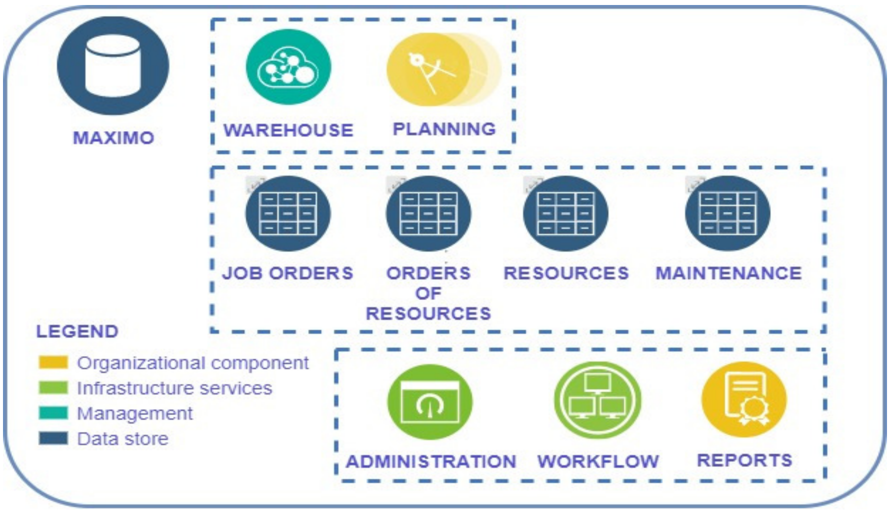

Fig. 2 The structure of the MAXIMO System

The work order module allows you to gather detailed information about the maintenance and repair work being carried out. In this way, it is possible to report, implement and implement any corrective and corrective actions, as well as to track their implementation, taking into account the resources necessary to perform them.

The maintenance module enables regular planning of maintenance and repair work, taking into account the operational strategy. The strategy is selected, for example, based on service and repair cycles or the results of diagnostic measurements.

The warehouse module is the central part of the system, implementing two main goals. The first is to maximize the availability of spare parts for work orders. The second is the organic storage of spare parts in warehouses.

The resource module allows you to collect historical data resulting from the work of objects. It is a part of the analysis that aims to reduce unplanned downtime.

The order module allows you to acquire spare parts and services. The MAXIMO

system works with most business systems.
The planning module allows creating templates for tasks as part of repair and maintenance work, including all resources.
The reports module allows displaying ready-made standard reports as well as interactive creation of own based on collected data.
The work flow module enables automation of maintenance and repair tasks based on process methods with immediate information transfer. This module improves the efficiency of the tasks carried out.
The administration module allows you to manage the MAXIMO system in terms of personalizing system settings, interface, availability, database configuration and data reporting.
The MAXIMO system also has a large range of additional tools, the functions of which relate to a wide range of non-operating activities.
ZMT is another reliable system supporting the maintenance of traffic (permanent property management - the name comes from the Polish meaning). The system enables collection and analysis of necessary data on the current state of machinery and equipment, storage resources, necessary repair works, reported failures and defects, purchase costs or planned service activities.
The system structure is based on three basic layers: database server, application server and client server. The most important system functions include: asset records, maintenance management, warehouse management and reporting. The view of the system is shown in the diagram below, Fig. 3.

