Improving the efficiency and quality of the technological process of repairing traction motors by reducing production defects

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Abstract. Reliability and efficiency of the use of traction rolling stock are the determining parameters for the technical and economic development of railway transport. About 20% of the total costs of the railway industry are for maintenance and repair, since the technical condition of each unit of rolling stock is a fundamental element of traffic safety. According to research, more than 60% of malfunctions of technical facilities during operation are in direct correlation with locomotive failures that occurred due to poor quality of maintenance and repair. Aim: Consideration of the main problems related to the quality of factory repairs of traction collector electric motors, as well as the development of measures aimed at improving the quality of technological repair processes. Materials and Methods: The research was conducted through causal analysis and the theory of operations research. Results: The analysis of the work of each stage of repair of traction motors is carried out. Measures aimed at improving the quality of the technological process of repair have been developed. Conclusion: The main problems of poor quality of factory repair of collector traction motors are highlighted. The measures aimed at eliminating the listed negative factors and improving the quality of factory repairs are proposed.

1 Introduction

Collector electric motors are widely used in various fields, including in railway transport. Electric locomotives with collector electric motors are still one of the most common types in Russia.

The Order of JSC "Russian Railways" dated January 17, 2005 No. 3r "On the system of maintenance and repair of locomotives" provides for maintenance (maintenance) and maintenance (TR) carried out at the depot and medium (SR), major repairs (CR) carried out at specialized plants.

Unfortunately, currently the indicators of downtime for all types of repairs, the number of unplanned repairs and failures remain at a fairly high level. This circumstance depends on a combination of various factors, one of which is a low level of quality of performance, appropriate maintenance and routine repairs, as well as violation of operating modes of a unit of traction rolling stock [1, 2].

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According to JSC "Russian Railways" for 2022, the share of faults of traction electric motors (TED) of various kinds of current accounts for about 40% of all faults of electric locomotives. Of these, the most common malfunctions for asynchronous machines are: inter-turn short circuits in the stator winding, melting of the rotor winding, malfunction of bearing assemblies and breakdown of the insulation of the stator winding on the housing [3-5]; for DC motors: damage to anchors, motor-axial bearings, poles and compensation windings, as well as connections between poles and output cables [6, 7]. A small part of the malfunctions of traction electric motors can be handled at the depot, however, depot repair according to the repair and operation manual is designed to maintain the electric locomotive in working condition and regulates the timing of all types of maintenance before the electric locomotive is installed at the locomotive repair plant for medium and major repairs. Reducing the costs of performing maintenance, as well as increasing the inter-repair runs of locomotives while maintaining reliability at the required level, are the main directions of the organization of a planned warning system. To obtain a result in the form of an increased inter-repair mileage of the locomotive, it is necessary to increase the efficiency and quality of factory repairs [8, 9].

The object of this study is DC traction motors. The subject of the study is the improvement of the TEM factory repair through the development of measures aimed at improving the quality and efficiency of the repair technological processes.

The purpose of this article is to consider the main problems related to the quality of factory repair of traction collector electric motors, as well as the development of measures aimed at improving the quality of the technological processes of repair of TEM.

2 Materials and research methods

The main purpose of locomotive repair enterprises is to reduce wear, eliminate various types of damage to traction rolling stock units and increase the reliability index in operation. The main role for solving these tasks is assigned to the repair units of railway transport.
The organization of their operation and repair technology have a significant impact on the system of maintenance and repair of electric locomotives.
Figure 1 shows a causal diagram of factors affecting the reliability of traction rolling stock.
Due to the rather low level of reliability and non-compliance with the repair technology, the Traction Directorate of JSC "Russian Railways" contains an excess of about 1400 locomotives.

