USAGE OF INTELLIGENT TECHNOLOGIES IN CHOOSING THE STRATEGY OF TECHNICAL MAINTENANCE OF LOCOMOTIVES

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Abstract. The paper substantiates the need to improve the existing strategy in organization of maintenance and repair of locomotives. Many railway companies continue to use the preventive maintenance system for railway engines repairs. This system of maintenance requires considerable funds for repair work, and the amount of repair work not always corresponds to the actual technical condition of the locomotive. The usage of this approach in the organization of maintenance can be considered as morally obsolete. Especially this approach is not effective for locomotives equipped with on-board diagnostic systems. The analysis of maintenance and repair system for locomotives used on Ukrainian and Lithuanian railways is carried out. Alternative approaches to the organization of the locomotive maintenance system and experience of their use in the world are considered. Approaches and methods for the development of an intelligent strategy of maintenance and repairs are proposed. Requirements to the structure and contents of the baseline data for the development of intelligent systems are formulated. A technology for the collection and processing the information of the diagnostic systems for the intellectual strategies development of technical content is proposed. The transition to more advanced strategy of hauling equipment maintenance will lead to a reduction in the cost of repairs while achieving a high level of reliability.

Keywords: locomotive, maintenance, repair, intelligent technologies, diagnosis

In most cases, speaking about intelligent (Smart) transport technologies, first of all, one means different rolling stock and infrastructure management systems, information monitoring and security systems, interactive systems of customer communication and so on. In addition to these systems, it is necessary to develop intelligent systems for the organization of repair and maintenance of rolling stock for the improvement of all modes of transport. The purpose of creating such systems is to reduce operating costs while improving reliability and traffic safety.

In general, the maintenance (repair) strategy is a system of rules (a set of provisions) for managing the technical state of a product in the process of maintenance (repair). At this, the adopted rules and regulations are based on the usage of diagnostics, forecasting theories, automatic control, probabilities, machine reliability and optimization [5].

Developments of intelligent strategies of repair management are conducted for various modes of transport [1-5], including for railway transport. When organizing repair of locomotives, existing strategies for organizing of intelligent life-cycle management systems (system management of maintenance) used in other transport industries can be applied. The possibility of using the existing strategies is explained by the analogy of the physical processes leading to failures and by similar purposes of creating the such systems.

The development of intelligent strategies for organizing the repair of rolling stock must first of all be performed for locomotives, since the locomotive is a technically complex object with a high cost. Modern locomotives are equipped with on-board diagnostics systems. For example, on Ukrainian railways there are electric locomotives DS3, VL11M/6, fast-speed passenger trains HRCS2; on the Lithuanian railways ER20CF diesel-electric locomotives are operated, diesel-electric trains 620M, 630M, electric trains EJ575.

The review given in [4, 7] considers intelligent systems of analyzing data and monitoring the state of locomotives developed by leading world companies, as well as managing the reliability of a locomotive fleet. Companies provide their services to owners of rolling stock equipped with on-board electronics systems. The general trends of the developed systems are: usage of wireless technologies for data transmission, remote monitoring of the technical state of the locomotive, usage of date analysis technologies for a large amount. An increase in the time of the locomotive usage, reduction of failures in the route, reduction in the time spent in the depot is the result of using the locomotive fleet management systems.

The development of an intellectual strategy for the technical maintenance of locomotives requires the use of a systematic approach, since the objective of the system is to manage with the reliability of the entire locomotive fleet and plan the work of the repair units. When developing a strategy for the technical maintenance of locomotives, it is necessary to solve the following problems:

1. Development of a technique for the nodes ranking according to the degree of their impact on locomotive efficiency and traffic safety.
2. Development of a technique for choosing a node that limits the setting of the entire locomotive for repair based on the results of diagnosis.
3. Choice of the criterion, according to which the locomotive is planned to be repaired when it is selected from the general locomotive fleet.
4. Development of a technique for determining the residual technical resource for the node, system and the locomotive in general.
5. Development of a technique for determining the rational volume of locomotive repair operations.
6. Development of a technique for planning the loading of repair units, taking into account the techni-

cal state of the locomotive fleet and the volume of planned repair work.
7. Development of a technique for planning the logistic support for repair units, taking into account the technical state of the locomotive fleet and the volume of planned repair work.
8. Choice of the criterion for the organization of control systems for the reliability of rolling stock fleet using diagnostic results.
9. Technology development of organizing the collection, analysis and storage of information of the locomotive fleet reliability management system.

