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Modern methods for diagnosing electric circuits of electric trains

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Modern methods for diagnosing electric circuits of electric trains

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Abstract. The article describes the field of application of these diagnostic methods. Much attention is given to the classification of methods for diagnosing electrical circuits, the assessment, and quality of diagnostic systems, as well as the improvement of diagnostic methods for electrical circuits of electric trains.

1. Introduction

Timely and high-quality performance in the full scope of maintenance and current repairs in accordance with the established scheduled preventive system is the most important condition for maintaining the high reliability and efficiency of electric trains [1, 2]. In turn, the quality of work during repair and maintenance depends on the volume of identified faults and the clarity of their elimination, the availability, and the degree of perfection of technical diagnostic tools. The efficiency of maintenance and repair of the electric train will be much higher, and the costs are much lower if the setting for repair and the execution of the repair cycle are carried out taking into account the actual state of the equipment, which can be determined by organizing test or functional diagnostics [3].

2. Materials and methods

Means of technical diagnostics (STD), depending on whether they are connected to the diagnostic object only for the period of checking its condition or connected to it, are divided into external and built-in [4].

External STD can be universal (general), specialized floor-standing (installed on the stretch). Universal (general) STD is intended for diagnosing objects of various design and functional purposes and allows you to check the entire electric train or essential components [5].

When choosing diagnostic parameters, it is necessary to perform research work, operational tests, and a reliability calculation. The basis of such studies is the study of operating conditions and patterns of development of failures. On the basis of the theory of probability and mathematical statistics, a system of diagnostic parameters, a diagnostic technique are selected and diagnostic tools are developed for a group of devices and power circuits. The key task is the development and selection of sensors for picking up information signals and converting them into a form convenient for transmission to the means of processing the received information. The sensors must provide accurate measurements, small dimensions, high noise immunity, and reliability [6].

Technical diagnostics is a branch of knowledge that includes the theory and methods for determining the technical state of the diagnostic object. Technical diagnostics solve three types of problems. The first type includes tasks to determine the state in which the object is currently located - to establish a diagnosis. The tasks of the second type are the tasks of predicting the state in which the object will be at a certain moment of time - forecasting tasks. The third type includes the problem of determining the state in which the object was at some point in the past – the problem of genesis. Technical diagnostics of traction rolling stock is associated with high labor intensity, this is due to the complexity of its design, intensity of operation, and increased requirements for reliability and safety, which does not allow to determine its technical condition in an intuitive and manual way. Therefore, the use of specialized diagnostic tools makes it possible to reliably determine the technical condition of the locomotive. The main tasks of diagnostics include: checking the health of the object, its operability, correct functioning, and troubleshooting. The solution to these problems is possible only when the diagnosis is carried out at three stages: production; operation and repair of the facility [7].

3. Results and discussion

Currently, more than 14 thousand workers of various skill levels (from engineers to workers) are employed in non-destructive testing in railway transport. About 10 thousand flaw detectors of various types are in operation.

More than 4.5 million km of the track are monitored annually; 2.5 million welded joints of rails, 4.5 million parts and units of rolling stock; more than 70 thousand potentially possible breaks of critical units of technical objects of the track and rolling stock are prevented. Detection of defects by means of non-destructive testing (NDT) is 99.3–99.7% [8]. Operating NDT systems during the repair of rolling stock make it possible to detect many dangerous defects, thereby preventing the entry of defective parts into operation.

NDT systems should include a modular range of mechanized and automated means of integrated control, ensuring the identification of internal defects in parts repaired using CIP technology. They must ensure the detection of dangerous defects and assess the accumulated fatigue of structures (side frames and bolsters of bogies, wheelsets). Work in this area is carried out in four important areas: development of methods and tools for NDT and technical diagnostics (TD), development of a unified control system for objects, improvement of diagnostic technologies, and organizational support for NDT and TD. When creating NDT and TD technical means, the transition from manual scanning to mechanized and automated scanning was implemented, operational and technological documentation and software were developed [9-13].

The creation of technical diagnostics systems is an integral part of the complex of works to ensure the quality of the functioning of machines and mechanisms. The main goal of technical diagnostics is to organize effective processes for determining the technical condition of traction rolling stock. Depending on the tasks of diagnosing locomotives, hardware or software tools, built-in or external technical means are used that implement the developed diagnostic algorithm. When researching, developing, and implementing the processes of technical diagnostics of locomotives, another problem is solved, associated with the development and implementation of the control process as a whole [14-17]. Along with the listed tasks, priority ones are also being solved – the study of the physical properties of objects and their malfunctions, construction of mathematical models of objects and models of faults, analysis of the object model in order to obtain the data necessary for the construction of diagnostic algorithms. Classification of the main subjects of research of technical diagnostics Figure 1.

