Developing the System of Monitoring and Diagnostics to Increase the Availability of Equipment

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Abstract. The purpose of undertaken work, part of which was presented in this paper is to develop a system of collecting and processing information for monitoring, diagnosing, and predicting the future condition of the equipment that is needed to increase the coefficient of readiness and, ultimately, the reliability of restored equipment.

1. Introduction
With increasing operating time of the conveyor line, its reliability is reduced in comparison with the project due to depreciation of conveyor parts and handling stations. This is not taken into account in the design of conveyor lines. With the increase of operational time of conveyor lines increases the number of failures, cost of recovery and downtime of conveyor lines and associated loss of coal mining. Therefore, the research and development of methods and technical tools to ensure the required level of reliability of mining equipment and, in particular, the belt conveyor, is an actual task.

Currently undertaken researches and experiments to expand the implementation of the principle of technical operation of components, units, assemblies and subassemblies "on-condition maintenance". The duration of technical operation for the elements is determined by the limit value of the controlled parameters of the uptime and the amount and frequency of work depends on the value of the controlled parameter. Scheduled maintenance is the only work to control technical condition. Non-routine maintenance and repair, be determined by the results of the control, i.e. the main purpose of the transition to the principles of "technical condition" service:
• improving reliability;
• reduction in maintenance operation.

Efficient method for improving reliability is the repair of failed devices. One means of increasing reliability is to reduce recovery time.

The transition to the maintenance on the "technical condition" principle requires significant improvement in the quality of works performance on technical inspection. Here it is necessary to solve problems related to failure detection and the search of failed elements. The efficiency of diagnosis increases with the use of automated control systems.

Creating monitoring systems is a logical consequence of technological development on the modern stage. Today, the system of automatic control is considered not only as a system of passive supervision and warning, but as an intelligent diagnostic system of monitoring and control.
2. Results and discussion

Availability factor Kg is the probability that the product will be operational at a randomly selected point in time except for planned periods during which the targeted application of the system is not assumed.

Statistically, the availability factor is defined as the ratio of time of correct operation to the total time of correct operation and downtime of the system taken for the same calendar period:

$$K_a = \frac{t_u}{t_u + t_r}$$  \hspace{1cm} (1)

where $t_u$ - is the uptime of the system; $t_r$ - the recovery time, i.e. the time spent on preventive maintenance and repair of system.

The efficiency of the conveyor lines operation is greatly influenced by their reliability: in case of failure of conveyors or handling stations decreases the throughput of the transport system due to the reduction of conveyors operational time. When designing conveyor lines the availability factor of the individual conveyor take an equal to $K_a$, but during operation, it reduced due to physical deterioration of conveyors. The average daily operational time of the conveyor line is reduced in some cases up to 12 hours against 16-18 h, embedded in the design.

Currently, network technologies are becoming more widespread in digital drive control systems of industrial plants. This approach is proposed to use for the diagnosis, monitoring and control of belt conveyors.

Automatic control system must perform the following functions:
- measurement of physical values characterizing the operation of the conveyor;
- a comparison of the values of the measured variables with their defined boundary values (admission control).
- generation with the results of admission control the control actions to the actuators to ensure the maintenance of values of these variables are within specified admissions;

Control system of coal mine includes the monitoring of technological processes and the environment; ensure the collection, transmission, processing, display, recording and printout of data on the main production sectors, and outputs control signals to the underground and overground transport systems of the mine. At the same time monitoring of the mine atmosphere, ventilation systems, temperature, etc.

High-speed CAN bus includes two signal lines CAN_H and CAN_L line and potential-GRD (Fig. 1). The transmission of information is carried out by changing the potential difference between the signal lines. This structure allows to reduce the influence of electromagnetic interference, since the physical bus is done in the form of twisted pairs and common mode interference does not change the potential difference between the lines. To reduce the influence of noise on data transmitted at the ends of the bus terminator resistors are installed. CANbus can be in two States: dominant – corresponding to logical zero and the recessive is a logical one. In case of simultaneous placing on the bus the recessive and dominant status of different nodes on the bus will be dominated by a dominant level. Thus there is the concept of non-destructive bus arbitration when simultaneous exposure of packages.
Node A contains the microcontroller (with integrated CAN–controller) and the CAN transceiver. The node B CAN–controller and the CAN transceiver.

A node C - microcontroller (without integrated CAN–controller), external CAN controller and CAN transceiver.

Characteristics of the CAN Protocol show that the application of this Protocol in ACS conveyor transport will provide [6]:
• high reliability of the communication channel;
• built-in self-test;
• registering and recording messages;
• ability to remotely modify (upgrade) the software.

