A method of definition of life-cycle resources of electromechanical equipment

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Abstract. The problems of developing a diagnostic system of electromechanical equipment of mining industry are described in this article. This system is a platform for changing the strategy from periodic maintenance in the direction of predictive maintenance. The researches of different methods of malfunctions detection have been carried out and described. These researches have helped to make a conclusion that implementation of a safety diagnostic system without determination of many interdependent diagnostic parameters is not possible. The results of these researches will help to develop the system of monitoring, diagnostic and definition of life-cycle resources of electromechanical equipment. This system will able to take into account the differences of technological processes and will base on the subsystems of simulation and prediction of malfunctions. In addition, development of a subsystem of monitoring, diagnostic and definition of life-cycle resources of electromechanical equipment has been described. This subsystem will evaluate the life-cycle resources in different periods of time and make the machine control possible, using the information about the fault values and availability of spare parts, tools and equipment in addition.

1. Introduction
The safety of technological processes is the main tasks of factories in mining industry. Electromechanical equipment plays a main role in safety, especially when electromechanical equipment is used in hazardous and harmful areas. To ensure protection against faults, periodic maintenance is used. During the periodic maintenance faults are detected by traditional methods. Consequently the cost of maintenance is increased because the time between two maintenances is less than the time that is really required for safe use of mechanical equipment [2]. Moreover, sometimes the electromechanical equipment operates in the hard-to-get-at places and specialists have to halt technological processes during maintenances. Instead of using typical methods, condition-based predictive methods are more reasonable to use, especially for electromechanical equipment of mining industry [2, 4]. They allow evaluating the life-cycle of equipment, decreasing the cost of maintenances and increasing the economic efficiency of production.

So, the definition of life-cycle resources of electromechanical equipment is an important topic of scientific researches.
2. A traditional approach to fault detection of electromechanical equipment

There are a few parameters that are measured by a traditional approach of fault detection of electromechanical equipment: vibrations, audible noise, heating of individual elements of a machine, a thermal imaging survey, electrical parameters, including deviations of currents and voltages from the nominal values (amplitude, frequency, phase), an origin of high-harmonic in the spectrum of currents and voltages [3]. Each of the measured parameters can be correlated with one or more diagnostic elements of the object. Therefore, each of the traditional approaches of fault detection has some disadvantages that do not allow any possibilities to detect fault at an early stage of fault emergence, but let us identify the indirect causes of fault (table 1). There are approaches that can help detect fault, but cannot assess the extent of the fault, hence, we are not able to predict machine malfunction. The reason for this is that the defective parts of a machine influence the parts that are faultless. Besides, these parts have close electromagnetic, mechanical and technical relationships. If the physical fault appears in one of the machine parts, other parts will have an indirect fault.

If the physical fault appears in the several parts of the machine, the task of finding machine fault parts will be difficult. The complex methods of measuring the diagnostic parameters are needed in this case. In addition to the above-mentioned, plenty of diagnostic parameters can be measured at the same time, so all of the measuring devices must be time-triggered.

Table 1. A traditional approach to fault detection of the induction motor.

| A method of fault detection | Diagnostic parts of the induction motor |
|-----------------------------|----------------------------------------|
| Vibration Analysis          | Isolation winding relative to the housing | 0^a | 0 | 0 | K | K | X | X | K |
| Acoustic analysis           | Phase barrier                          | 0   | 0 | X | K | K | X | X | K |
| Spectral analysis of currents| Winding Insulation                     | 0   | 0 | X | X | X | K | K | X |
| Measurement of an external electromagnetic field | The stator winding | 0   | 0 | 0 | X | B | K | K | B |
| Temperature, thermal analysis | The rotor winding | 0   | K^b | B^d | B | 0 | B | 0 | 0 |
| Leakage currents            | Bearings                                | X^c | X | 0 | 0 | 0 | 0 | 0 | 0 |
| The level of dielectric strength | Rotor                                  | X   | X | X | 0 | 0 | 0 | 0 | 0 |
| Multivariate analysis of electrical parameters (wattmeter graphics) | Active steel stator | B   | B | X | X | X | K | K | B |

^a The type and values of fault cannot be detected.
^b The type and values of fault can be detected indirectly.
^c The type of fault can be detected.
^d The type and values of fault can be detected.

Most diagnostic systems based on traditional approaches to respond to one of its parts at a moment when the motor is already out of order or it suffered from internal damage or exceeded the setting of one of the monitored parameters (current, temperature, vibration), the cause of the incident is not defined [4]. However, the main types of damage to the electro-mechanical equipment, such as violations of the electric and magnetic symmetry of the rotor, develop gradually, so monitoring of the
accumulation of the diagnostic information in the time domain is a very important factor that allows one to predict the failure of the engine at a certain moment beforehand on the basis of the modeling state.