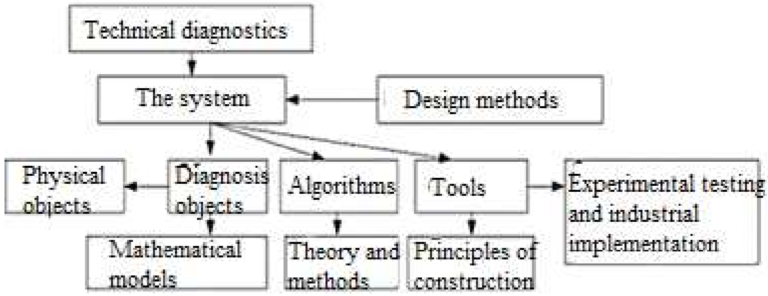

Figure 1. Block diagram of the classification of the main tasks of technical diagnostics.

There are the following types of technical diagnostics systems:

- Test diagnostic systems. The check signal is generated in the blocks of the diagnostic system and is fed through the information transmission channels to the inputs of the diagnostic object. Test influences can be applied to the main inputs of the object (i.e., to those inputs that are used for the input or output of operating signals) and additional ones used specifically for the purposes of diagnostics.
- Systems of working diagnostics. The main inputs of the diagnostic object receive working influences in accordance with its working algorithm of functioning, which, as a rule, cannot be selected from the conditions of the effective organization of the diagnostic process.

Various methods are used to diagnose the technical condition of locomotives, their systems, components, and assemblies [11, 18-20]. The variety of diagnostic methods is mainly due to two reasons: the complexity of the diagnostic systems, determined by the complexity of the structure of locomotives as an object of diagnostics, and the variety of technical diagnostics tasks arising from the requirements for the maintenance and repair of locomotives [21-23]. Methods for diagnosing locomotives differ depending on the combination of features that characterize the features of the structure and interaction of the three main parts of the technical diagnostics system: the diagnostic object, the system for collecting, converting and transmitting information, and the system for processing, accumulating and displaying the diagnostic results (Figure 2).

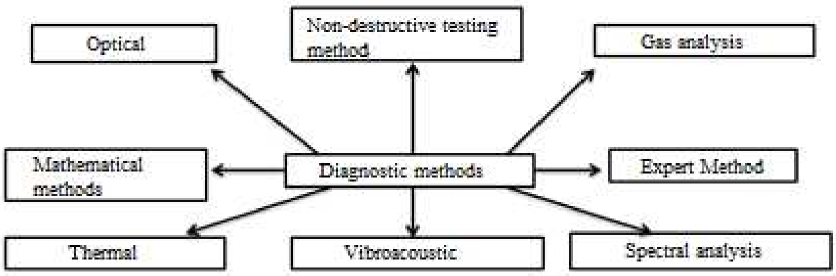

Figure 2. Block diagram of diagnostic methods.

Vibroacoustic diagnostic methods. These diagnostic methods are widely used in the locomotive economy, since they do not require disassembly of locomotive units and assemblies.

The methods are based on the processes occurring in the friction and interface units during the operating mode. The operation of the units, as a rule, is accompanied by noise and vibrations, according to which the maintenance personnel determine the technical condition of the object, listening attentively to the work of each unit. The vibration of the mechanism is its reaction to the action of the applied disturbing forces. Usually, several different forces simultaneously act on the mechanisms, leading it to such a state when the balance is disturbed, extraneous noises, shocks occur, vibration intensifies. Faults can be caused by maximum displacements, vibration velocities or accelerations, maximum values of deformation, stress, or force. During the operation of the unit, the malfunction makes itself felt by increased vibration or vibrations. Different defects vibrate at different frequencies. There are several reasons vibrating mechanism. One of them is associated with the imbalance of moving parts. It forces the mechanisms to oscillate as a whole in relation to the equilibrium position. These vibrations are characterized by low frequencies, relatively large displacement amplitudes, and low accelerations. The dependence of the vibration frequency on the speed of the mechanism is a characteristic feature of this type of vibration, which makes it easy to detect and isolate. The basic vibration frequency of the mechanism is equal to the frequency of rotation of the shaft on which the unbalanced mass is located. The vibration amplitude is proportional to the square of the angular speed of rotation of the shaft and depends on the mass of the mechanism and the rigidity of its attachment to the base. The second source of vibration of the mechanism is the collision of its parts, caused by increased clearances. These vibrations are characterized by higher vibration frequencies, small-displacement amplitudes, and significant accelerations. Most often, parts and assemblies experience simple sinusoidal oscillations, which are characterized by three related quantities: oscillatory displacements *x (t)*, velocity *V (t)*, and acceleration *a (t)*. If the oscillation has the form of a purely translational movement of the body along only one axis, then the instantaneous value of each of its coordinates is called displacement and is determined by the formula:

$$x = X_{max} \cdot sin\left(2\pi / T\right) \cdot t = X_{max} \cdot sin \cdot \pi \cdot ft,$$

where $V_{max} = \omega X_{max}$

$$a = dv / dt = -\omega X_{max} \sin\omega t = A_{max} \sin\left(\omega t + \pi\right),$$

where $A_{max} = \omega X_{max}$ is the vibration amplitude.

One of the priority directions in the development of station systems of railway automatics and telemechanics is the introduction of computer systems for electrical interlocking. In addition to the main functions of managing the transportation process, the use of computer technology makes it possible to implement information and analytical subsystems in such devices. The subsystem for technical diagnostics of its own computer equipment and station is one of the main subsystems of relay-processor centralization based on micro-computers and programmable controllers ETs-MPK. The main functions inherent in such a subsystem make it possible to increase the fault tolerance of station devices and the awareness of the maintenance and operating personnel.