The structural scheme of the proposed intellectual strategy for locomotive fleet management is shown in Figure 1. The initial data for the locomotive fleet management system is live data of operation (actual mileage, performed work), data on performed repairs (type of repair, date and mileage at the time of repair), and data of diagnostic systems. Based on the initial data, the control system selects the locomotives from the general fleet in accordance with the used criteria and potentials of the repair units.

An integral part of the intellectual strategy for organizing the repair of rolling stock is the maintenance and repair system. The maintenance and repair system includes a combination of technical means, regulatory documentation for maintenance and repair, and contractors. The objective of the technical maintenance system of vehicles is constant monitoring and maintenance of their technical condition and reliability at a level sufficient to fulfill their assigned functions or readiness for usage and performance of operating objectives. In general, such service systems in the theory of the organization of repair and maintenance of technical means are as follows:
- maintenance and repair system for failure,
- routine-preventive system,
- repair system upon actual status,
- combined maintenance and repair system.

The Lithuanian and Ukrainian railways use a routine-preventive system of maintenance and repair for locomotives. It is known that the routine-preventive system of maintenance requires considerable funds for repair work, and the amount of repair work not always corresponds to the actual technical condition of the locomotive. The usage of such approach in the organization of maintenance can be considered as morally obsolete. Especially this approach is not effective for modernized locomotives and new ones equipped with on-board diagnostics systems. Maintenance systems taking into account the actual technical condition of the locomotives or the combined system of maintenance are more progressive. For example, linking of repair intervals to the hours of a diesel operation does not take into account the diesel operating modes, idle speed or run positions.

When using diagnostic systems, it becomes possible to take into account the power realized by the diesel-generator set (for diesel-electric locomotives with electrotransmission). It more accurately reflects the performed work and takes into account the operating conditions.

In order to use the results of diagnostic systems, it is necessary to create information-and-technical centers for managing the technical condition of locomotives. The objective of these centers is the development and implementation of supporting systems for maintenance and repair of locomotives in live mode.

The work of these systems should be based on modern mathematical methods using: reliability theory, statistical analysis, fuzzy logic systems and neural networks, queuing theory, logistics methods, etc. The development of such systems is a time consuming and science-intensive objective. The transition to a more advanced maintenance system of the locomotive fleet will be a result of their introduction. It will lead to a reduction in repair costs, while ensuring a high level of reliability. A simple control of the repair intervals in