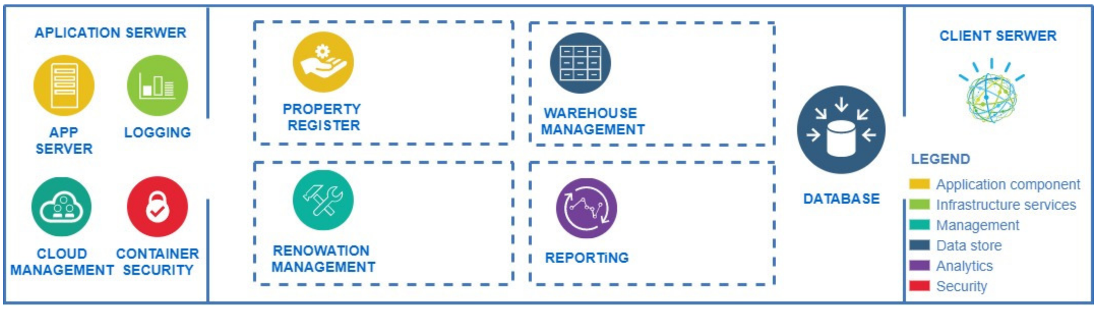

Fig. 3 Structure of the ZMT System

Records of assets – this module allows you to manage information about the operated facility and its components. It enables the collection and management of technical documentation, warranty cards, service cards, diagrams, specifications, etc. An important element is the access to the full service history of devices, for example: installations, repairs, maintenance, inspections.
Renovation economy – this module supporting planning and monitoring the implementation of maintenance and repair work. It enables preparation of a schedule with consideration of necessary resources, including temporary work standards.
Warehouse management – this module allows you to manage, track and control the resources of spare parts of machinery and equipment necessary for maintenance and repair work.
Reporting – a module that provides mechanisms for conducting and visualizing analyzes. It enables generating brochures in tabular form on the basis of data provided in the database.

THE CONCEPT OF UR W 4.0

The concept of Industry 4.0 means the fourth industrial revolution, involving the integration of intelligent machines, systems, people and introducing changes in production processes. The changes are aimed at increasing work efficiency and personalized production, which means introducing the possibility of flexible changes in the assortment. Industry 4.0 applies not only to technology, but also to new ways of working and the role of people in the industry. Increasing the level of computerization, communication and integration of artificial intelligence leads to a significant improvement of work safety and efficiency (Timofiejczuk, Brodny, Loska, 2018, Jasiulewicz-Kaczmarek, Waszkowski, Piechowski, Wyczółkowski, 2018)

The concept of the fourth revolution is based on 9 leading pillars: autonomous robots simulations, systems integration, the Internet of Things, cybersecurity, cloud computing, additive manufacturing, augmented reality, big data.

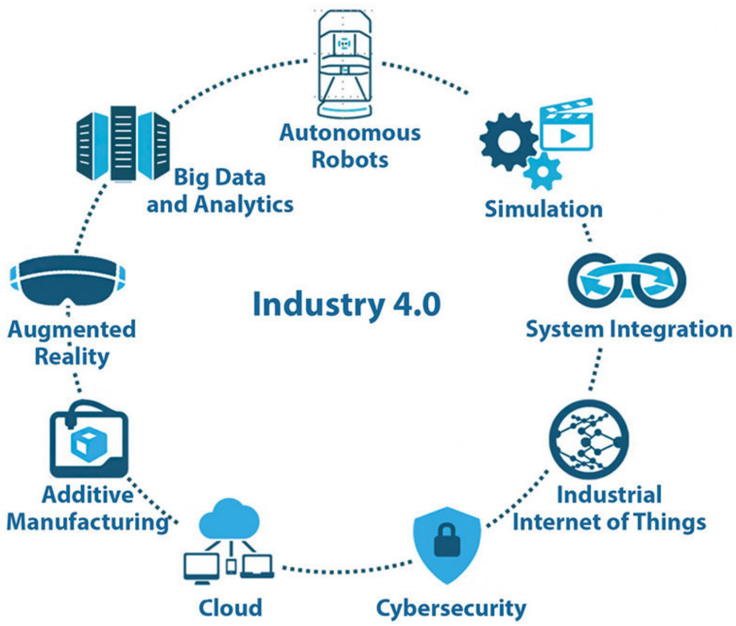

Fig. 4 Pillars of the fourth industrial revolution

DEVELOPMENT CONCEPT UR FOR 4.0

Internet of things

The use of data collected using IoT (artificial intelligence) platforms to predict potential machine downtime, increase work/production productivity, and organize proactive traffic maintenance.

The predictive maintenance strategy, which aims to predict machine failures before they occur, is based on the combination of traditional equipment condition monitoring with data analytics algorithms.