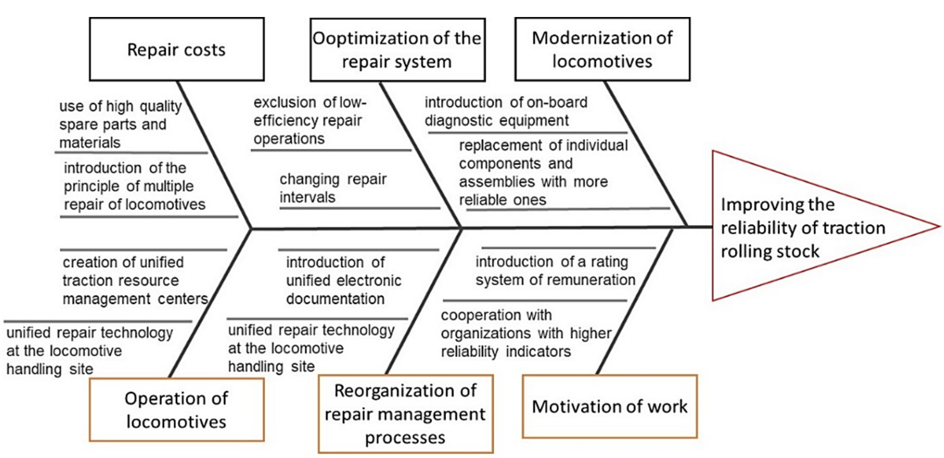

Fig. 1. Causal diagram of factors affecting the reliability of traction rolling stock.

The factors located in the black rectangles are factors that have a direct impact on reliability, in the orange ones – indirectly.

Let's proceed directly to the consideration of the repair of the traction electric motor of an electric locomotive.

The interpretation of the definition of the TEM life cycle is similar to the product life cycle [10] and it usually consists of five stages: development, production, operation, modernization and disposal.

At the stage of modernization, it is possible to replace as a whole node or add a single element to this node, in order to increase the reliability of the object being repaired.

The main stages (Fig. 2) and the factors of poor-quality repairs during factory repairs of traction motors are summarized in Table 1.

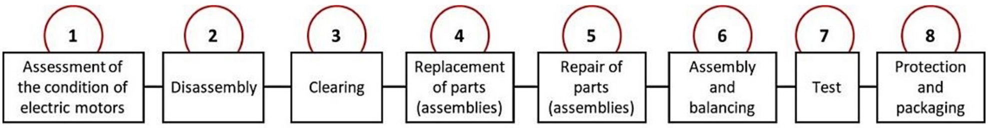

Fig. 2. Stages of repair of the traction motor.

Table 1. The main stages of repair and factors that have a negative impact on their implementation.

Repair stage	Factors influencing
1. Assessment of the engine condition. At this stage, a visual inspection and diagnostics of the engine is performed to determine its condition and establish the necessary amount of work.	Insufficient visual inspection and incorrect measurements; Incorrect determination of the scope of work may lead to the replacement of unnecessary parts or insufficient replacement of necessary parts.
2. Disassembly. At this stage, the engine is disassembled into its component parts, including the armature, stator, covers and other parts.	Improper disassembly can damage engine parts and increase the amount of time to complete the work; The lack of the necessary tools or experience can lead to incomplete disassembly or violation of the structural integrity of parts and elements.
3. Cleaning. After disassembly, the engine parts undergo a stage of cleaning from dirt, oil residues and other substances.	Improper use of cleaning agents can damage engine components and reduce their insulating properties.
4. Replacement of parts, assemblies. At this stage, parts (assemblies) that are defective or worn out, such as bearings, brushes and other parts, are replaced.	The use of substandard parts may cause damage to the engine; Incorrect installation of new parts can lead to improper operation of the engine.
5. Repair of parts, assemblies. If necessary, at this stage repairs are made of parts (assemblies) that can be restored, for example, coil windings, surfacing to drawing dimensions, mechanical surface treatment, surface treatment.	Improper repairs can lead to damage to parts or improper operation of the engine; Lack of necessary experience or tools can lead to incorrect repairs.
6. Assembly and balancing. After replacement and repair of parts, the engine is assembled in reverse order and balanced.	Incorrect assembly may cause the engine to malfunction or damage it. Lack of necessary experience or tools may lead to incomplete assembly or omission of important parts.
7. Test. After assembly, the engine is tested on special stands to check its operability, output parameters and efficiency.	Non-compliance by employees of the test station with the modes of the acceptance test program; Lack of necessary experience to analyze the test results of an electric machine.

8. Protection and packaging. After testing and tuning, the engine is packed and protected for transportation and storage.	Improper packaging and installation in the vehicle body may cause damage to the engine during transportation.

Each stage of factory repair of traction motors is quite important and requires a professional approach and technical competence to achieve the best result.