3. A new approach of fault detection of electromechanical equipment

The complex systems of monitoring and protection along with the systems of prediction and detection of the life-cycle stage of electromechanical equipment functioning together in a diagnostic center, can help to solve the problem of traditional methods [4].

3.1. The module information analysis system of fault detection of electromechanical equipment

The module information analysis system (IASFD) consists of several modules. Each of them is developed specifically for each type equipment. In summary, it has a typical structure, links and connections. A scheme of this system is shown in figure 1. It consists of subsystems of obtaining data: on-line and off-line parameters, subsystems of data verification, subsystem of fault simulation, subsystem of prediction and detection of the life-cycle stage of electromechanical equipment.

![Figure 1. The module information analysis system of fault detection of electromechanical equipment.](image)

ON-Line parameters are required for operational monitoring and prediction in the short period of time, which suffice to satisfy the continuity of the process and the possibility of early detection of the accident. Based on data, IASFD will advance to signal a possible accident and halt the equipment if necessary.

Off-Line parameters are required for the subsequent modeling and forecasting for a short or long period of time, which, in its turn, will organize optimally scheduled maintenance, decommissioning work and ordering spare parts. In addition to the basic parameters, which are removed to the On-Line mode for the system requires data on the repairs, accident data, the data obtained from the comprehensive and rapid diagnostics. On the basis of the aggregate input IASFD generates a report about the deterioration of the individual electric nodes and the likelihood of the release of their failure. At the next stage, the causes of wear and their contribution to the deterioration of a certain motor
unit are considered. Based on this knowledge, we can make a decision about how to manage stress and ordering of spare parts, and the wear exceeding a threshold value. A separate module of IASFD calculates the additional losses that arise in the motor resulting in considerable wear and tear, inadequately supplied voltage, overheating or electric motor optimum performance. These data are a proposition on energy saving.

A distinctive feature of the proposed system is ability to inform a manager about the impending threat of a failure of the equipment. To do this on the basis of modeling it is necessary to select the appropriate time intervals based on a survey to obtain data on the probability of occurrence of a specific defect. This in turn not only avoids serious accidents, but also managing the loading equipment on the basis of its projected state and the availability of spare parts. In the case of absence of certain parts it is possible to decide on the removal of the load on the production site so that the failure of the equipment does not lead to a lengthy downtime of the enterprise or an individual plant [1].

3.2. The subsystem of fault prediction
The main module of IASFD is a module of fault prediction. The module implements a constant or periodic monitoring of equipment condition and determines the remaining service life of the equipment [1, 3]. In this case, decisions on the repair and renovation plan is based on information about the technical condition of the monitored objects formed with the help of the module, including intelligent processing of diagnostic parameters.

In developing the structure and algorithm of the module one first has to allocate an additional subsystem allowing one to solve the issues of information failure. For the problem considered it is advisable to carry out the development of the following subsystems:

1. The subsystem of life-cycle assessment of the electromechanical equipment.
2. The subsystem of forecasting the development of the defect.
3. The intelligent subsystem determines the parameters of the equipment in the period between diagnoses (a subsystem solving a problem of information insufficiency).
4. The subsystem forming a part of the information field of the information database of the enterprise.

To solve analytical problems and a diagnostic module based on the selected subsystems it is possible to use a system block diagram, which is shown in Figure 2.

![Figure 2. A subsystem of fault prediction.](image-url)
For the operation and design of analysis modules of the system we can use various principles, among which it is advisable to use neuro-fuzzy algorithms of neural networks and genetic algorithms [3, 4]. The efficiency of these algorithms depends on the quality of the information that was the basis for their development. Therefore, upon receipt of unsatisfactory results in the process of testing these algorithms on the performance it is necessary to make adjustments in the information space of the data generated for the system operation.

3.3. The prospect of the research
The formation of the information field is the next step of this research. In future the main task is the search of calibrated values of the parameters of electromechanical equipment, especially the values that cannot be found using traditional methods. These values help to predict the stages of electromechanical equipment more correctly because they will use a special knowledge about working parameters of equipment.

4. Conclusions
Currently, a transition to the system of condition-based predictive maintenance is blocked by deficiency of methods of definition of life-cycle resources of electromechanical equipment. In the existing systems there are no simulation modules and fault prediction modules and they are unable to provide a high level of safety for technological processes, therefore many companies are unwilling to change the maintenance strategy of electromechanical equipment. The results of this research help to solve this problem and allow developing the system, which will be able to define life-cycle resources of electromechanical equipment on the base of the simulation, taking into account the differences of technological processes that will be widely used in technological practices. These systems will allow evaluating the current state of electromechanical equipment without halting the processes and losing the profit of mining industry companies.

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