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TECHNOLOGY FOR RESTORING THE INSULATION OF NB-514E TRACTION ELECTRIC MOTORS BASED ON INFRARED RADIATION

Toshtemirov Humoyun Shokir ugli
Tashkent State Transport University (Tashkent, Uzbekistan)

Abstract. The article considers the causes of armature winding insulation damage in NB-514E traction electric motors, the need for post-repair control after KT-1 maintenance, and a technology for restoring insulation by local impregnation and infrared thermal radiation. The proposed approach is aimed at assessing the actual technical condition of the motor after repair, restoring moistened or weakened front connection insulation, shortening the drying time, and reducing the risk of repeated failures.

Keywords: NB-514E, traction electric motor, armature winding, insulation resistance, front connections, infrared drying, compound, stationary test stand.

INTRODUCTION

In modern railway transport, improving the operational reliability of locomotives, increasing the quality of repair processes, and reducing economic losses caused by unscheduled failures are among the most important scientific and technical tasks. In electric locomotives operating under heavy freight conditions, traction electric motors are among the most responsible units, and their technical condition directly affects locomotive availability, traffic safety, and energy efficiency.

The NB-514E traction electric motor operates under the influence of high current loads, vibrations, dust, moisture, temperature changes, and reduced cooling-system efficiency. Under these conditions, the insulation system, commutator-brush assembly, armature winding, bearing units, and electrical contact connections require special monitoring.

Many failures occurring in traction electric motors are associated with deterioration of insulation condition, moisture absorption, thermal aging, or reduction of dielectric strength. Therefore, after KT-1 maintenance, it is not sufficient to perform only an external inspection of the motor; a comprehensive assessment of its electrical, thermal, and mechanical parameters is required.

The purpose of this article is to assess the insulation condition of NB-514E traction electric motors, substantiate the technical feasibility of restoration based on infrared thermal radiation, and show ways to improve diagnostic efficiency through a stationary post-repair test stand [1].

PROBLEM STATEMENT AND RESEARCH OBJECT

The main problem considered in this article is that the traditional control methods performed after KT-1 maintenance of NB-514E traction electric motors do not always provide a sufficiently reliable assessment of the motor for subsequent operation. As a rule, inspections are limited to an external examination, evaluation of the commutator-brush assembly, measurement of insulation resistance, and control of individual circuits.

Such an approach does not allow hidden defects to be fully detected, including moisture in the insulation layer, local overheating, micro-damage in front connections, deterioration of cooling conditions, or initial signs of bearing-unit defects. As a result, a failure may recur shortly after the motor is returned to operation.

The research object is the NB-514E traction electric motor. The research subject includes the stationary test stand intended for assessing the technical condition of the motor after KT-1

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maintenance, its measuring channels, the procedure for recording diagnostic parameters, and the processes of restoring the insulation system under the effect of infrared heat.

The test process should not be limited to a single parameter. Insulation resistance, winding integrity, the operating condition of the commutator-brush assembly, bearing vibration and temperature indicators, no-load current, and heating processes must be evaluated together.

FACTORS CAUSING DAMAGE TO NB-514E INSULATION

The operational reliability of the NB-514E traction electric motor largely depends on the condition of its insulation system. The insulation used in the armature winding, pole windings, and their connection parts ensures the normal operation of the electrical machine. When the dielectric strength of the insulation layer decreases, leakage current to the frame, inter-turn short circuits, local overheating, and, at the final stage, insulation breakdown may occur.

The main factors causing insulation damage can be divided into the following groups: thermal factors, moisture influence, electrical loads, mechanical and dynamic impacts, cooling-system faults, poor operation of the commutator-brush assembly, and violation of repair technology. In practical conditions, these factors often act together and rapidly reduce the insulation service life.

The first important factor is thermal influence and thermal aging. When a traction electric motor operates under heavy load, a high current flows through the armature windings. An increase in current sharply increases Joule-Lenz heat generation in the conductors. Excessive temperature changes the physical and chemical structure of insulating materials, makes them brittle, and reduces dielectric strength [2].

$$Q = I^2 \cdot R \cdot t$$

where Q is the amount of heat generated in the winding, J; I is the current flowing through the winding, A; R is the winding resistance, Ω; and t is the current exposure time, s.