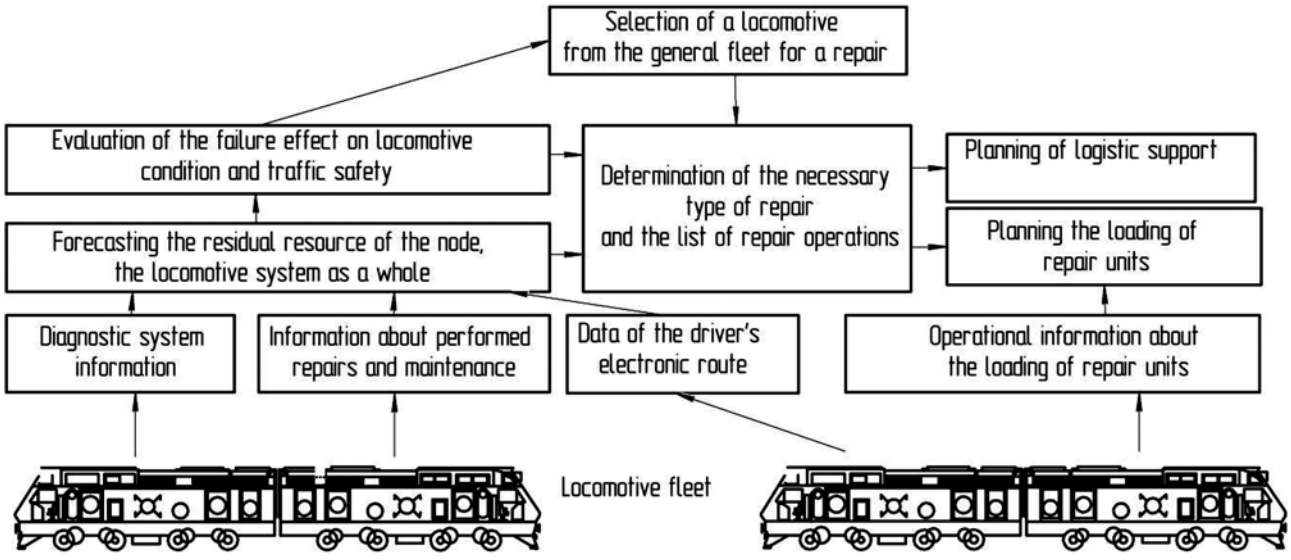

Figure 1. Structural diagram of the intellectual strategy of locomotive fleet management

the direction of increasing or decreasing their values is an analogy of guessing the answers, which can have serious consequences both from technical and economic points of view [6].

When researching the technical state of locomotive nodes upon the results of diagnosis, statistical methods of research are the most common ones. Statistical methods are based on the forecasting the failure situation of a locomotive node, taking into account the statistical law of the residual resource distribution. The technology of using such methods is known, it consists in the statistical analysis of data sets. Using the existing mathematical packages in order to analyze statistical data greatly simplifies the calculation process. The main problem of usage of statistical methods is the determination of the criterion, that is, the parameter by which the change in the technical state of each particular node and the locomotive unit will be evaluated, as well as the determination of the corresponding law by which this parameter occurs. Usage of statistical methods is expedient only if the law of variation in the technical state of each particular node corresponds to one of the basic types of distribution laws for which the basic calculated relations are known.

Analysis of modern methods of the diagnostic results and forecasting changes of parameters in different technical areas has shown that to date neural networks are widely used in solving of various problems in different fields of human activity. Neural networks are actively used wherever conventional algorithmic methods prove to be ineffective or completely impossible.

The neural network functions similarly to the human brain; the principle of its operation is the parallel operation of many simple elements (neurons) and their interaction with each other. In the human brain, neurons interact through a series of pulses lasting several milliseconds. Each pulse represents a frequency signal with a frequency of several to hundreds of hertz. The frequency of neuron interaction is much less than the frequency of modern computers, but at the same time, the human brain can process analog information much faster than a computer, that is: recognize images, detect taste, recognize sounds, read the handwriting of others, and operate with qualitative parameters. All this is realized through a network of neurons connected by links. In other words, the brain is a system of parallel processors, working much more efficiently than popular now sequential calculations, which allows us to talk about the promise of neural networks.

The main question that can be solved in the study of the technical state of locomotive nodes using neural networks is the problem of the classifying the locomotive node failures, determining the technical state of the locomotive based on an analysis of the previous experience and the results of their diagnosis. Artificial neural networks can be used to solve the problem of classifying the faults of locomotive nodes and forecasting the values of the nodes parameters. The architecture of an artificial neural network, which has the name of a multilayer perceptron, received the most common application to solve these problems. The structure of the multilayer perceptron is shown in Figure 2.

An example of a neural network [9] used for studying the traction motors operation of DE1 electric locomotives is shown in Figure 3. The list of controlled parameters is established in accordance with the list of parameters controlled by the on-board diagnostics system of DE1 electric locomotives.

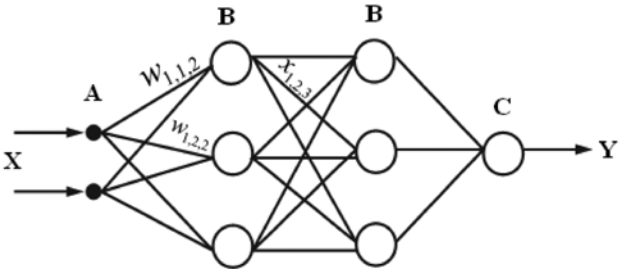

Figure 2. Structure of the multilayer perceptron. A – input layer of neurons, B – hidden layer of neurons, C – output layer of neurons, X – set of input signals, Y – set of output signals, *w* – weighting coefficients of links between neurons