Big data

The PdM strategy (predictive maintenance) is a strategy that assumes optimum use of machines and devices by eliminating the occurrence of failures and optimizing the planning of maintenance work based on the technical condition. To do this, pre-emptive actions are carried out that help assess the technical condition of machinery

and equipment and on this basis allow decisions to be made about the possible replacement of individual worn parts, regeneration, adjustment, cleaning, etc.
Big data makes it possible to assess the technical condition on the basis of ultrasound and thermographic tests.
The abovementioned detection techniques are empirical techniques (interpretation of values based on a database), they consist in analyzing the signal from the sensor and comparing the values with the normal value, and consequently switching on the alarm in case of a value deviating from the norm.

Additive printing
The industrial use of incremental technology makes it possible to streamline the production process by prototyping and the creation of selected parts of machinery and equipment needed anywhere and at any time. Thanks to the implementation of 3D printing to the industry, it is possible to produce lighter, more complex structures.

Augmented reality
Thanks to the use of glasses, eg Microsoft HoloLens, it is possible to provide the user with an additional digital layer of information about real objects. This means that you have access to the knowledge needed to complete tasks. It also enables audiovisual communication without the use of mobile devices. Augmented reality is effective support for maintenance workers, logistics planning, assembly and production, as well as prototyping. For managers, the implementation of AR technology is a process-oriented approach to creating documentation and using data to analyze and optimize the processes for which they are responsible.

An example of the application of new solutions in the mining industry
The maintenance is of particular importance in industries in which we observe the slow introduction of the idea of industry 4.0. An example of such an industry is mining, which in Poland is a significant economic area. Generally, this industry is considered very conservative, which makes it difficult to accept new technical and organizational solutions (Brodny and Tutak, 2019, Winkler, 2012).
The changes in the economy cause, however, that also in the mining industry we observe an increasing interest in new technologies and striving for the most optimal use of technical resources. One such example is the use of an industrial automation system to assess the degree of use of mining machinery (Palka, Stecuła, Brodny, 2017). The developed system, based on machine diagnostic data, analyzes their availability, performance and product quality. On this basis, it evaluates the use of these machines based on a modified OEE model (Brodny & Tutak, 2016).
The effect of using this system based on the analysis of large databases is the value of the total effectiveness index. It is the basis for the assessment of the degree of use of individual machines in each of the analyzed areas.
The transmission course of changes in the value of this indicator for a longwall shearer is shown in Figure 5 (Stecuła, Tutak, Brodny, 2017, Brodny & Tutak, 2018).

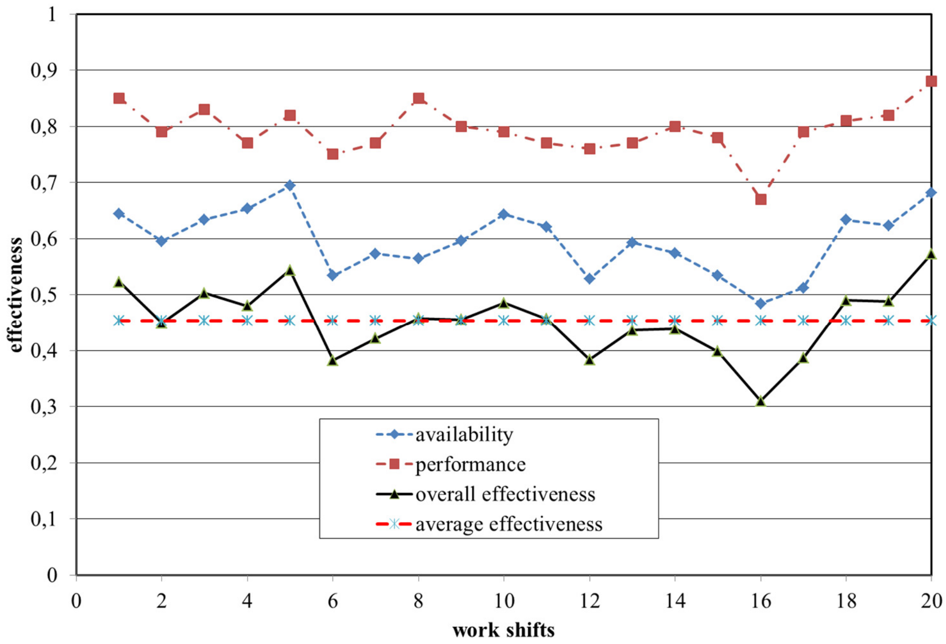

Fig. 5 The values of the availability, performance and OEE indicator of the longwall shearer