The second factor is insufficient cooling-air flow. When ventilation channels are partially blocked by dust and contamination, the air flow decreases, heat exchange deteriorates, and winding temperature increases. The thermal condition of the motor can be estimated by the simplified expression:

$$\Delta T = P_{loss} / (\alpha \cdot F)$$

where ΔT is the temperature rise, °C; Ploss is the power loss generated inside the motor, W; α is the heat-transfer coefficient; and F is the heat-exchange surface area, m².

The third factor is moisture and insulation wetting. Moisture reduces the electrical resistance of insulating materials and creates conditions for leakage currents. Insulation resistance is one of the main diagnostic indicators used to assess insulation condition:

$$R_{ins} = U_{test} / I_{leak}$$

where Rins is the insulation resistance, Ω; Utest is the test voltage, V; and Ileak is the leakage current passing through the insulation, A.

The fourth factor is mechanical and dynamic loading. The front connections of the armature windings are exposed to centrifugal forces due to high rotational speed. These forces create pressure on the insulation layer and cause microcracks and interlayer separation.

$$F_{cf} = m \cdot r \cdot \omega^2$$

where Fcf is the centrifugal force, N; m is the mass of the rotating element, kg; r is the radius of rotation, m; and ω is the angular velocity, rad/s.

Table 1.

Parameters for post-repair control of the NB-514E motor

Parameter	Control stage	Purpose
Insulation resistance	Before and after drying	Assessment of moisture

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		and dielectric condition
Leakage current	At test voltage	Detection of insulation weakening
Heating temperature	During infrared drying	Prevention of overheating
Commutator-brush assembly	Inspection after KT-1	Assessment of commutation quality
Bearing vibration	During no-load test	Early detection of mechanical faults

PROPOSED RESTORATION TECHNOLOGY

The main purpose of the proposed restoration technology is to clean and dry the damaged or weakened insulation layer, re-impregnate it with an electrical insulating compound, and provide fast and high-quality polymerization using infrared thermal radiation. The technology is aimed at restoring the insulation of the front connections of the NB-514E armature windings.

The process is performed in the following sequence: receiving the motor for repair and performing initial diagnostics; identifying damaged areas of the armature winding insulation; cleaning the front connection area from dust, oil, moisture, and aged insulation residues; measuring insulation resistance; impregnating the restored area with an electrical insulating compound; drying and polymerizing it by infrared radiation; and performing final electrical tests.

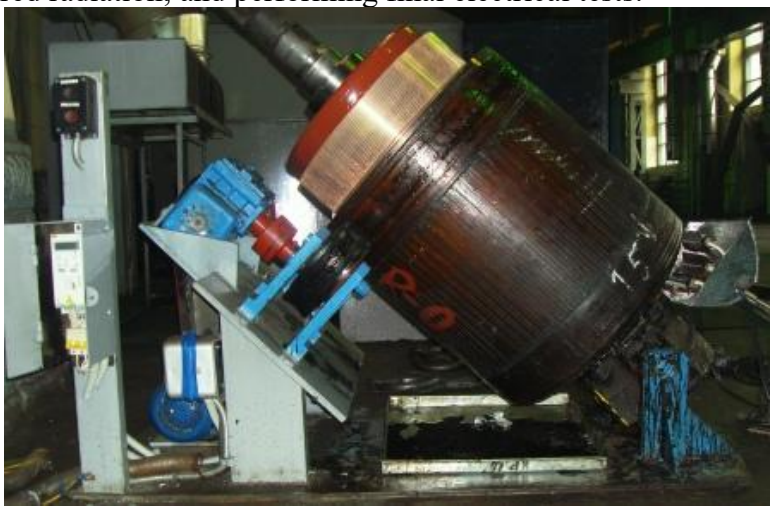


Figure 1. First version of the device for restoring NB-514 armature winding insulation

The first version of the device is intended for rotating the armature and drying the front connection area by infrared heat. The device consists of an electric drive, a transmission mechanism, armature supports, and an infrared radiation source.