However, in order to carry out a full-fledged prediction of failures of EC devices, the diagnostic subsystem requires a further increase in the number of diagnostic parameters obtained from the control object and an expansion of functionality. For example, in a phase-sensitive rail circuit, it is also necessary to measure the voltage at the supply end of the rail circuit and the phase angle between the voltages of the track and local elements of the receiver – an important diagnostic parameter.

Comprehensive diagnostics are the most promising type of monitoring the technical condition of thyristor converters on electric locomotives and electric trains. The complex includes built-in and external (stationary) diagnostic tools. The built-in tools work on the principle of operational diagnostics. In this case, thyristors are determined that have a breakdown, an internal break, thermal overloads, and a deterioration in operating conditions due to the spread of their characteristics.

The diagram of the stand for test diagnostics of partial failures of power thyristors is shown in (Figure 3). Using this stand, the following parameters are controlled:

- Leakage current at forward and reverse anode voltages equal to the rating data of the thyristor of the corresponding class. In this case, the excess of the leakage current over the permissible (10 mA) is recorded.
- Switching on the thyristor by the control current at the forward anode voltage equal to the thyristor voltage of the corresponding class. In this case, the stand determines the belonging of the tested thyristor to one of the discharges for the unlocking control current.
- Thyristor turn-on time at a forward pulse current with an amplitude of 250 A, followed by application of a forward voltage with an amplitude of 100 V and a slope of 10 V / µs after a certain adjustable time interval. The range of the measured turn-off time under the given conditions is 5–375 μs.

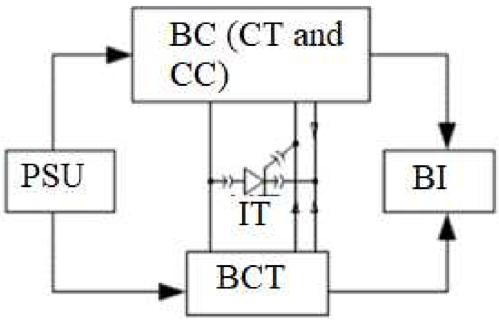

Figure 3. Block diagram of a portable thyristor parameter monitoring device. PSU is the power supply unit; BC (CT and CC) – thyristor class control unit and control current; BCT – on and off time control unit; BI – display unit; IT – test thyristor.

The development and implementation of effective diagnostic methods should be accompanied by a choice of diagnostic parameters, which depends on many requirements for the technical diagnostics system. The most important requirements include the purpose of diagnosis, maintenance strategy, time, cost of funds, and the process itself, taking into account the downtime of the diagnosed object in the diagnostic mode. The selected diagnostic parameter should: have sufficient information content; instantly respond to any changes occurring in the diagnosed object; have good access to its measurement; have high noise immunity and reliability, the ability to transform when using automatic information processing tools. A large number of diagnostic parameters makes it possible to obtain a sufficient depth of troubleshooting, but at the same time leads to an increase in the cost of diagnostics. Therefore, when developing diagnostic systems, it is necessary to solve the problem of optimizing diagnostic parameters, diagnostic tools, and their power consumption.

The development and implementation of technical diagnostics systems for traction rolling stock are the main factors in increasing operational reliability and reducing maintenance and repair costs. First of all, those units and parts of the rolling stock that ensure traffic safety and safe maintenance (wheelsets, axle boxes, spring suspension, and locking devices) are subject to diagnosis. The second stage includes locomotive units that ensure its operability and units that have rather low reliability (power circuits and locomotive control circuits, protection equipment, and control devices). In the third stage, nodes are diagnosed that indirectly affect the functioning of the rolling stock (control equipment and instruments, cooling systems, and auxiliary machines).

4. Conclusion

The main task at the stage of developing a diagnostic system is the choice of diagnostic parameters, which can be used to determine the technical condition of the diagnostic object with a high degree of reliability. Diagnostic parameters include such values or characteristics of an object, exceeding the values of which leads to failure of machine elements, and then of the entire machine or mechanism. For each of the elements, there are, as a rule, several parameters that determine their reliability, but not all of them are diagnostic in the diagnostic system being created, which is explained by their diversity, the inability to identify these parameters by one diagnostic method, and an excessive increase in the complexity and cost of diagnostic systems. However, despite this, it is necessary to ensure the maximum completeness of the diagnosis.

Summing up, we can say that the diagnostics system should be an obligatory part of the system for preventive maintenance of rolling stock. The article describes the purpose and tasks of technical diagnostics, as well as the means by which technical diagnostics are carried out in the depot. The types of technical diagnostics systems are analyzed, diagnostics algorithms are described and factors that must be taken into account when developing and implementing effective control methods are listed. Three types of diagnostic problems are considered, which determine the technical state of the object at the time of the direct impact on it of the means of technical diagnostics. Problems of the second type are aimed at predicting the state in which an object will find itself at a certain moment in time and the third type of tasks is to determine the state.

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