Another example of the use of advanced research methods based on digital analysis is the study of ventilation parameters and the state of ventilation hazard in the mine (Brodny & Tutak, 2019). The application of the analysis of large data sets enables quick and effective diagnosis and forecasting of the state of pollination and methane and fire hazards in mines (Brodny, 2011).

Figure 6 shows the distribution of oxygen concentration in the goafs at a distance of 2.0 m from the floor of the exploited seam for rocks lying in the goaf of an average weighted release resistance value of 3.0 MPa (a) and 6 Mpa (b).

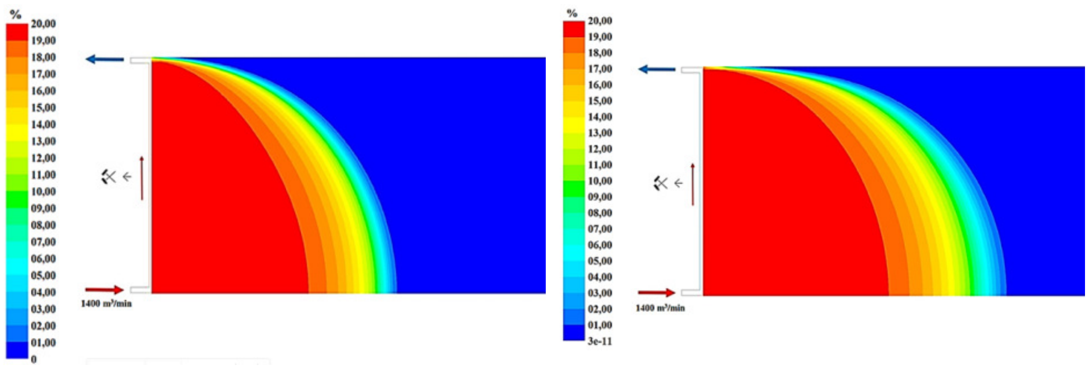

Fig. 6 Oxygen concentration distribution in goaf with caving in a distance of 2.0 m from slough of exploited seam for remaining rocks in goafs with weighted means values of destratification resistance amounted to 3 MPa (a) and 6 MPa (b).

In contrast, Figure 7 presents an example of methane hazard forecasting using the method combining neural networks and fuzzy sets (Felka & Brodny, 2017).

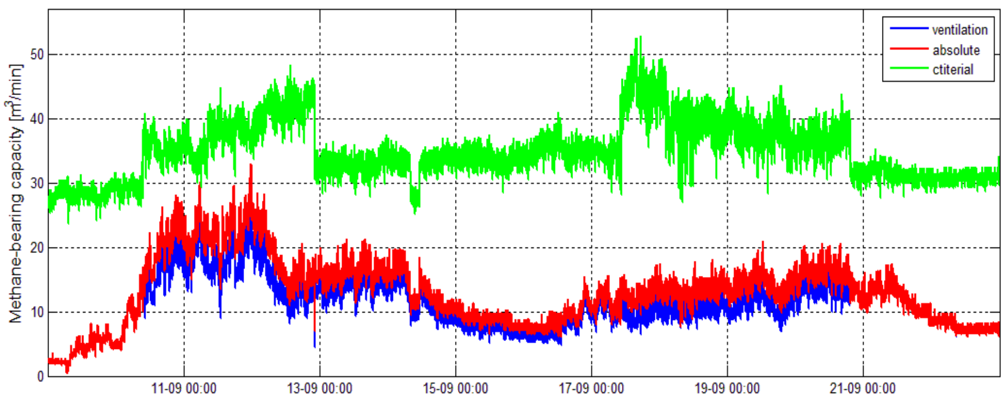

Fig. 7 Methane-bearing capacity at longwall N-2 area during trials

Advanced research and design methods are also used to analyze mining housing (Szurgacz & Brodny, 2019). Cyber-physical systems are increasingly used mainly to analyze and optimize the work of powered roof supports. An example of this is the view of the prototype control system of a mechanized enclosure shown in Figure 8 (Brodny, 2011).