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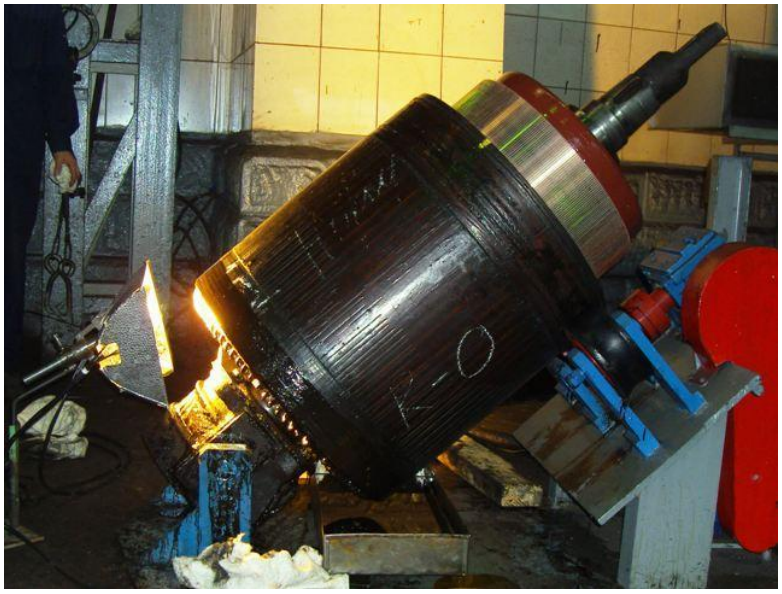


Figure 2. Experimental process of drying the front connections of the NB-514 armature winding using infrared radiation

Unlike conventional convective drying methods, the technology directs heat not to the entire volume of the part, but directly to the insulation zone that must be restored. As a result, energy consumption decreases, drying time is shortened, local heating of the insulation is controlled, and the possibility of restoring post-repair dielectric strength increases.

At the infrared drying stage, the radiation flux is directed to the front connection area treated with compound. The temperature is monitored using an infrared thermometer, and it is ensured that the permissible thermal limit of the insulating material is not exceeded.

$$Q = P_{IR} \cdot \eta \cdot t$$

where Q is the useful heat energy supplied to the insulation zone, J; PIR is the power of the infrared radiator, W; η is the coefficient of radiation-energy utilization; and t is the drying time, s.



Figure 3. Second version of the device for restoring NB-514 armature winding insulation

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In the second version, impregnation is performed using special sprayers, while the infrared radiators are arranged around the perimeter of the armature front connections. This solution increases the uniformity of the heating zone and improves drying quality.

In the improved version of the device, it is possible to supply the impregnation liquid automatically or semi-automatically, optimally arrange the infrared radiators around the front connections, and conveniently control the armature position. This makes repair quality less dependent on the human factor [3].

$$K_{rec} = R_{ins2} / R_{ins1}$$

where Krec is the insulation restoration efficiency coefficient; Rins1 is the insulation resistance before restoration; and Rins2 is the insulation resistance after restoration. If Krec > 1, the insulation condition is considered to have improved after the restoration process.



Figure 4. Improved device version for restoring NB-514 armature winding insulation

CONCLUSION

The study shows that the reliability of the NB-514E traction electric motor mainly depends on the condition of its insulation system, especially the insulation of the armature winding and front connections. During operation, this insulation is affected by high current loads, heating, vibration, moisture, dust and insufficient cooling. These factors accelerate insulation aging and may lead to leakage current, local overheating and insulation breakdown.

Conventional inspection after KT-1 maintenance is not always enough to detect hidden defects. Therefore, the motor should be checked by a complex diagnostic approach, including insulation resistance, leakage current, winding integrity, no-load current, heating condition, bearing vibration and the state of the commutator-brush unit.

The proposed technology is based on local impregnation of weakened insulation areas with an electrical insulating compound and subsequent drying by infrared thermal radiation. This method allows heat to be directed only to the required insulation zone, reduces drying time, decreases energy consumption and improves the quality of insulation restoration.

The use of this technology together with a stationary test stand makes it possible to evaluate the real technical condition of the motor after repair. By comparing diagnostic parameters before and after restoration, the effectiveness of the repair can be assessed more accurately.

Thus, local compound impregnation, infrared drying and post-repair testing can improve the dielectric reliability of the NB-514E traction motor, reduce repeated failures and extend its service life.

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This approach is practical for locomotive repair enterprises and can contribute to increasing the operational readiness of traction rolling stock.

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