The electric drive system of the conveyor is multi-engine. The system comprises two or more of the motor converters of electrical energy. For example, consider the work of the conveyor shown in Fig. 2.

The flexibility and high noise immunity of the communication system CAN allows to combine the whole electrical and control systems and control units of the conveyors in a common control system. The core of the control system will be an industrial computer that performs the following functions: processing of information (download of elementary information, the task mode, report generation, data exchange with the subsystems, etc.), visualization of status and parameters of the object nodes for staff, communication with external devices (ACS top level of the hierarchy), the formation of local task control systems. The role of slave devices in industrial network will carry the controllers of the individual systems – control systems of drives, control systems of tape tension, monitoring load, etc.

The final goal of diagnostic testing as the last phase of the diagnostic control – determine the type and amount of repairs to increase a residual resource or to restore an operable state [7].
Tasks of the diagnostic condition monitoring of the equipment of coal mine belt conveyor are solved in two ways [8] (Fig. 3):

- through occasional determination of the most important settings through the diagnostic.
through continuous supervision of the most informative parameters by means of monitoring.

Consider the diagnosis of one of the types of belt conveyors equipment - induction motors. Analysis of factors affecting the reliability of induction motors and the well-known and promising methods of diagnosis, led to the conclusion about expediency of use their main electrical parameters as an informative diagnostic parameters of engines (voltages and currents of phases), the ambient temperature, as well as vibration displacement of the machine casing and, in addition, requires additional parameters which are calculated using existing mathematical models [9].

A number of studies of the damage modes of AC motors has the following statistics /1-2/:
- Damaged bearing elements - 40%
- Damaging the stator - 38%
- Damage to the components of the rotor - 10%
- Other damages - 12%

To study various faults of induction motors, collection of statistical information on failures and future forecasting has been created a laboratory stand consisting of electrical machines, DAQ board and a personal computer.

The scheme of the stand (Fig. 4):

![Figure 4 – The scheme of the stand](image)

The physical principle underlying the operation of a diagnostic system lies in the fact that any disturbance in operation of electrical and/or mechanical parts of the motor and the associated device result in changes in the magnetic flux in the gap of the electric machine and therefore for the weak modulation of consumed electric current.

Thus, the presence in the spectrum of the motor current characteristic (not identical) frequencies of specific size indicates the presence of damage to electrical and/or mechanical parts of the motor and associated mechanical devices.

For example, the breakage of the rods of the rotor winding reduces the starting torque and increases the slip, while the frequency of rotation at no load does not reach the nominal and under load start may not take place.

Breakage of the rods is accompanied by vibration and noise changes periodically at a frequency equal to twice the slip frequency, which depends on the load and the number of damaged rods. At the breakage of two, four and six rods the slip will increase by 8, 17 and 41%, respectively [10].

Fault diagnosis of AD according to the analysis of harmonic spectral components in the voltages and currents of the stator in the electromagnetic and vibro-acoustic processes of functioning of asynchronous drive in artificially-defined faults (various types of short circuits in the stator winding,
broken rotor bars, eccentricity of the rotor) dedicated a series of publications [2, 4-6, etc.], which presents evidence that the most informative for these purposes, is a 3rd harmonic component.

As an example, below are the results of the spectral analysis of currents.

![Figure 5](image1)

**Figure 5** – Range of voltage in logarithmic scale (a - new motor, b - long operated motor)

![Figure 6](image2)

**Figure 6** – Range of currents in logarithmic scale (a - properly functioning motor, b - motor with the broken rod)

In the above drawings it is seen as an increase of the number of frequency bands corresponding to different types of damage and the growth of their value (with meaningful level of signals in the frequency range from -80 dB) for the electric motor, a long time in work (Fig. 5).

Damage to the rotor of the motor (broken rods, loose rods to the slip rings, the hidden defect the casting). This breakdown is detected by the presence of 2 symmetric peaks in relation to the mains frequency in the current spectrum (Fig. 6).

### 3. Conclusions

In a workable system it is necessary to know its behavior in the future. The answer to this question is predictive control. It is the result of the measurement. The received control data is used for planning the future operation of the system. The task of forecasting is extremely important, particularly, for organization of technical maintenance of objects in terms of condition (instead of maintenance by time or by resource).

Well-organized diagnostic support of object with the storage of all previous diagnostic results can provide useful and objective information, representing the background (dynamics) of the process of changing the technical characteristics of the object in the past, which can be used for the systematic correction of the forecast and improve its accuracy.
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