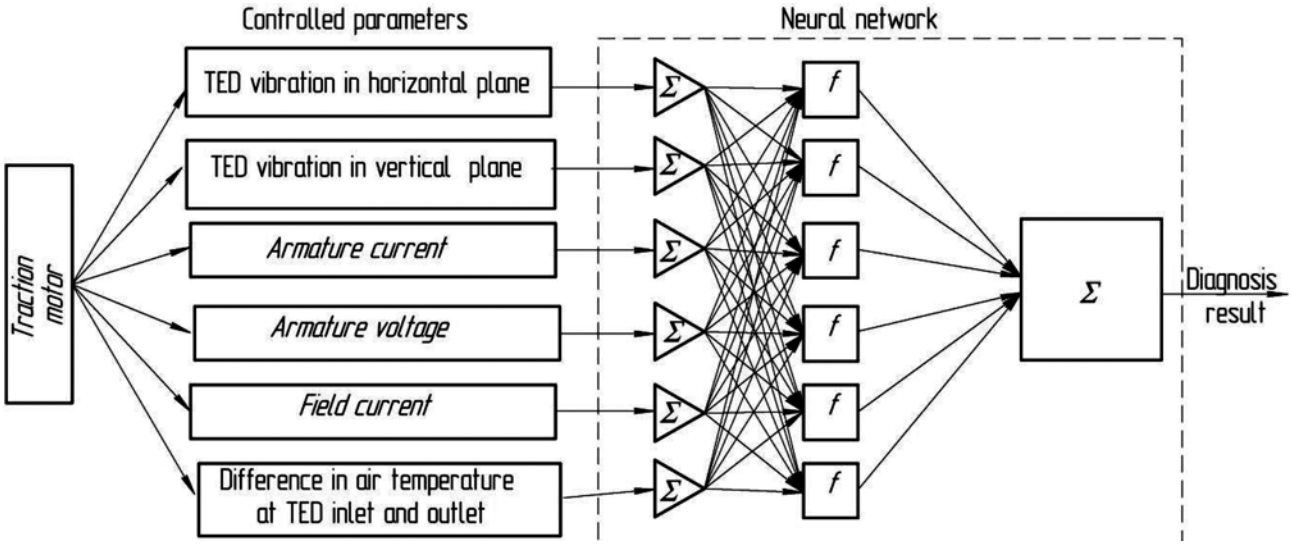

Figure 3. Structure of the neural network for the study of the traction engines operation of DE1 electric locomotives

When solving the problem of classifying faults of locomotive nodes using the multilayer perceptron, the controlled node is characterized by a set of parameters. For analysis, it is necessary to determine the possible number of serviceable and unserviceable technical states of this node. Based on the control parameter sets, it is determined to which class the node belongs, that is, it is necessary to choose the exact technical state to which the node belongs. The availability of sufficient data will allow solving the problems of changes forecasting in the technical condition of the nodes. Electric locomotives DE1 are equipped with an on-board diagnostic system, its operation results can be processed using neural networks, which will increase the efficiency of the diagnostic system and the reliability of electric locomotives.

In addition, neural networks allow solving the problems of approximation, determining the unknown law of changing the values of the sampled data. A feature of neural networks is the ability to analyze data subject to complex multidimensional dependencies, as well as data analysis distorted by external noises.

The above considered examples allow us to talk about the prospects of using the neural networks and systems of not clear logic for analyzing the technical state of locomotives. The mathematical apparatus of neural networks is designed at a sufficient level, which makes it possible to use applied mathematical packages for the analysis of data sets.

The result of the introduction of intelligent control systems for the reliability of the locomotive fleet will be the transition from a routine-preventive strategy to a maintenance one taking into account the actual state and results of diagnosis.

The main advantages of the intellectual strategy of the locomotive fleet maintenance are as follows:

- possibility of forecasting the failure of locomotive units on the basis of an individual operating history and forecast models;
- diagnosis and accounting of the work performed by the locomotive without entering the depot of the registry, remote monitoring of the technical state of the locomotive;
- automation of the planning and organization process of repair services, taking into account resources limitations and the consequences of possible failures.

The introduction of such systems is obvious and unavoidable for a locomotive fleet, in view of the rate of development of artificial intelligence systems and the analysis of large amounts of data. The first stage of the introduction of such systems is the creation of automated systems of accumulation and date analysis on the reliability and operation of a locomotive fleet.

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