3 Consideration

3.1 Stage "Assessment of the state of the electric motor"

Let's look at each stage of the factory repair in the most detail and determine what causes affect the final result.

When conducting a TEM inspection and collecting information, the masters ignore modern diagnostic technologies and conduct a visual inspection, giving only tentative conclusions about malfunctions.

At the present stage of development of diagnostic systems, there are various methods [11-13] and means for detecting malfunctions, some of them:

- Vibration analyzers. They are used to determine the vibration level of an electric motor. An increase in the vibration level may indicate the presence of defects in the system, such as unbalanced rotors, worn bearings, etc.

- Thermographs. They are used to measure the temperature of an electric motor. A high temperature may indicate the presence of defects, such as wear on the insulation of wires or problems with the cooling system.

- Megohmmeters. they are used to measure the insulation level of an electric motor. A decrease in the insulation level may indicate the presence of defects, such as cracks in the insulation.

- Oscilloscopes. They are used to measure and analyze electrical signals generated by an electric motor. Disturbances in electrical signals may indicate the presence of defects, such as a short circuit.

- Spectral analyzers. The devices are used to analyze the frequency spectrum of signals generated by an electric motor. Changes in the frequency spectrum may indicate the presence of defects, such as an unbalanced rotor or worn bearings.

Thanks to these specialized systems, the type and nature of the damage will be determined with a high degree of reliability and in a short period of time.

3.2 The "Disassembly" stage

At the "Disassembly" stage during factory repairs, the most common problem is the high probability of damage to the technical condition of the nodes. The dominant reasons are the low level of competence of employees and the lack of specialized tools. To improve the quality of this stage, it is necessary:

- Conduct high-quality training in the correct disassembly technique of employees. The training should include a theoretical and practical part so that employees receive the necessary skills and knowledge.

- Use of a specialized tool. A high degree of its availability and serviceable condition must be ensured. Using a specialized tool will help reduce the risk of damage to engine parts and increase the efficiency of the process.

- Control and verification of compliance with the TEM disassembly procedure established by the manufacturer. To improve disassembly, it is advisable to implement modern technologies, such as 3D modeling and blockchain. The use of these technologies will become a kind of catalyst for improving the quality of the disassembly process, with subsequent positive results such as reducing the time of the workflow and reducing the risk of damage to parts.

3.3 The "Cleaning" stage

Often, the "Cleaning" stage is considered insignificant by the working staff, not worth much attention, but this is a huge mistake. The entire volume of contamination (dirt, dust, brush chips, etc.) has a significant impact on the efficiency of the TEM, its reliability and the occurrence of possible failures. It is known that various kinds of pollution are conductors and reduce the electromagnetic properties of the machine, thereby increasing the probability of failures. This phenomenon is especially dangerous for insulating materials [14, 15].

To clean TEM, various tools and equipment are usually used that can help remove dirt from the surface of windings, manifolds and bearings. Recommendations for the selection of equipment and means for cleaning traction motors are as follows:

- Steam cleaning. Steam cleaning is one of the most effective ways to clean TEM. It is based on the use of hot water vapor under high pressure to remove impurities. This method allows not only to clean the surface, but also to disinfect it. When choosing steam cleaning, it is necessary to make sure that the equipment complies with safety standards.
- Chemical cleaning. It is based on the use of special chemical solutions that destroy impurities and wash them off the surface. However, not all chemical solutions are suitable for cleaning TEM, as they can damage the surface or negatively affect the operation of parts. Therefore, when choosing chemical cleaning, it is necessary to make sure that the selected solution is safe to use and will not damage the electric motor.
- Vacuum cleaning. It is based on the use of a vacuum pump that removes dirt from the surface of the electric motor. This method is usually used to remove fine particles such as dust or sand. It is safe and does not damage the surface, however, it may be less effective in removing heavier contaminants.
- Brush cleaning. It is carried out with the help of special brushes and brushes that can help remove dirt from the surface of the electric motor. This method may be effective in removing dirt in hard-to-reach places, but may be less effective when cleaning large surfaces.
- Ultrasonic cleaning. Uses high-frequency waves to remove dirt from the surface of the electric motor. This method may be effective in removing small particles and contaminants in hard-to-reach places, but may be less effective in cleaning large contaminants.