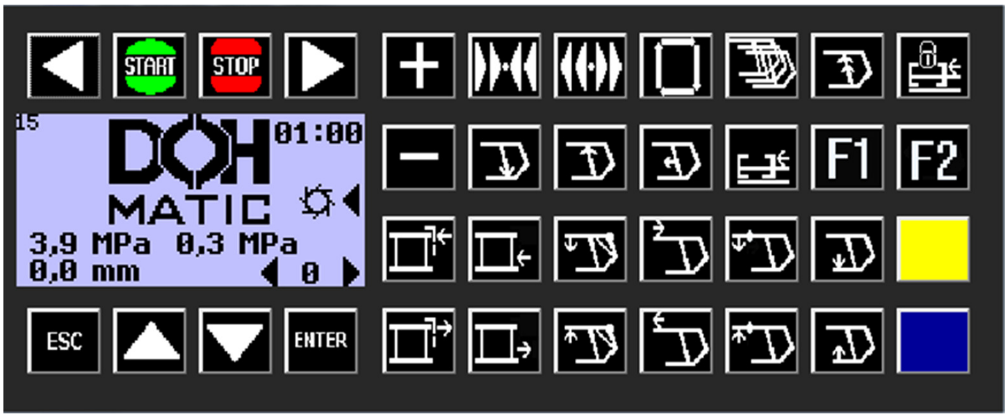

Fig. 8 Display of the control system of the mechanized housing control system

The presented examples clearly show that even in such conservative industries as mining, in order to fully utilize the owned machines, the soybean is reaching bolder IT solutions based on digital technologies. The efficiency of these enterprises depends to a large extent on efficient and effective maintenance systems related to increasingly intelligent machines.

The human factor is also very important in this process. Without his conviction and commitment, these solutions can not be effectively implemented.

CONCLUSION

The basis of a well-functioning enterprise is proper resource management. In industrial enterprises, the decisive resource are machines and devices used in production processes. Effective exploitation of technical systems is called "maintenance" affects work safety, its efficiency and economy. Taking into account certain technical techniques in the decision making process and taking into account technical, organizational and IT aspects, we call the strategy. The aim of the article is to show a new concept of maintenance development in the context of the fourth industrial revolution.

The dynamic development of technology and computerization makes it possible to monitor the technical condition of objects through mounted sensors monitoring various parameters, as well as collecting large amounts of data continuously, advanced methods of their processing and expert knowledge allows for early detection of technical system anomalies. The current response to signals of potential emergency situations ensures the continuity of machines operation and also extends their life. This approach is called the condition based maintenance strategy, which consists in rejecting prevention for the benefit of prediction.

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Abstract. The aim of the article is to present the perspective of maintenance development in the context of the 4.0 industry concept. One of the factors that determine the safe and effective use of machines and devices is the properly maintained maintenance process. Correct performance of activities as part of this process requires the use of appropriate knowledge and experience from people implementing this process. Very important in this process is, above all, good organization of work and technical knowledge. The very rapid development of technology causes that teams dealing with the maintenance of traffic in enterprises must systematically acquire knowledge and optimize their activities. Effective exploitation of all types of devices is a set of rules, rules, procedures and actions, the main aspect of which is a human being. Knowledge resources should have appropriate substantive content adapted to the recipient. The article presents a modern solution supporting the maintenance process, taking into account the tools supporting the activities of human teams. The basic principles of maintenance in the enterprise covering machine monitoring systems, production management and management of information on the state of the machine park are discussed. There are also examples of the use of selected tools in the mining industry. Reference was also made to the prospects and directions of the development of maintenance in relation to the fourth industrial revolution.

Keywords: maintenance, operation, industry 4.0, ERP systems, CMMS systems