Various means, such as solvents, special cleaners and others, can also be used to remove dirt from the surface of the TEM. However, when choosing the means, it is necessary to make sure that they are safe to use and will not damage the surface of the electric machine. When choosing the means and equipment for cleaning TEM, it is necessary to take into account the type and nature of contamination, as well as the features of a specific model of the electric motor. It is recommended to use combined cleaning methods for better cleaning.

3.4 Stages "replacement and repair of parts (assemblies)"

All responsibility at the stages of "Replacement, repair, installation of components and parts" falls on the shoulders of the team. The main problems are the quality of the replaced part, the lack of specialized tools and equipment for installation, as well as the low level of competence of employees performing repair and installation work. The ways to improve the quality of work performed at this stage are:

- Testing of parts and assemblies purchased or manufactured on the territory of the plant by using modern methods of diagnostics and quality control.

- Conducting training and advanced training of employees conducting this type of work.

3.5 The "Assembly and balancing" stage

At the "Assembly and balancing" stage, the accuracy of the installation of each element or node becomes of fundamental importance. Often the installation takes place without the use of modern technologies and tools. Repair crews use templates, levels and calipers, instead of high-precision equipment such as laser alignment systems, automated assembly systems. This technique, combined with a computer model that determines the optimal configurations for balancing and assembly, will reduce the likelihood of errors and lead to stable engine operation after repair.

3.6 The "Test" stage

The "Test" stage, as well as the previous stages, has a very significant significance. For its high-quality implementation, employees need to have the necessary competencies and knowledge to competently expose the test objects and analyze the results obtained. All tests are carried out on high-precision stands, which are regularly checked and adjusted. The only reason for the decrease in the quality of this stage is a person, i.e. his incompetence, a large amount of work and tight deadlines. To reduce the human factor, it is necessary:

- Do not deviate from the test regulations, conduct a competent and thorough analysis of all collected data.
- Conduct training of personnel on working with equipment and stands.
- To monitor trends in the development of equipment and test methods, to carry out their timely updating.

3.7 The "Protection and packaging" stage

The final stage in the TED repair process is the "Protection and packaging" stage. At this stage, the TED is subjected to staining and surface treatment with special means to prevent corrosion and increase its tightness. The weak point of the stage is the way the engine is installed. Employees, ignoring the regulated method of installation and transportation, lead to the fact that during transportation TED can beat against the walls of the body of the transport vehicle or leave it altogether, which of course will lead to the failure of some nodes. To avoid negative consequences, it is necessary:

- Strictly control the packaging process.
- Comply with all rules and regulations of storage and transportation.

4 Conclusion

Having conducted this study, among the main problems of poor quality of factory repair of collector engines, the following can be distinguished: the absence or unsatisfactory condition of the necessary equipment and tools; unsatisfactory quality of materials and components; low qualification of personnel.

To improve the factory repair of TEM, it is necessary to eliminate the above problems by:

1. Using high-quality materials. To ensure the durability and reliability of collector electric motors, it is necessary to use only high-quality materials. This applies both to materials for the manufacture of spare parts and to materials for repairs. When choosing

materials, it is necessary to take into account the features of the equipment, operating conditions and other factors.

2. Application of modern technologies. Modern technologies can significantly improve the quality of factory repair of collector electric motors. For example, the use of computer modeling allows you to accurately determine the dimensions and parameters of spare parts. The use of laser cutting and welding can significantly improve the quality of manufacturing and repair of parts.

3. Professional development of personnel. Professional development of personnel engaged in the repair of collector electric motors is a prerequisite for improving the quality of repairs. Specialists should have in-depth knowledge in the field of electrical engineering, mechanics and other related fields, as well as be able to apply modern technologies and methods.

4. Quality control. Quality control is a necessary step in the process of factory repair of collector electric motors. It allows you to identify and correct errors and shortcomings in the work of specialists, and also guarantees that the quality of repairs meets the requirements and standards. As part of quality control, various methods can be used, for example, visual inspection, testing on special equipment, etc.

5. Preventive maintenance. Conducting an appropriate maintenance will allow to identify problems and malfunctions at an early stage, which will contribute to their rapid elimination and prevention of serious breakdowns. Regular maintenance also allows you to extend the service life of the equipment.

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